PUBLIC DRAFT RECOVERY PLAN

FOR
THE EVOLUTIONARILY SIGNIFICANT UNITS
OF
SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON
AND
CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

AND

THE DISTINCT POPULATION SEGMENT
OF
CENTRAL VALLEY STEELHEAD

Winter-run

Spring-run

Steelhead

National Marine Fisheries Service

Southwest Regional Office

Sacramento, California

DISCLAIMER

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the National Marine Fisheries Service (NMFS), sometimes prepared with the assistance of recovery teams, contractors, State agencies and others. Recovery plans do not necessarily represent the views, official positions or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Assistant Administrator. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any general agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

LITERATURE CITATION:

This public draft should not be cited nor distributed to non-governmental or non-tribal entities.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

National Marine Fisheries Service
Office of Protected Resources
1315 East-West Highway, 13th floor
Silver Spring, MD 20910
301-713-1401 or 301-713-2322

Final Recovery plans can be downloaded from the NMFS website:

http://www.nmfs.noaa.gov/pr/recovery/plans.htm

ACKNOWLEDGEMENTS

The authors would like to thank and acknowledge participants in the Central Valley Technical Recovery Team, in particular Steve Lindley, whom provided much of the technical information used in the development of this Recovery Plan, and the Sacramento Area Water Forum for providing technical assistance. We also would like to acknowledge the staff of the Southwest Regional office of the National Marine Fisheries Service including Naseem Alston, Gretchen Umlauf, Howard Brown, Brian Ellrott, Nancy Fisher, Letia Gathright, Madelyn Martinez, Shawn Martin, Jeff McLain (currently with USFWS), Bruce Oppenheim, Maria Rea, Rosalie del Rosario, Erin Strange, Eric Theiss, Mike Tucker, Shirley Witalis, Rhonda Reed, Karen McCartney, Ken Cumming, Steve Hillyer, Garwin Yip, Monica Gutierrez, Chris Kwan, and Diane Windham for their contributions in preparation of this plan. This recovery plan could not have been completed without the hard work of HDR/SWRI staff including Paul Bratovich, Dianne Simodynes, Morgan Neal, John Cornell, Carol Brown, and Adrienne Moore.

The authors also would like to extend recognition to all of the many individuals who have worked over the years to conserve and protect anadromous salmonids and their habitat in the Central Valley. This recovery plan builds on the dedication of these individuals and their efforts to preserve an invaluable natural resource.

EXECUTIVE SUMMARY

Introduction: Implementation of this Recovery Plan for endangered Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), threatened Central Valley spring-run Chinook salmon (ESU), and threatened Central Valley steelhead Distinct Population Segment (DPS) is necessary to improve the viability of these species such that they can be removed from Federal protection under the Endangered Species Act. This Recovery Plan serves as a roadmap that describes the steps, strategy, and actions that must be taken to return winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to viable status in the Central Valley, California thereby ensuring their long-term (time scales greater than 100 years) persistence and evolutionary potential.

Background: The rivers draining the Great Central Valley of California ("Central Valley") and adjacent Sierra Nevada and Cascade Range once were renowned for their production of large numbers of Pacific salmon (Clark 1929; Skinner 1962 *in* Yoshiyama *et al.* 1998). The Central Valley system historically has been the source of most of the Pacific salmon produced in California waters (CDFG 1950, 1955; Fry and Hughes 1951; Skinner 1962; CDWR 1984 *in* Yoshiyama *et al.* 1998). Chinook salmon *(Oncorhynchus tshawytscha)* historically were, and remain today, the only abundant salmon species in the Central Valley system (Eigenmann 1890; Rutter 1908 *in* Yoshiyama *et al.* 1998), although small numbers of other salmon species also have occurred occasionally in its rivers (Collins 1892; Rutter 1904a, 1908; Hallock and Fry 1967; Moyle *et al.* 1995 *in* Yoshiyama *et al.* 1998). Anadromous steelhead (*O. mykiss)* apparently were common in Central Valley tributaries (USFC 1876; Clark 1973; Latta 1977; Reynolds *et al.* 1993 *in* Yoshiyama *et al.* 1998), but records for them are few and fragmented, partly because they did not support commercial fisheries (Yoshiyama *et al.* 1998).

Since European settlement of the Central Valley in the mid-1800s, populations of native Chinook salmon and steelhead have declined dramatically. California's salmon resources began to decline in the late 1800s, and continued to decline in the early 1900s, as reflected in the decline of Chinook salmon commercial harvest. The total commercial catch of Chinook salmon in 1880 was 11 million pounds, by 1922 it had dropped to seven million pounds, and reached a low of less than three million pounds in 1939 (Lufkin 1996).

In addition to commercial harvest of Chinook salmon, another major factor affecting anadromous salmonids during this period was hydraulic gold mining, which began in the 1850s. By 1859, an estimated 5,000 miles of mining flumes and canals diverted streams used by salmonids for spawning and nursery habitat. Habitat alteration and destruction also resulted from the use of hydraulic cannons, hydraulic and gravel mining, which leveled hillsides and sluiced an estimated 1.5 billion yd^3 of debris into the streams and rivers of the Central Valley (Lufkin 1996).

Despite the prohibition of hydraulic mining in 1894, habitat degradation continued. Habitat quantity and quality have declined due to: construction of levees and barriers to migration, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution from agriculture and industry (Lufkin 1996).

Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following construction of major water project facilities (USFWS 2001), which primarily occurred around the mid- 1900s. Many of these water development projects completely blocked the upstream migration of Chinook salmon and steelhead to spawning and rearing habitats, and altered flow and water temperature regimes downstream from terminal dams. As

urban and agricultural development of the Central Valley continued, numerous other stressors to anadromous salmonids emerged and continue to affect the viability of these fish today. Four of the more important stressors include: barriers to historic habitat, the continued commercial and recreational harvest of Chinook salmon, predation of Chinook salmon and steelhead from introduced species such as striped bass and black bass, and the high demand for limited water supply resulting in reduced instream flows, increased water temperatures and highly altered hydrology in the Sacramento-San Joaquin Delta.

Recovery Strategy: A broadly focused framework is necessary to serve as a strategic planning guide to integrate the actions contributing to the overarching goal of recovery of the two Chinook salmon ESUs and the steelhead DPS. Because of the complexity associated with the multi-faceted considerations for Central Valley recovery efforts, this strategic planning framework incorporates: (1) viability at both the ESU/DPS and population levels; (2) prioritizing watersheds currently occupied by at least one of the three listed species into three tiers - core 1, 2, or 3; and (3) prioritizing unoccupied watersheds for re-introductions.

Bridging the gap between the ESU/DPS and population levels are population groups or salmonid ecoregions, which are delineated based on climatological, hydrological, and geological characteristics. The Central Valley Technical Recovery Team's (TRT) identification of four population groups (hereafter referred to as diversity groups) that Chinook salmon historically inhabited in the Central Valley are as follows:

- The **basalt and porous lava diversity group** composed of the upper Sacramento River and Battle Creek watersheds;
- The **northwestern California diversity group** composed of streams that enter the mainstem Sacramento River from the northwest;
- The **northern Sierra Nevada diversity group** composed of streams tributary to the Sacramento River from the east, and including the Mokelumne River; and
- The **southern Sierra Nevada diversity group** composed of streams tributary to the San Joaquin River from the east.

Historically, the Sacramento River winter-run Chinook salmon ESU was composed of four populations within the basalt and porous lava diversity group and the Central Valley spring-run Chinook salmon ESU was represented in all four of the diversity groups, with as many as 18 or 19 total populations. In addition to the four previously mentioned diversity groups, the Central Valley steelhead DPS has two more historic diversity groups: the Suisun Bay region which consists of tributaries to or near Suisun Bay and the Central Western California region, which contains west-side San Joaquin Valley tributaries. It is hypothesized that historically 81 independent populations of steelhead were dispersed throughout the six diversity groups.

Currently, the Sacramento River winter-run Chinook salmon ESU is composed of a single population which is dependent on hatchery production and the Central Valley spring-run Chinook salmon ESU is composed of three diversity groups with fish exhibiting spring-run Chinook salmon life histories occurring in 12 watersheds. Only three of those 12 watersheds contain viable spring-run Chinook salmon populations. The current distribution of steelhead is less well understood, but the DPS is composed of at least four diversity groups and at least 26 populations.

Three priority levels have been established to help guide recovery efforts for watersheds that are currently occupied by at least one of the three listed Chinook salmon and steelhead species. Of highest priority are Core 1 populations, which have been identified based on a variety of factors, including: (1) the known ability or significant immediate potential to support independent populations; (2) the role of the population in meeting the spatial and/or redundancy viability criteria; (3) the severity of the threats facing the populations; (4) the potential ecological or genetic diversity the watershed and populations could provide to the species; and (5) the capacity of the watershed and population to respond to the critical recovery actions needed to abate those threats. Core 1 populations form the foundation of the recovery strategy and must meet the population-level biological recovery criteria for low risk of extinction set out in Table 4-1. NMFS believes that this set of Core 1 populations should be the first focus of an overall recovery effort. Core 2 population areas also form part of the recovery strategy by contributing to the highest potential to support geographically diverse populations. Core 2 populations must meet the biological recovery criteria for moderate risk of extinction set out in Table 4-1. These populations are of secondary importance in terms of recommended priority of recovery efforts. Finally, the complete attainment of ESU/DPS-level biological recovery criteria will likely also require the presence of populations listed as Core 3. Core 3 populations are present on an intermittent basis and are characterized as being dependent on other nearby populations for their existence. The presence of these populations provides increased life history diversity to the ESU/DPS and is likely to buffer against local catastrophic occurrences that could affect other nearby populations. Dispersal connectivity between populations and genetic diversity may be enhanced by working to recover smaller Core 3 populations that serve as stepping stones for dispersal.

Addressing the primary threats and risk factors for each of the ESU and DPS's will require reintroducing populations to historic, and currently unoccupied habitats. Candidate areas for reintroduction have been identified and prioritized as either primary or secondary. Efforts to reintroduce fish to these areas will be challenging, expensive, and will require unparalleled efforts to gain stakeholder support. We prioritized these areas based on watershed-specific information, which is summarized in Chapter 5 (Recovery Scenarios) and described in more detail in Appendix A (Watershed Profiles). Some areas that were historically accessible to anadromous salmonids have been excluded from consideration for reintroductions because they are so critically impaired by hydroelectric development and channel inundation that we felt efforts should be focused on areas with a higher potential for success.

Recovery will be expensive and time-consuming, and will require changes in the management and monitoring of aquatic resources and habitats. Successful implementation of this recovery plan will require the support, efforts and resources of many entities, from Federal and state agencies to individual members of the public. Because of these challenges, the Recovery Plan requires an achievable strategy to select and implement recovery actions.

This Recovery Plan establishes a strategic approach to recovery. Because recovery of the two Chinook salmon ESUs and the steelhead DPS will require implementation over an extended period of time, a stepwise strategy has been adopted, based on the threats assessment process and identification of priority threats, which first addresses more urgent near-term needs, upon which to build toward full recovery. As this Recovery Plan is implemented over time, additional information will become available to help determine whether the threats have been abated, to further develop understanding of the linkages between threats and Chinook salmon and steelhead population responses, to identify any additional threats, and to evaluate the viability of Chinook salmon and steelhead in the Central Valley.

The general near-term strategic approach to recovery includes the following elements:

- *Secure all extant populations*. Both ESUs and the DPS are far short of being viable, and extant populations, even if not presently viable, will likely be needed for recovery. The Central Valley TRT recommends that every extant population be viewed as necessary for the recovery of the ESU and DPS. Wherever possible, the status of extant populations should be improved.

- *Begin collecting distribution and abundance data for O. mykiss in habitats accessible to anadromous fish*. This is fundamental to designing effective recovery actions and eventual delisting. Of equal importance is assessing the relationship of resident and anadromous forms of *O. mykiss*, including the role the resident fish play in population maintenance and persistence.

- *Minimize straying from hatcheries to natural spawning areas*. Even low levels of straying from hatchery populations to wild ones works against the goal of maximizing diversity within ESUs and populations. A number of actions could reduce straying from hatcheries to natural areas, including replacing off-site releases with volitional releases from the hatchery, allowing all fish that attempt to return to the hatchery to do so, marking or tagging programs that could be used to separate wild and hatchery stocks, and reducing the amount of fish released (see CDFG and NMFS (2001), for a review of hatchery issues).

- *Conduct critical research on fish passage above rim dams, reintroductions, and climate change*. Current climate change information suggests that the Central Valley will become warmer, a challenging prospect for Chinook salmon and steelhead – both of which are coldwater fish at the southern end of their distribution. To recover Central Valley salmon ESUs and the steelhead DPS, some populations will need to be established in cooler, high elevation areas now blocked by dams or insufficient flows. Assuming that most of these dams will remain in place for the foreseeable future, it will be necessary to facilitate the movement of fish around the dams in both directions. The near-term will include assessing habitat suitability and passage logistics.

- *Listed salmonid ESUs are likely to be conservation-reliant (*Scott *et al*. 2005*)*. It seems highly unlikely that enough habitat can be restored in the foreseeable future such that Central Valley salmonid ESUs (and DPS) could be expected to persist without continued conservation management. Rather, it may be possible to restore enough habitat such that ESUs (and DPS) can persist with appropriate management, which should focus on maintaining ecological processes at the landscape level.

The long-term approach to recovery includes the following elements:

- Ensure that every extant diversity group has a high probability of persistence.

- Until all ESU viability criteria have been achieved, no population should be allowed to deteriorate in its probability of persistence.

- High levels of recovery should be attempted in more populations than identified in the diversity group viability criteria because not all attempts will be successful.

- Individual populations within a diversity group should have persistence probabilities consistent with a high probability of diversity group persistence.

- Within a diversity group, the populations restored/maintained at viable status should be selected to:
  - Allow for normative meta-population processes, including the viability of core populations, which are defined as the most productive populations.
  - Allow for normative evolutionary processes, including the retention of the genetic diversity, as well as an increase in genetic diversity through the addition of viable populations in historic habitats.
  - Minimize susceptibility to catastrophic events.

In addition to the general near- and long-term strategies, applying the viable salmonid population guidelines and recovery criteria presented in this recovery plan results in specific recovery needs for each species. In summary, a program that ultimately results in re-establishing at least two viable populations within each diversity group will be needed to recover winter-run, spring-run, and steelhead. Some flexibility around this criteria is warranted as is explained in the Recovery Scenario chapter, which gives top-down, conceptual descriptions of what a recovered ESU/DPS would look like for each of the three species.

Recovery Goals, Objectives, and Criteria: The overarching goal of this Recovery Plan is the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and Central Valley steelhead DPS in the Central Valley Domain from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11). The objectives and criteria to accomplish this goal builds upon the technical input and guidance provided by the Central Valley TRT, and much of the following discussion is taken directly from information developed by the TRT (Lindley et al. 2004; 2006; 2007).

In order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, each Diversity Group must be represented, and population redundancy within the groups must be met to achieve Diversity Group recovery. Therefore, Diversity Group criteria include:

- Three viable populations of winter-run Chinook salmon within the winter-run Chinook salmon Diversity Group at low risk of extinction;
- A minimum of two viable populations of spring-run Chinook salmon within each of the four spring-run Chinook salmon Diversity Groups, with the exception of the Northwestern California Diversity Group which historically did not contain independent spring-run Chinook salmon populations. For the Northwestern California Diversity Group, observed occupancy will suffice rather than viability, as defined; and
- A minimum of two viable populations of steelhead within each of the four extant steelhead Diversity Groups (i.e., the Basalt and Porous Lava Diversity Group, the Northwestern California Diversity Group, the Northern Sierra Nevada Diversity Group and the Southern Sierra Nevada Diversity Group)

Recovery criteria at the population level were established by the Central Valley TRT and are included in this recovery plan (and apply to all three species), as described in Lindley *et al*. (2007). The TRT incorporated the four viable salmonid population parameters (McElhany *et al*. 2000) into assessments of

population viability, and two sets of population viability criteria were developed, expressed in terms of extinction risk. The first set of criteria deal with direct estimates of extinction risk from population viability models. If data are available and such analyses exist and are deemed reasonable for individual populations, such assessments may be efficient for assessing extinction risk. In addition, the Central Valley TRT also provided simpler criteria. The simpler criteria include population size (and effective population size), population decline, catastrophic rate and effect, and hatchery influence. For a population to be considered at low risk of extinction (i.e., < 5 percent chance of extinction within 100 years), the population viability assessment must demonstrate that risk level or all of the following criteria must be met:

- The effective population size must be > 500 or the population size must be > 2,500
- The population growth rate must show that a decline is not apparent or probable
- There must be no apparent or minimal risk of a catastrophic disturbance occurring
- Hatchery influence must be low, as determined by levels corresponding to different amounts, durations and sources of hatchery strays

Additionally, qualitative threat abatement criteria must be met demonstrating that specific threats have been addressed and alleviated. These threat abatement criteria are established to address threats to, or resulting from, spawning grounds, habitat quality and quantity, overutilization, disease or predation, inadequate regulatory mechanisms, artificial propagation, climate change, water diversions, and non-indigenous aquatic nuisance species.

Recovery Scenarios: Conceptual recovery scenarios for each species (i.e., winter-run, spring-run, and steelhead) are presented in Chapter 5 of this Recovery Plan to provide initial descriptions of what a recovered ESU/DPS would look like. These ESU/DPS-level recovery scenarios have been developed based on ESU/DPS, population, and ecological considerations to identify a combination of populations and population and habitat status levels that meet biological and threat abatement recovery criteria. The scenarios represent some of the many possible combinations of populations, restoration actions, risk minimization and threat abatement.

Considerations for ESU/DPS viability depends on the number of populations within the ESU/DPS, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and diversity of the populations and their habitats. In the most general terms, ESU/DPS viability increases with the number of populations, the viability of these populations, the diversity of the populations, and the diversity of habitats that they occupy (Lindley et al 2007).

The Central Valley TRT described the historical populations of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon ESUs in the Central Valley (Lindley et al. 2004). They considered geography, migration rates, genetic attributes, life history diversity, population dynamics, and environmental characteristics in grouping the populations into independent populations and dependent populations. For the Central Valley steelhead DPS, Lindley et al. (2006) identified historical independent populations based on a model that identifies discrete habitat and interconnected habitat patches isolated from one another by downstream regions of thermally unsuitable habitat.

In addition to ESU/DPS and population viability, structure and distribution considerations, the conceptual recovery scenarios incorporate ecological or habitat objectives for each Diversity Group:

- The recovery scenario must address the entire natural ecosystem
- The recovery scenario should reflect that viable ESUs/DPSs and populations require a network of complex and interconnected habitats, which are created, altered, and maintained by natural physical process
- The spatial distribution and productive capacity of freshwater and estuarine habitats should be sufficient to maintain viable populations identified for recovery
- The diversity of habitats for recovered populations generally should resemble historic conditions given expected natural disturbance regimes (wildfire, flood, volcanic eruptions, etc.). Historic conditions represent a reasonable template for a viable population - the closer the habitat resembles the historic diversity, the greater the confidence in its ability to support viable populations
- At a large scale, habitats should be protected and restored, with a trend toward an appropriate range of attributes for salmonid viability

The conceptual recovery scenarios were developed with consideration of the biological significance and recovery feasibility of each population. Biological significance was based on current status, potential for improvement, historical significance, proximity to other selected populations with reference to catastrophic risks, and spatial distribution between independent and dependent populations. Feasibility of recovery was based on expected progress as a result of existing programs, absence of apparent impediments toward recovery, and other management considerations (e.g. fish passage potential).

As this Recovery Plan is implemented over time, additional information will become available to help determine whether the threats have been abated, to further develop understanding of the linkages between threats and Chinook salmon and steelhead population responses, identify any additional threats, and to evaluate the viability of Chinook salmon and steelhead in the Central Valley. Monitoring and adaptive management in the course of implementation of this Recovery Plan will provide more information on the feasibility of recovering the winter- and spring-run Chinook salmon ESUs and the steelhead DPS in the Central Valley Domain. Such information is expected to lead to adjustments in recovery expectations and restoration actions and, thus, recovery scenarios.

Recovery Actions: Many complex and inter-related biological, economical, social, and technological issues must be addressed in order to recover anadromous salmonids in the Central Valley. Policy changes at the Federal, State and local levels will be necessary to implement many of the recovery actions identified in this Recovery Plan. For example, without substantial strides in habitat restoration, fish passage, and changes in water use, recovery will be difficult if not impossible. In many cases, such as the Sacramento-San Joaquin Delta, an improved governance structure is needed to consolidate, streamline and focus the many, often conflicting, regulatory and land use mandates that influence water and habitat management, and species status and recovery. Most importantly, achieving a recovered species status is not likely without a focused effort to secure core populations, reintroduce fish to priority watersheds (where the majority of historic spawning habitat is located), and to restore the ecological function of the interconnected habitats upon which the species depend for their survival.

Implementation and Cost Estimates: It is a challenging undertaking to facilitate a change in practice and policy that reverses the path towards extinction of a species to one of recovery. This change can only be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift agency and societal attitudes, practices and understanding. Implementation of the recovery plan by NMFS will take many forms and is described in the NMFS Protected Resources Division Strategic Plan 2006 (NMFS 2006a). The Recovery Planning Guidance (NMFS 2006b) also outlines how NMFS shall cooperate with other agencies regarding plan implementation. These documents, in addition to the ESA, shall be used by NMFS to set the framework and environment for plan implementation. The PRD Strategic Plan asserts that species conservation (in implementing recovery plans) by NMFS will be more strategic and proactive, rather than reactive. To maximize existing resources with workload issues and limited budgets, the PRD Strategic Plan champions organizational changes and shifts in workload priorities to focus efforts towards "…*those activities or areas that have biologically significant beneficial or adverse impacts on species and ecosystem recovery* (NMFS 2006a)." The resultant shift will reduce NMFS engagement on those activities or projects not significant to species and ecosystem recovery.

NMFS actions to promote and implement recovery planning shall include:

- Formalizing recovery planning goals on a program-wide basis to prioritize work load allocation and decision-making (to include developing the mechanisms to make implementation (e.g., restoration) possible)
- Conducting an aggressive outreach and education program.
- Facilitating a consistent framework for research, monitoring, and adaptive management that can directly inform recovery objectives and goals.
- Establishing an implementation tracking system that is adaptive, web-based (internet), and pertinent to support the annual reporting for the Government Performance and Results Act, Biennial Recovery Reports to Congress and the 5-Year Status Reviews.

NMFS' efforts must be as far-reaching (beyond those under the direct regulatory jurisdiction of NMFS) as the issues adversely affecting the species. Thus, to achieve recovery, NMFS will need to promote the recovery plan and provide needed technical information and assistance to other entities that implement actions that may impact the species' recovery. For example, NMFS will work with key partners on high priorities such as facilitating passage assessment and working with Counties to ensure protective measures consistent with recovery objectives are included in their General Plans.

An implementation schedule describing time frames and costs associated with individual recovery actions has been developed and is included in this Recovery Plan. Cost estimates for near-term and longer-term recovery actions have been provided wherever possible. Cost estimates have not been identified for all actions due to uncertainties associated with new types of actions that have not been implemented before. Total cost to recovery is challenging to reliably estimate because the biological response of recovery actions is uncertain, achieving recovery will be a long-term effort likely requiring at least a few decades, and new stressors may emerge over time. However, it is estimated that the cost for implementing recovery actions will range from $1.04 to 1.26 billion over the next 5 years, and over $10 billion over the next 50 years.

TABLE OF CONTENTS

PAGE

1.0 INTRODUCTION **1**

1.1 The Great Central Valley of California **2**

1.2 Salmon & Steelhead at Risk **2**

1.3 The Recovery Planning Process **4**

1.3.1 A Collaborative Effort 5

1.4 Recovery Plan Content **7**

2.0 BACKGROUND **9**

2.1 Winter-run Chinook Salmon **9**

2.1.1 Brief Overview/Status of the Species 9

2.1.2 Species Description and Taxonomy 10

2.1.3 Life History/Habitat Requirements 10

2.1.4 Abundance Trends and Distribution 16

2.1.5 Critical Habitat 18

2.1.6 Reasons for Listing/Threats Assessment 19

2.1.7 Conservation Measures 23

2.1.8 Biological Constraints and Needs 24

2.2 Spring-run Chinook Salmon **25**

2.2.1 Brief Overview/Status of the Species 25

2.2.2 Species Description and Taxonomy 26

2.2.3 Abundance Trends and Distribution 28

2.2.4 Habitat Requirements 31

2.2.5 Critical Habitat 31

2.2.6 Reasons for Listing / Threats Assessment 34

2.2.7 Conservation Measures 37

2.2.8 Biological Constraints and Needs 37

2.3 Steelhead **38**

2.3.1 Brief Overview/Status of the Species 38

2.3.2 Species Description and Taxonomy 40

2.3.3 Life History 40

2.3.4 Abundance Trends and Distribution 41
2.3.5 Habitat Requirements 43
2.3.6 Critical Habitat 44
2.3.7 Reasons for Listing / Threats Assessment 45
2.3.8 Conservation Measures 49
2.3.9 Biological Constraints and Needs 49

3.0 RECOVERY STRATEGY 50
3.1 Strategic Framework 50
3.1.1 Population Viability 50
3.1.2 ESU Viability 52
3.1.3 Strategy for Success 56
3.2 Applied Strategic Framework 60
3.2.1 Sacramento River Winter-run Chinook Salmon 60
3.2.2 Central Valley Spring-run Chinook Salmon 60
3.2.3 Central Valley Steelhead 61
3.3 Recovery Plan Strategy 61
3.3.1 Near-term Strategic Approach 61
3.3.2 Long-term Strategic Approach 62
3.4 Core Populations 63
3.5 Reintroduction Priorities 64

4.0 RECOVERY GOALS, OBJECTIVES AND CRITERIA 67
4.1 Recovery Goals 67
4.2 Integrating TRT Products into Recovery Objectives and Criteria 68
4.2.1 Biological Recovery Criteria 68
4.3 Biological Objectives and Criteria at the ESU/DPS and Diversity Group Level and Population Level 72
4.3.1 ESU/DPS and Diversity Group Objectives 72
4.3.2 Population Objectives 74
4.4 Threat Abatement Criteria 75

5.0 RECOVERY SCENARIOS 83

5.1 Overview 83

5.2 Recovery Scenario Considerations 84

5.2.1 ESU/DPS Level Considerations 84

5.2.2 Population Level Considerations 86

5.2.3 Ecological (Habitat) Restoration Considerations 87

5.2.4 Threat Abatement 88

5.3 Process for Recovery Scenario Development 89

5.4 Conceptual Recovery Scenarios 89

5.4.1 Spatial Distribution and Abundance 89

5.4.2 Network of Complex and Interconnected Habitats 90

5.4.3 Hatchery Management 92

5.4.4 Winter-run Chinook Salmon 93

5.4.5 Spring-run Chinook Salmon 98

5.4.6 Steelhead 121

6.0 RECOVERY ACTIONS 153

6.1 Priority 1 recovery actions for the Central Valley 154

6.1.1 Recovery Action Narrative 155

7.0 CLIMATE CHANGE AND RECOVERY OF SALMON AND STEELHEAD 164

7.1 Overview 164

7.2 Climate Change and Environmental Variability 165

7.3 Climate Change Effects on Ocean Conditions 168

7.3.1 California Current Ecosystem 168

7.4 Recommended Strategies for Considering Climate Effects and Application to Recovery Planning 175

7.5 Climate Change in Relation to Central Valley Domain Recovery 177

7.6 Additional Considerations Applied to the Conceptual Recovery Scenarios 180

7.6.1 Resiliency 180

7.6.2 Refugia 180

7.6.3 Restoration 181

8.0 IMPLEMENTATION AND COST ESTIMATES 182

8.1 Time and Cost 182

8.2 Implementation Table 183

8.3 Integrating Recovery into NMFS Actions 206

8.3.1 Working with Constituents and Stakeholders 207

8.3.2 ESA Section 4 207

8.3.3 ESA Section 5 209

8.3.4 ESA Section 6 209

8.3.5 ESA Section 7 211

8.3.6 ESA Section 9 213

8.3.7 ESA Section 10 213

8.3.8 Fisheries Management and EFH 216

8.3.9 Coordination with other NMFS Divisions and the PFMC 216

8.3.10 Technical Assistance 216

9.0 GLOSSARY 218

LITERATURE CITED 228

LIST OF FIGURES

PAGE

Figure 1-1. Central Valley Region of California 2

Figure 2-1. Current and Historical Sacramento River Winter-run Chinook Salmon Distribution. 11

Figure 2-2. Estimated Sacramento River Winter-run Chinook Salmon Run Size 17

Figure 2-3. Sacramento River Winter-run Chinook Salmon Designated Critical Habitat and Distribution 20

Figure 2-4. Central Valley Spring-run Chinook Salmon ESU, and Current and Historical Distribution. 27

Figure 2-5. Central Valley Spring-run Chinook Salmon Run Size Estimates 30

Figure 2-6. Mill, Deer, and Butte Creek Combined Spawning Run Size Estimates for Central Valley Spring-run Chinook Salmon 30

Figure 2-7. Central Valley Spring-run Chinook Salmon Spawning Run Size Composition 32

Figure 2-8. Central Valley Spring-run Chinook Salmon Designated Critical Habitat and Distribution 33

Figure 2-9. Central Valley Steelhead Distinct Population Segment, and Current and Historical Distribution. 39

Figure 2-10. Central Valley Steelhead Designated Critical Habitat and Distribution 46

Figure 3-1. Viable salmonid population (VSP) parameters and their attributes. 51

Figure 3-2. Diversity Groups for the Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon ESUs in the Central Valley Domain. 54

Figure 3-3. Diversity Groups for the Central Valley Steelhead DPS in the Central Valley Domain. 55

Figure 4-1. Extinction Risk Levels Corresponding to Different Amount, Duration and Source of Hatchery Strays. 72

Figure 5-1. Sacramento River Winter-run Chinook Salmon ESU Conceptual Recovery Footprint. 95

Figure 5-2 Central Valley Spring-run Chinook Salmon ESU Conceptual Recovery Footprint. . 101

Figure 5-3. Central Valley Steelhead DPS Conceptual Recovery Footprint.. 125

Figure 7-1. Summary of Projected Global Warming Impacts 166

Figure 7-2. Schematic of Coastal Upwelling Near the California Coast. 167

Figure 7- 3. The Principal Ocean Currents Affecting the Coastal Waters off of California. 170

Figure 7-4. Schematic of the Flow of the North Pacific Current South into the California Current and North into the Gulf of Alaska……174

LIST OF TABLES

PAGE

Table 2-1. The Temporal Occurrence of Adult and Juvenile Sacramento River Winter-run Chinook Salmon in the Sacramento River 13

Table 2-2. Winter-run Chinook Salmon Juvenile Releases from LSNFH (Broodyears 1998-2008) and Date of Initial Recapture at Chipps Island..... 17

Table 2-3. Temporal Occurrence of Adult and Juvenile Sacramento River Spring-run Chinook Salmon in the Sacramento River 29

Table 2-4. The Temporal Occurrence of Adult and Juvenile Sacramento River Steelhead in the Sacramento River 42

Table 2-5. Hatcheries Producing Steelhead in the Central Valley..... 47

Table 3-1. Recovery Priorities for Central Valley Watersheds Currently Occupied by Winter-run, Spring-run, or Steelhead. 65

Table 3-2. Reintroduction Priorities for Central Valley Watersheds. 66

Table 4-1 Criteria for assessing the Level of Risk of Extinction for Populations of Pacific Salmonids, Applied to the Chinook Salmon ESUs and the Steelhead DPS in the Central Valley Domain ……..……..……..71

Table 4-2 Estimation Methods and Data Requirement for Population Metrics……71

Table 8-2. Implementation table for priority 1 recovery actions. 184

Table 8-3. Summary of approaches NMFS intends to use when implementing various sections of the ESA and MSFCMA. 210

LIST OF APPENDICES

Appendix A Central Valley Watershed Profiles

Appendix B Threats Assessment for the Evolutionarily Significant Units of Winter-run Chinook Salmon *(Oncorhynchus tshawytscha)* and Central Valley Spring-run Chinook Salmon *(O. tshawytscha)*, and the Distinct Population Segment of Central Valley Steelhead *(O. mykiss)*

Appendix C Priority 2 Recovery Actions/Implementation Schedule

Appendix D Central Valley Technical Recovery Team Reports

Appendix E Habitat Restoration Cost References for Salmon Recovery Planning

LIST OF ACRONYMS

ACOE	U.S. Army Corps of Engineers
AFRP	Anadromous Fish Restoration Program
Bay/Delta	San Francisco Bay/Sacramento-San Joaquin Delta
BRT	Biological Resource Team
CALFED	CALFED Bay-Delta Program
CAMP	Comprehensive Assessment and Monitoring Program
CBDA	California Bay/Delta Authority
CCWD	Contra Costa Water District
CCWMG	Cow Creek Watershed Management Group
CDFG	California Department of Fish and Game
CESA	California Endangered Species Act
CMARP	Comprehensive Monitoring Assessment and Research Program
cm	centimeters
cm/sec	centimeters per second
CNFH	Coleman National Fish Hatchery
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement act
CVSEPWT	Central Valley Salmonid Escapement Project Work Team
CWT	Coded Wire Tag
Delta	Sacramento-San Joaquin Delta
DPS	Distinct Population Segment
DWR	Department of Water Resources
ERP	Ecosystem Restoration Program
ESA	Federal Endangered Species Act
ESU	Evolutionarily Significant Unit
EWA	Environmental Water Account
FERC	Federal Energy Regulatory Commission
FL	fork length
FRFH	Feather River Fish Hatchery
ft/sec	feet per second
HGMPs	Hatchery and Genetic Management Plans
IEP	Interagency Ecological Program
m	meters
mi^2	square miles
m/sec	millimeters per second
mm	millimeters
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PCSRF	Pacific Coastal Salmon Recovery Fund
PVA	Population Viability Analyses
QC	Quality Control
RBDD	Red Bluff Diversion Dam
Reclamation	Bureau of Reclamation
RM	River Mile
RST	Rotary Screw Trap
SWP	State Water Project

TRT	Technical Recovery Team
USFWS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Population

1.0 Introduction

"Salmon was now abundant in the Sacramento. Those which we obtained were generally between three and four feet in length, and appeared to be of two distinct kinds. It is said that as many as four different kinds ascend the river at different periods. The great abundance in which this fish is found gives it an important place among the resources of the country."

- Captain John C. Frémont, memoirs for 30 March-5 April 1846 *in* Yoshiyama et al. 1998

The rivers draining the Great Central Valley of California ("Central Valley") and adjacent Sierra Nevada and Cascade Range once were renowned for their production of large numbers of Pacific salmon (Clark 1929; Skinner 1962 *in* Yoshiyama *et al.* 1998). The Central Valley system historically has been the source of most of the Pacific salmon produced in California waters (CDFG 1950, 1955; Fry and Hughes 1951; Skinner 1962; CDWR 1984 *in* Yoshiyama *et al.* 1998).

Chinook salmon *(Oncorhynchus tshawytscha)* historically were, and remain today, the only abundant salmon species in the Central Valley system (Eigenmann 1890; Rutter 1908 *in* Yoshiyama *et al.* 1998), although small numbers of other salmon species also have occurred occasionally in its rivers (Collins 1892; Rutter 1904a, 1908; Hallock and Fry 1967; Moyle *et al.* 1995 *in* Yoshiyama *et al.* 1998). Anadromous steelhead (*O. mykiss)* apparently were common in Central Valley tributaries (USFC 1876; Clark 1973; Latta 1977; Reynolds *et al.* 1993 *in* Yoshiyama *et al.* 1998), but records for them are few and fragmented, partly because they did not support commercial fisheries (Yoshiyama *et al.* 1998).

Anadromous salmonids, in particular Chinook salmon, have and continue to be an important resource, both revered and harvested by humans. The Native American people depended upon these fishes for subsistence, ceremonial, and trade purposes. Prior to Euro-American settlement, Native Americans within the Central Valley drainage harvested Chinook salmon at estimated levels that reached 8.5 million pounds or more annually (Yoshiyama *et al.* 1998). With the advent of the California gold rush in the mid-1800s, a commercial Chinook salmon fishery developed in the San Francisco Bay and Sacramento-San Joaquin Delta ("Delta") region. Annual catches by the early in-river fisheries commonly reached 4-10 million pounds. The first west coast salmon cannery opened on a scow moored near Sacramento in 1864. Within 20 years, 19 canneries were operating in the Delta region, and processed a peak of 200,000 cases (each case comprised of 48, 1-pound cans) in 1882 (Lufkin 1996). The salmon fishery remained centered in the Delta region until the early 1900s, when ocean salmon fishing began to expand and eventually came to dominate the fishery.

1.1 The Great Central Valley of California

The northern half of the Central Valley is comprised of the Sacramento River Basin (covering approximately 24,000 square miles [mi^2]), with the southern half (covering approximately 13,540 mi^2) primarily composed of the San Joaquin River Basin (**Figure 1-1**). The broad expanse of the Central Valley region of California once encompassed numerous salmon-producing streams that drained the Sierra Nevada and Cascade mountains on the east and north and, to a lesser degree, the lower-elevation Coast Range on the west. The large areal extent of the Sierra Nevada and Cascades watersheds, coupled with regular, heavy snowfalls in those regions, provided year-round streamflows for a number of large rivers which supported substantial runs of Chinook salmon (Yoshiyama *et al.* 1998).

Figure 1-1. Central Valley Region of California

In the Sacramento River Basin, most Coast Range streams historically supported regular salmon runs, although their runs were limited by the volume and seasonal availability of streamflows due to the lesser amount of snowfall west of the valley (Yoshiyama *et al.* 1998). In the San Joaquin River Basin, a number of major streams (e.g., the Merced, Tuolumne, and upper San Joaquin rivers) sustained very large salmon populations, while other streams with less regular streamflows had intermittent salmon runs in years when rainfall provided sufficient flows. All of the westside San Joaquin River Basin streams flowing from the Coast Range were highly intermittent (Elliott 1882) and none are known to have supported anadromous salmonids (Yoshiyama *et al.* 1998).

1.2 Salmon & Steelhead at Risk

Since settlement of the Central Valley in the mid-1800s, populations of native Chinook salmon and steelhead have declined dramatically. California's salmon resources began to decline in the late 1800s, and continued to decline in the early 1900s, as reflected in the decline of commercial harvest. The total commercial catch of Chinook salmon in 1880 was 11 million pounds, by 1922 it had dropped to 7 million pounds, and reached a low of less than 3 million pounds in 1939 (Lufkin 1996).

History and Current Status of Commercial Harvest

Although Chinook salmon remain an important resource, fishing for salmon has changed, most notably, in the last 20 years. 28 evolutionarily significant units (ESU'S) and distinct population segments (DPS's) of salmonids have been listed under the Endangered Species List by the National Marine Fisheries Service (NMFS) on the West Coast of the United States since 1989. This is significant because commercial ocean harvest and sport fishing for salmon, has undergone dramatic management and regulatory implementations in order to continue with the commercial fishery while at the same time finding and implementing an exploitation rate that enables sustained Chinook populations into the future. It is also now possible for the ocean fishery to be managed for specific river fisheries through genetic

sampling of the ocean harvest along the Pacific Coast. This change has altered the way ocean harvest is carried out, and further protects critical species in that life stage.

New matrixes developed by the National Oceanic and Atmospheric Administration (NOAA) Pacific Northwest Region emphasize that commercial fishing or ocean harvest is a critical parameter in the decisions used to manage sustainable fisheries or to reestablish enough returning numbers of fish to create reasonable escapement.

The National Marine Fisheries Service establishes fishery management measures in the Pacific Ocean for Chinook salmon to prevent overfishing of this species. The current management measures serve to:

- apportion ocean harvest equitably among treaty Indian, non-treaty commercial and recreational fisheries
- provide in-season adjustment flexibility so that the fishing can provide for spawning escapement that meets replacement curves
- provide in-season adjustments to manage for ESA listed species.

Sources of Habitat Decline

In addition to commercial harvest, another major factor affecting Chinook salmon and steelhead during this period was hydraulic gold mining, which began in the 1850s. By 1859, an estimated 5,000 miles of mining flumes and canals diverted streams used by salmonids for spawning and nursery habitat. Habitat alteration and destruction also resulted from the use of hydraulic cannons, which leveled hillsides and sluiced an estimated 1.5 billion yd^3 of debris into the streams and rivers of the Central Valley (Lufkin 1996).

Since hydraulic mining was prohibited in 1894, habitat degradation continued. Habitat quantity and quality have declined due to construction of levees and barriers to migration, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution (Lufkin 1996). Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following completion of major water project facilities (USFWS 2001) which primarily occurred around the mid- 1900s.

Numerous water development projects blocked the upstream migration of Chinook salmon and steelhead, and altered flow and water temperature regimes downstream from terminal dams. An extensive network of reservoirs and aqueducts has been developed throughout much of California to provide water to major urban and agricultural areas. The largest system of surface reservoirs and aqueducts in California is in the Central Valley. Surface reservoirs collecting runoff in the Central Valley have a combined total capacity of about 29 million acre-feet. The two largest water projects in the Central Valley, the State Water Project (SWP) and the Federal Central Valley Project (CVP), provide a combined average total of about 10 million acre-feet of water annually for urban and agricultural uses (DWR 2006). More than 20 million Californians rely on the SWP and the CVP for at least part of their water supply, and these projects irrigate an average of nearly 3.6 million acres of farmland each year (DWR 2005a).

It has been estimated that 1,126 miles of main stream lengths presently remain of the more than 2,183 miles of Central Valley streams that were originally available to Chinook salmon – indicating an overall loss of at least 1,057 miles (48 percent) of the original total (Yoshiyama *et al.* 2001). The estimated habitat loss includes the lengths of stream used by salmon mainly as migration corridors, in addition to holding and spawning habitat. This estimated loss of habitat does not include the Delta, comprising about 700 miles of river channels and sloughs (USFWS 1995), available to various degrees as migration corridors or rearing areas for Chinook salmon and steelhead.

It is likely that the lower reaches of the Sacramento and San Joaquin rivers historically were used as rearing areas (at least during some

flow regimes) as the juveniles moved downstream, but recently they have been less suitable for rearing due to alterations in channel morphology and other degraded environmental conditions. In terms of only spawning and holding habitat, the proportionate loss of historically available habitat far exceeds 48 percent, much of which was located in upper stream reaches that have been rendered inaccessible by terminal dams (Yoshiyama *et al.* 2001). Excluding the lower stream reaches that were used as adult migration corridors (and, to a lesser degree, for juvenile rearing), it has been estimated that at least 72 percent of the original Chinook salmon spawning and holding habitat in the Central Valley drainage is no longer available (Yoshiyama *et al.* 2001).

The amount of steelhead habitat lost most likely is much higher than that for Chinook salmon, because steelhead were undoubtedly more extensively distributed. Due to their superior leaping and swimming ability, the timing of their upstream migration (which coincided with the winter rainy season), and their less restrictive preferences for spawning gravels, steelhead likely used at least hundreds of miles of smaller tributaries not accessible to even the highest migrating winter-run and spring-run Chinook salmon (Yoshiyama *et al.* 2001).

In addition to commercial exploitation, large-scale habitat degradation, blockage of historically available habitat and altered flow and water temperature regimes, other factors that may have adversely affected natural stocks of Chinook salmon and steelhead include overharvest, illegal harvest, hatchery production, entrainment, and introduction of competitors, predators and diseases. Fish populations also vary due to natural events, such as droughts and poor ocean conditions (e.g., El Niño). However, populations in healthy habitats typically recover within a few years after natural events. In the Central Valley, the decline of fish populations has continued through cycles of beneficial and adverse natural conditions, indicating the need to improve habitat (USFWS 2001).

1.3 The Recovery Planning Process

The Federal Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq.*) mandates the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) to develop and implement plans (*i.e.*, recovery plans) for the conservation and survival of NMFS listed species. Winter-run Chinook salmon are listed as endangered under the Federal ESA (as well as the California ESA [CESA]), and spring-run Chinook salmon and steelhead are listed as threatened. Implementation of the Recovery Plan for the Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), Central Valley spring-run Chinook salmon ESU, and Central Valley steelhead Distinct Population Segment[1] (DPS) is vital to the continued persistence and recovery of these populations. The Recovery Plan serves as a guideline for achieving recovery goals by describing the steps that must be taken to improve the status of the species. Although recovery plans provide guidance, they are not regulatory documents. The success of this Recovery Plan depends upon the cooperation of all stakeholders and regulatory entities to ensure appropriate implementation.

Pursuant to Section 4(f) of the ESA, a recovery plan must be developed for species listed as threatened or endangered, and this plan must be implemented unless it is found not to promote the conservation of the species. A recovery plan must include the following:

- A description of site-specific management actions necessary for recovery;
- Objective, measurable criteria, which when met, will allow delisting of the species; and

[1] On January 5, 2006, NMFS departed from their previous practice of applying the ESU policy to steelhead. NMFS concluded that within a discrete group of steelhead populations, the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a separate DPS (71 FR 834 (January 5, 2006)).

- Estimates of the time and cost to carry out the recommended recovery measures.

The purpose of this Recovery Plan is to guide implementation of recovery of the species by resolving the threats to the species and ensuring self-sustaining populations in the wild, and thereby ensuring viable Chinook salmon ESUs and the steelhead DPS. This Recovery Plan may be used to inform all stakeholders including Federal, State, Tribal, and local agencies and land use actions, but it does not place regulatory requirements on such entities.

Past recovery plans generally have focused on the abundance, productivity, habitat and other life history characteristics of a species. While knowledge of these characteristics is certainly important for making sound conservation management decisions, the long-term sustainability of a species in need of recovery can only be ensured by alleviating the threats that are contributing to the status of the species as threatened or endangered. Therefore, the identification of the threats to the species is a key component of this Recovery Plan.

To be most useful for recovery planning, a threats assessment should be used to determine the relative importance of various threats to a species. A threats assessment includes: (1) identifying threats and their sources; (2) evaluating the effects of threats; and (3) ranking each threat based on relative effects. The Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2006b) recommends "…*using a threats assessment for species with multiple threats to help identify the relative importance of each threat to the species' status, and, therefore, to prioritize recovery actions in a manner most likely to be effective for the species' recovery*." This Recovery Plan uses this recommended approach to identify and prioritize threats to the Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon ESUs, and the Central Valley steelhead DPS. The prioritized threats are then used to guide the identification of specific recovery actions.

The methodology used in the threats assessment for this Recovery Plan is generally described in the next chapter (Background) and is fully described in Appendix B.

1.3.1 A Collaborative Effort

NMFS believes it is critically important that ESA recovery plans for Pacific salmon use as their foundation the many Federal, State, regional, local, and private conservation efforts already underway throughout the region. Local support of recovery plans by those whose activities directly affect the listed species, and whose actions will be most affected by recovery requirements, is essential.

Central Valley Technical Recovery Team

As part of its recovery planning efforts, the NMFS Southwest Region designated the Central Valley as a "Recovery Domain." The NMFS Southwest Region established the Central Valley Technical Recovery Team (TRT) to provide technical assistance to the recovery planning process for the Central Valley Domain. The NMFS' intent in establishing the Central Valley TRT was to seek unique geographic and species expertise, and to develop a solid scientific foundation for the Recovery Plan. The Central Valley TRT identified unique habitat and biological characteristics in the Central Valley, made technical findings regarding limiting factors and stressors for each ESU and DPS and its component populations, recommended biological viability criteria at the ESU/DPS- and population-level, and provided scientific review of local and regional recovery planning efforts.

The Central Valley TRT, a collaborative body of biologists that were selected based on their expertise and local knowledge, produced three documents heavily relied upon in preparation of the Recovery Plan: (1) *Population Structure of Threatened and Endangered Chinook Salmon ESUs in California's Central Valley Basin* (Lindley *et al.* 2004); (2) *Historical Population Structure of Central Valley Steelhead and its Alteration by Dams* (Lindley *et al.* 2006); and (3) *Framework for Assessing Viability of*

Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin (Lindley *et al.* 2007).

Public Participation

NMFS conducted a series of Recovery Planning Workshops, designed as round-table discussions, to solicit information and promote dialogue as part of the development of the Federal Recovery Plan for winter-run Chinook salmon, spring-run Chinook salmon and steelhead in the Central Valley Domain. Public workshops were held in Sacramento, California on July 20, 2006, in Redding, California on August 15, 2006, and in Stockton, California on August 17, 2006. At these workshops, NMFS provided a general overview of: (1) the Federal recovery planning process; (2) the timeline for NMFS recovery plan development; (3) the current understanding of Chinook salmon and steelhead populations and their habitats; and (4) threats identified in original ESA listing documents.

Following the overviews, workshop participants were separated into smaller facilitated discussion groups to generate more in-depth dialogue and identify threats to specific Chinook salmon and steelhead populations and their habitats.

Information obtained at the initial series of workshops also was used in additional workshops to develop recovery actions that reduce or eliminate identified threats. These additional workshops were held in Sacramento, California on May 22, 2007 and in Redding, California on May 24, 2007.

Existing Efforts

Local water agencies and irrigation districts, municipal and county governmental agencies, watershed groups, and State and Federal agencies have undertaken major habitat restoration efforts in many parts of the Central Valley and Delta. These actions include the addition of gravel below dams, removal of small dams, riparian revegetation, bank protection, structural habitat enhancement, restoration of floodplain and tidal wetlands, development and implementation of new flow and water temperature requirements below dams, and operational constraints in the Delta. Although local watershed efforts are vital to recovery, foremost among restoration efforts in terms of Central Valley-wide application are the programs established under the Anadromous Fish Restoration Program (AFRP) of the Central Valley Project Improvement Act (CVPIA) and the Ecosystem Restoration Program (ERP) of the California Bay/Delta Authority (CBDA, also called CALFED), and the Bay Delta Conservation Plan. Shared purposes of the AFRP and the ERP are to protect and restore diversity within and among the various naturally-producing populations of Chinook salmon and steelhead in the Central Valley, and to restore the habitats upon which the populations depend. The purpose of the Bay Delta Conservation Plan (BDCP) is to help recover endangered and sensitive species and their habitats in the Delta in a way that also will provide for a reliable water supply.

The AFRP promotes collaboration between the Department of Interior (USFWS and the Bureau of Reclamation [Reclamation]) with other agencies, organizations and the public to increase natural production of anadromous fish in the Central Valley by augmenting and assisting restoration efforts presently conducted by local watershed workgroups, the California Department of Fish and Game (CDFG), and others. Purposes of the CVPIA (Section 3402) relevant to the AFRP are: (1) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley; (2) to address impacts of the CVP on fish, wildlife, and associated habitats; (3) to improve the operational flexibility of the CVP; (4) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay and Sacramento-San Joaquin Delta Estuary; and (5) to achieve a reasonable balance among competing demands for the use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors (USFWS 2001).

CALFED's objective for ecosystem restoration is to improve and increase aquatic and terrestrial habitats and improve ecological functions in the

Bay/Delta to support sustainable populations of diverse and valuable plant and animal species. All CALFED elements will contribute in varying degrees, but the ERP is the principal program element designed to restore the ecological health of the Bay/Delta ecosystem. The ERP includes actions throughout the Bay/Delta watershed and focuses on the restoration of ecological processes and important habitats. In addition, the ERP aims to reduce the effects of stressors that inhibit ecological processes, habitats and species (CALFED 1999b).

The BDCP is a multi-stakeholder effort intended to develop a long-term solution to competing demands for water in the Delta. NMFS serves in an ex-offio capacity on the Steering Committee of the BDCP, collaborating with State and Federal water agencies and contractors, non-governmental organizations, and State and other Federal fish and wildlife agencies to develop a Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP) covering take of listed species resulting from certain activities over a 50 year period. The HCP aims to conserve Federal and State listed species while providing a reliable source of freshwater for agricultural and urban uses in California. Further information is available at the BDCP website: http://resources.ca.gov/bdcp/.

A proposed BDCP water conveyance system would include new points of diversion in the north Delta in concert with improvements to the current through-Delta water export system in the south Delta. Actions under discussion include operation of a dual conveyance system, habitat restoration, and measures to reduce other stressors to the Delta ecosystem and covered species.

The operation of a conveyance structure that diverts water directly from the Sacramento River carries additional risk for listed species that migrate, spawn, or rear in the Sacramento River or North Delta. Any new conveyance will be subject to ESA consultation, and issues of injury or mortality of juvenile fish associated with all diversion facilities, reduction of flow variability for fish life history functions, reduction of Shasta Reservoir storage necessary for mainstem temperature control, and other potential adverse effects must be adequately addressed in any conveyance proposal.

Achieving an equitable balance between water demands and Delta ecosystem conservation will be challenging. From the salmon and steelhead recovery perspective, it is critical to ensure that the BDCP significantly improves Delta ecosystem function from its currently degraded state.

This Recovery Plan is consistent with the shared purposes of the AFRP, the ERP, and the BDCP, and recognizes the need to address populations of winter-run Chinook salmon, spring-run Chinook salmon and steelhead, and the habitats upon which they depend.

1.4 Recovery Plan Content

This introductory chapter provides an overview of many important facets of this Recovery Plan, and in particular describes the collaborative processes of the plan. The remainder of this Recovery Plan for the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU and the Central Valley steelhead DPS is presented in several chapters.

The second chapter provides background including the current regulatory status, a description of the population trends and distribution of each species, and a description of the life history and habitat requirements for each species. A brief description of the reasons for listing and a current threats assessment is then presented (a detailed threats assessment is presented in Appendix B). Finally, current conservation efforts and biological constraints are discussed, including limiting factors that must be considered for the species recovery.

Next, the Recovery Strategy Chapter presents and justifies the recommended recovery program for each species. This chapter also describes the key facts, concepts and assumptions upon which the recovery program is based, the primary focus and

objectives of the recovery effort, and the overarching objectives and recovery actions of the plan and their relative priorities.

Following the Recovery Strategy Chapter is a chapter describing the recovery goals, objectives, and criteria. The ultimate goal of the Recovery Plan is delisting of the Chinook salmon ESUs and the steelhead DPS. The recovery objectives basically subdivide the goal into discrete components which collectively describe the conditions necessary for delisting. Recovery criteria are the objective and measurable standards upon which a decision to delist the ESUs and DPS are based.

The recovery actions necessary to achieve the goals and objectives of this Recovery Plan are then presented. Recovery actions are linked to the identified threats (or stressors) individually for specific populations of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead within the Central Valley Domain, and are prioritized according to the priority of threats addressed.

Lastly, the Implementation Schedule and Cost Estimates Chapter is presented. This chapter is designed to satisfy the requirement under the ESA (Section 4 (f)(1)(A)(iii)) that Recovery Plans must contain "*…estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal.*"

2.0 Background

"The requirement for determining that a species no longer requires the protection of the ESA is that the species no longer be in danger of extinction or likely to become endangered in the foreseeable future based on evaluation of the listing factors specified in ESA Section 4(a)(1). Any new factors identified since listing must also be addressed in this analysis to ensure that the species no longer requires protection."

- NMFS Supplement to the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan 2005

The Central Valley Domain encompasses the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and Central Valley steelhead DPS. Following are descriptions of the current regulatory status, life histories, population trends and distribution, and the habitat requirements for winter- and spring-run Chinook salmon, and steelhead in the Central Valley. A brief description of the reasons for listing and a current threats assessment is then presented (a detailed threats assessment is presented in Appendix B). Finally, current conservation efforts and biological constraints are discussed, including limiting factors that must be considered for recovery of winter-run and spring-run Chinook salmon, and steelhead within the Central Valley Domain.

2.1 Winter-run Chinook Salmon

2.1.1 Brief Overview/Status of the Species

The Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) ESU, currently listed as endangered, was listed as a threatened species under emergency provisions of the ESA in August 1989 (54 FR 32085 (August 4, 1989)) and formally listed as a threatened species in November 1990 (55 FR 46515 (November 5, 1990)). In June 1992, NMFS proposed that winter-run Chinook salmon be reclassified as an "endangered"[2] species (57 FR 27416 (June 19, 1992)). NMFS finalized its proposed rule and re-classified winter-run Chinook salmon as an endangered species on January 4, 1994 (59 FR 440 (January 4, 1994)). NMFS concluded that winter-run Chinook salmon in the Sacramento River warranted listing as an endangered species due to several factors, including: (1) the continued decline and increased variability of run sizes since its first listing as a threatened species in 1989; (2) the expectation of weak returns in years as the result of two small year classes (1991 and 1993); and (3) continued threats to the "take" of winter-run Chinook salmon (65 FR 42421 (July 10, 2000)). On June 14, 2004, NMFS issued a proposed rule to reclassify the listing status of winter-run Chinook salmon from endangered to threatened (69 FR 33102 (June 14, 2004)). To prevent further decline of the ESU by preventing take of this species from activities that harm fish and fish habitat, NMFS proposed to apply the ESA Section 9(a) take prohibitions as the Section 4(d) limits to winter-run Chinook salmon (69 FR 33102 (June 14, 2004)).

[2] Under the ESA, an "endangered species" is "…any species which is in danger of extinction throughout all or a significant portion of its range…" (16 USC § 1533(20)).

Following a series of extensions to the public comment period on the proposed listing determinations, the public comment period closed during November 2004 (69 FR 61348 (October 18, 2004)). On June 28, 2005 NMFS issued a final listing determination for the Sacramento River winter-run Chinook salmon ESU, which concluded that the Sacramento River winter-run Chinook salmon ESU is "in danger of extinction" due to risks to the ESU's diversity and spatial structure and, therefore, continues to warrant listing as an endangered species under the ESA (70 FR 37160 (June 28, 2005)). Additionally, the Sacramento River winter-run Chinook salmon ESU is listed as "endangered" under the CESA.

The Sacramento River winter-run Chinook salmon ESU includes winter-run Chinook salmon spawning naturally in the Sacramento River and its tributaries, as well as winter-run Chinook salmon that are part of the conservation hatchery program at the Livingston Stone National Fish Hatchery (LSNFH) (70 FR 37160, June 2005). The Sacramento River winter-run Chinook salmon ESU is depicted in **Figure 2-1**.

2.1.2 Species Description and Taxonomy

Chinook salmon, also largely referred to as king salmon in California, are the largest of the Pacific salmon. The following physical description of the species is provided by Moyle (Moyle 2002). Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fins, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. Parr have 6 to 12 parr marks, each equal to or wider than the spaces between them and most centered on the lateral line. The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear.

2.1.3 Life History/Habitat Requirements

Chinook salmon is the most important commercial species of anadromous fish in California. Chinook salmon have evolved a broad array of life history patterns that allow them to take advantage of diverse riverine conditions throughout the year. Four principal life history variants are recognized and are named for the timing of their upstream migration: fall-run, late fall-run, winter-run, and spring-run. The Sacramento River supports all four runs of Chinook salmon. The larger tributaries to the Sacramento River (American, Yuba, and Feather rivers) and rivers in the San Joaquin Basin also provide habitat for one or more of these runs.

Winter-run Chinook salmon are unique because they spawn during summer months when air temperatures usually approach their yearly maximum. As a result, winter-run Chinook salmon require stream reaches with cold water sources that will protect embryos and juveniles from the warm ambient conditions in summer. Winter-run Chinook salmon are primarily restricted to the mainstem Sacramento River.

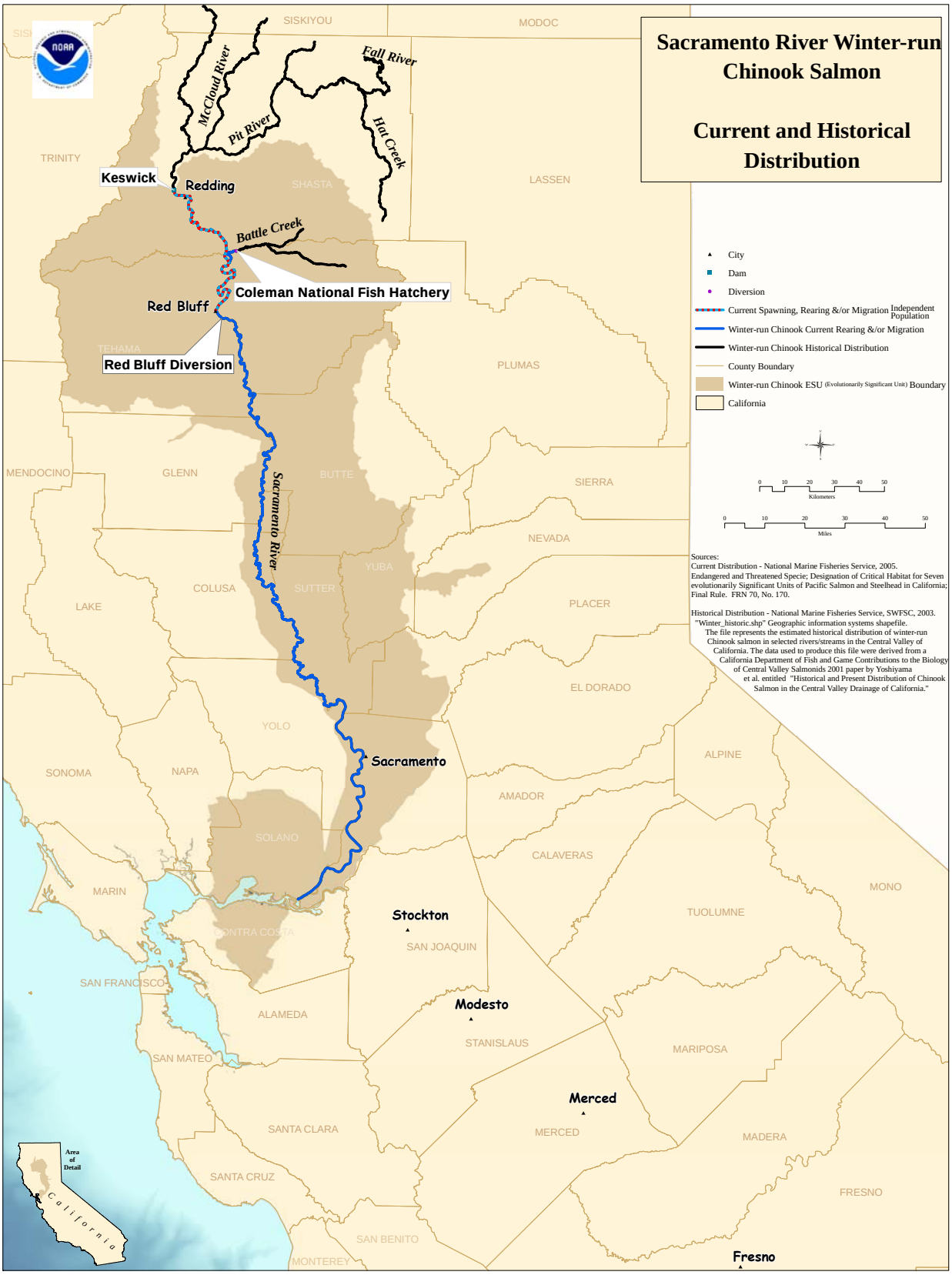


Figure 2-1. Current and Historical Sacramento River Winter-run Chinook Salmon Distribution.

.

Table 2-1 depicts the temporal occurrence of winter-run Chinook salmon life stages in the Sacramento River. Adult winter-run Chinook salmon immigration and holding (upstream spawning migration) through the Delta and into the lower Sacramento River occurs from December through July, with a peak during the period extending from January through April (USFWS 1995). Winter-run Chinook salmon are sexually immature when upstream migration begins, and they must hold for several months in suitable habitat prior to spawning. Winter-run Chinook salmon primarily spawn in the mainstem Sacramento River between Keswick Dam (River Mile [RM] 302) and RBDD (RM 243). Spawning occurs between late-April and mid-August, with a peak generally in June. Winter-run Chinook salmon embryo incubation in the Sacramento River can extend into October (Vogel and Marine 1991).

Winter-run Chinook salmon fry rearing in the upper Sacramento River exhibit peak abundance during September, with fry and juvenile emigration past Red Bluff Diversion Dam (RBDD) occurring from July through March (Reclamation 1992; Vogel and Marine 1991), although NMFS (1993; NMFS 1997) report juvenile rearing and outmigration extending from June through April. Emigration (downstream migration) of winter-run Chinook salmon juveniles past Knights Landing, located approximately 155.5 river miles downstream of the RBDD, reportedly occurs between November and March, peaking in December, with some emigration continuing through May in some years (Snider and Titus 2000a; Snider and Titus 2000c). The numbers of juvenile winter-run Chinook salmon caught in rotary screw traps (RST) at the Knights Landing sampling location were reportedly dependent on the magnitude of flows during the emigration period (Snider and Titus 2000a; Snider and Titus 2000c).

A description of freshwater habitat requirements for winter-run Chinook salmon is presented in the following sections. Habitat requirements are organized by life stage.

Adult Immigration and Holding

Suitable water temperatures for adult winter-run Chinook salmon migrating upstream to spawning grounds range from 57°F to 67°F (NMFS 1997). However, winter-run Chinook salmon are immature when upstream migration begins, and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature reported for holding is 59°F to 60°F (NMFS 1997). Because water temperatures in the lower Sacramento River below the RBDD generally begin exceeding 60°F in April, it is likely that little, if any, suitable holding habitat exists in the lower Sacramento River. It most likely is only used by adults as a migration corridor. Following installation of the water temperature control device on Shasta Dam in 1997, it is possible that some deep water pool habitat may exist for a short distance downstream of the RBDD with suitable cold water temperatures for adult holding.

Adult Chinook salmon reportedly require water deeper than 0.8 feet and water velocities less than 8 feet per second (ft/sec) for successful upstream migration (Thompson 1972). Adult Chinook salmon are less capable of negotiating fish ladders, culverts, and waterfalls during upstream migration than steelhead, due in part to slower swimming speeds and inferior jumping ability (Bell 1986; Reiser *et al.* 2006).

Chinook salmon generally hold in pools with deep, cool, well-oxygenated water. Holding pools for adult Chinook salmon have reportedly been characterized as having moderate water velocities ranging from 0.5 to 1.3 ft/sec (DWR 2000).

Table 2-1. The Temporal Occurrence of Adult and Juvenile Sacramento River Winter-run Chinook Salmon in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River Basin[1]												
Sacramento River[2]												
Juvenile												
Sacramento River at Red Bluff[3]												
Sacramento River at Red Bluff[2]												
Sacramento River at Knights Landing[4]												
Lower Sacramento River (Seine)[5]												
West Sacramento River (Trawl)[5]												

Sources: [1] Yoshiyama et al. (1998); Moyle (2002); [2] Myers et al. (1998); [3] Martin et al. 2001; [4] Snider and Titus (2000b); [5] USFWS 2001

Relative Abundance: = High = Medium = Low

Spawning

Spawning occurs from mid-April to mid-August, peaking in May and June, in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991). Chinook salmon spawn in clean, loose gravel, in swift, relatively shallow riffles, or along the margins of deeper river reaches where suitable water temperatures, depths, and velocities favor redd construction and oxygenation of incubating eggs. Winter-run Chinook salmon were adapted for spawning and rearing in the clear, spring-fed rivers of the upper Sacramento River Basin, where summer water temperatures were typically 50°F to 59°F. Water temperature conditions were created by glacial and snowmelt water percolating through porous volcanic formations that surround Mt. Shasta and Lassen Peak, which cover much of northeastern California. Chinook salmon require clean loose gravel from 0.75 to 4.0 inches in diameter for successful spawning (NMFS 1997). The construction of dams in the upper Sacramento River has eliminated the major source of suitable gravel recruitment to reaches of the river below Keswick Dam. Gravel sources from the banks of the river and floodplain have also been substantially reduced by levee and bank protection measures. Levee and bank protection measures restrict the meandering of the river, which would normally release gravel into the river through natural erosion and deposition processes. Moyle (2002) reported that water velocity preferences (i.e., suitability greater than 0.5) for Chinook salmon spawning range from 0.98 ft/sec to 2.6 ft/sec (0.3 to 0.8 meters per second (m/sec)) at a depth of a few centimeters (cm) to several meters (m), whereas USFWS (2003) reported that winter-run Chinook salmon prefer water velocities range from 1.54 ft/sec to 4.10 ft/sec (0.47 to 1.25 meters per second) at a depth of 1.4 to 10.1 feet (0.4 to 3.1 m).

Today, Shasta Dam denies access to historical winter-run Chinook salmon spawning habitats and they persist mainly because water released from Shasta Reservoir during the summer has been, for the most part, sufficiently cold. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam.

Embryo Incubation

In the Sacramento River, winter-run Chinook salmon spawning occurs from late April through mid August. Because the embryo incubation life stage begins with fertilized egg deposition and ends with fry emergence from the gravel, embryo incubation occurs from late April through mid-October. Fry emergence occurs from mid-June through mid-October (NMFS 1997). Within the appropriate water temperature range, eggs normally hatch in 40 to 60 days. Newly hatched fish (alevins) normally remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 1997).

Physical habitat requirements for embryo incubation are the same as the requirements discussed above for spawning. However, it is also important that flow regimes remain relatively constant or at least not decrease significantly during the embryo incubation life stage.

Juvenile Rearing and Outmigration

Upon emergence from the gravel, fry swim or are displaced downstream (Healey 1991). Fry seek streamside habitats containing beneficial aspects such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates for food, predator avoidance cover, and slower water velocities for resting (NMFS 1996a). These shallow water habitats have been described as more productive juvenile salmon rearing habitat than the deeper main river channels. Higher juvenile salmon growth rates, partially due to greater prey consumption rates, as well as favorable environmental temperatures have been associated with shallow water habitats (Sommer *et al.* 2001b). Similar to adult salmon upstream movement, juvenile salmon downstream movement is primarily crepuscular. Once downstream movement has commenced,

salmon fry continue this movement until reaching the estuary or they might reside in the stream for a time period that varies from weeks to a year (Healey 1991). Juvenile Chinook salmon migration rates vary considerably, presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al.* (Kjelson *et al.* 1981) found Chinook salmon fry traveled as fast as 30 kilometers (km) per day in the Sacramento River. Sommer *et al.* (2001b) found travel rates ranging from approximately 0.8 km (0.5 miles) per day, up to more than 9.7 km (6 miles) per day in the Yolo Bypass.

As juvenile Chinook salmon grow they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the USFWS (USFWS 1997) exhibited larger juvenile captures in the main channel and smaller-sized fry along the margins. Where the river channel is greater than nine to ten feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1979). Streamflow and/or turbidity increases in the upper Sacramento River basin are thought to stimulate emigration (Poytress 2007).

Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin after almost one year in the river. They begin to move down river as early as mid-July, typically peaking numbers in September, and can continue through March in dry years (NMFS 1997; Vogel and Marine 1991). From 1995 to 1999, all Sacramento River winter-run Chinook salmon outmigrating as fry passed RBDD by October, and all outmigrating pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001).

As Chinook salmon begin the smoltification stage, they are found rearing further downstream where ambient salinity reaches 1.5 to 2.5 parts per thousand (Healey 1979). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and vegetated zones (Healey 1979). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1981; MacFarlane and Norton 2002; Sommer *et al.* 2001a).

Juvenile Chinook salmon movements within the estuarine habitat are dictated by the interaction between tidally-driven salt water intrusions through the San Francisco Bay and fresh water outflow from the Sacramento and San Joaquin rivers. Juvenile Chinook salmon follow rising tides into shallow water habitats from the deeper main channels and return to the main channels when the tides recede (Healey 1991). Kjelson *et al.* (1981) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper three meters of the water column. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay, and grew little in length or weight until they reached the Gulf of the Farallon Islands (MacFarlane and Norton 2002).

Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May, based on data collected from trawls in the Sacramento River at West Sacramento (RM 57) (USFWS 2001). The timing of migration varies somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length (FL) of approximately 118 millimeters (mm) and are from five to 10 months of age. Emigration to the ocean begins as early as November and continues through May (Fisher 1994; Myers *et al.* 1998). The importance of the Delta in the life

history of Sacramento River winter-run Chinook salmon is not well understood.

Central Valley Chinook salmon begin their ocean life in the Gulf of the Farallones, then they distribute north and south along the continental shelf primarily between Point Conception and Washington State. Upon reaching the ocean, juvenile Chinook salmon feed voraciously on larval and juvenile fishes, plankton, and terrestrial insects (Healey 1991; MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment, with growth rates dependent on water temperatures and food availability (Healey 1991).

2.1.4 Abundance Trends and Distribution

One of the main threats to the Sacramento River winter-run Chinook salmon ESU is that it consists of only one population. Furthermore the one population has a small population size (Good *et al.* 2005). The population declined from an escapement of near 100,000 in the late 1960s to fewer than 200 in the early 1990s (Good *et al.* 2005). More recent population estimates of 8,218 (2004), 15,730 (2005), and 17,153 (2006) show a three-year average of 13,700 returning winter-run Chinook salmon (CDFG Website 2007). However, the run size decreased to 2,542 in 2007 and 2,850 in 2008. **Figure 2-2** depicts the estimated run sizes of Sacramento River winter-run Chinook salmon from 1970 through 2008.

The LSNFH on the upper Sacramento River has been producing and releasing winter-run Chinook salmon since 1998. This conservation program has apparently resulted in a net increase in the numbers of returning adult winter-run Chinook salmon, although hatchery fish make up a significant portion of the population (Brown and Nichols 2003).

Table 2-2 shows the annual number of winter-run Chinook salmon released from the facility from 1999 through 2006. The fish are marked with coded wire tags (CWT), adipose fin clipped and released as smolts each winter in late January or early February. The table also provides information based on data acquired during mark-recapture studies on the amount of time required by the smolts to migrate through the Delta.

Winter-run Chinook salmon originally spawned in the upper Sacramento River system (Little Sacramento, Pit, McCloud and Fall rivers) and in Battle Creek. There is no evidence that the winter-run existed in any of the other drainages prior to watershed development (Yoshiyama *et al.* 1996). The unique life history timing pattern of winter-run Chinook salmon, requiring cold summer flows, argues against this run occurring in drainages other than the upper Sacramento system and Battle Creek. Today, watershed development has eliminated all historical spawning habitat above Keswick Dam (approximately 200 river miles) and approximately 47 of the 53 miles of potential habitat in Battle Creek (Yoshiyama *et al.* 1996). Figure 2-1 depicts the current and historical distribution of Sacramento River winter-run Chinook salmon.

Currently, winter-run Chinook salmon spawning habitat is likely limited to the reach of the Sacramento River extending from Keswick Dam downstream to the RBDD. Prior to construction of Shasta and Keswick dams, the mainstem Sacramento River primarily functioned as a rearing and migration corridor because warm water temperatures likely precluded spawning. Winter-run Chinook salmon still have access to Battle Creek above the Coleman National Fish Hatchery (CNFH) weir from a fish ladder that is opened during the peak of the winter-run Chinook migration period (Ward and Kier 1999).

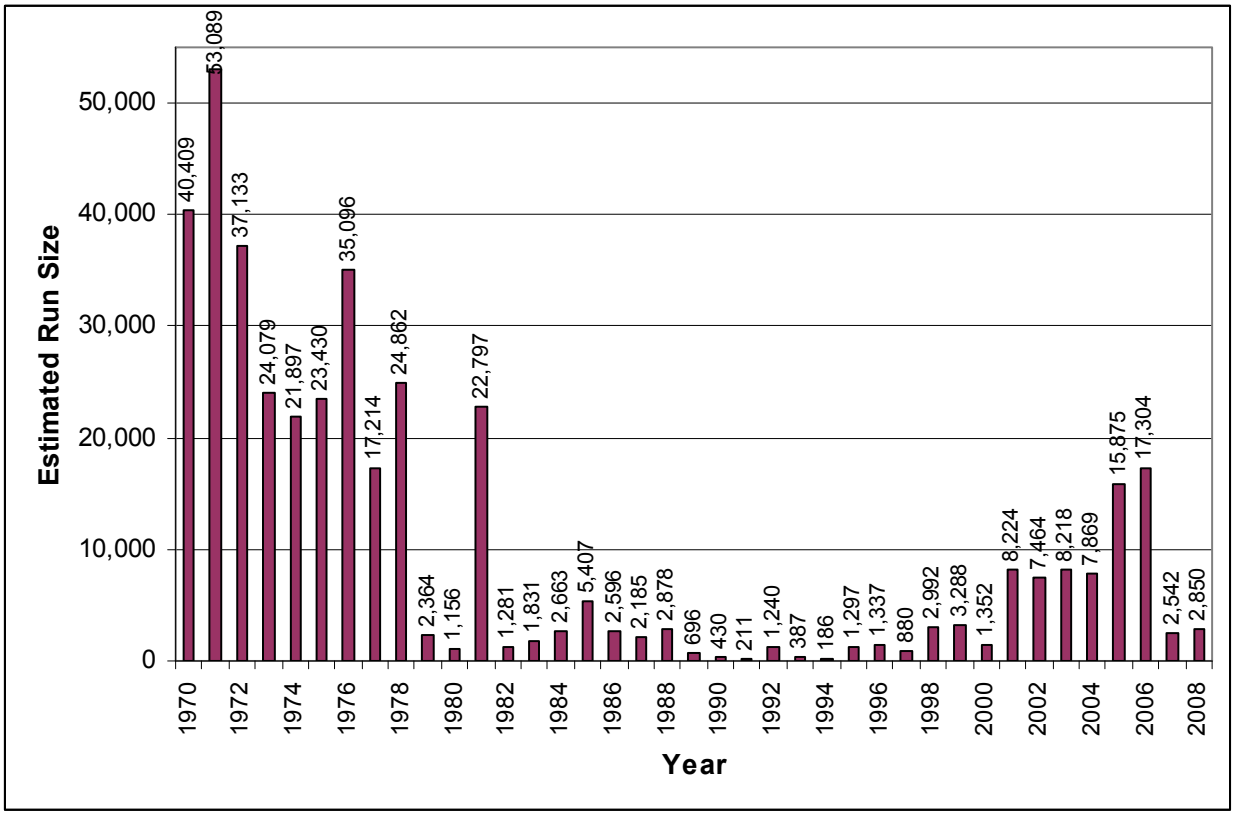


Figure 2-2. Estimated Sacramento River Winter-run Chinook Salmon Run Size (1970 – 2008). Total estimate includes mainstem in-river, tributaries, hatcheries, and angler harvest. Prior to 2001, mainstem in-river estimates upstream of RBDD were based on RBDD counts. Subsequent estimates were based on carcass survey data.
Source: **http://www.fws.gov/stockton/afrp/**

Table 2-2. Winter-run Chinook Salmon Juvenile Releases from LSNFH (Broodyears 1998-2008) and Date of Initial Recapture at Chipps Island.

Brood Year	Upper Sacramento River Release Date	Number of Pre-Smolts Released[1]	Initial Date[2] of Recapture at Chipps Island
1998	1/28/1999	153,908	3/15/1999
1999	1/27/2000	30,840	3/18/2000
2000	2/01/2001	166,206	3/09/2001
2001	1/30/2002	252,684	3/20/2002
2002	1/30/2003	233,613	2/14/2003
2003	2/05/2004	218,617	2/20/2004
2004	2/03/2005	168,261	2/22/2005
2005	2/02/2006	173,344	2/17/2006
2006	2/08/2007	196,288	2/17/2007
2007	1/31/2008	71,883	3/12/2008
2008	1/29/2009	146,211	
Source: ([1]USFWS Red Bluff; [2]Paul Cadrett, USFWS, personal com.)			

Currently, if a winter-run Chinook salmon population exists in Battle Creek, its population size is unknown, likely very small, and is potentially mainly or entirely composed of strays from the mainstem Sacramento River. Additionally, a winter-run Chinook salmon migration to the upper Calaveras River may have occurred between 1972 and 1984, but this population appears to have been extirpated by drought, irrigation diversions, and blocked access by the New Hogan Dam (NMFS 1997; NMFS 1999; NMFS 2003). This somewhat ephemeral population on the Calaveras River is also thought to have been late fall-run Chinook salmon that were mistakenly identified as winter-run Chinook salmon (Yoshiyama *et al.* 2000).

The winter-run Chinook salmon population is dependant upon the provision of suitably cool water temperatures during the spawning, embryo incubation, and juvenile rearing period. Water temperatures in the upper Sacramento River are the result of interaction among: (1) ambient air temperature; (2) volume of water; (3) water temperature at release from Shasta and Trinity dams; (4) total reservoir storage; (5) location of reservoir thermocline; (6) ratio of Spring Creek Power Plant release to Shasta Dam release; (7) operation of Temperature Control Device (TCD) on Shasta Dam; and (8) tributary inflows (NMFS 1997). Water temperature varies with location and distance downstream of Keswick Dam, and depends upon the annual hydrologic conditions and annual operation of the Shasta-Trinity Division of the CVP (NMFS 1997). In general, water released from Keswick Dam warms as it moves downstream during the summer and early fall months at a critical time for the successful development and survival of juvenile winter-run Chinook salmon (NMFS 1997).

Suitable water temperatures for adult winter-run Chinook salmon migrating upstream to spawning grounds range from 57°F to 67°F (NMFS 1997). However, winter-run Chinook salmon are immature when upstream migration begins and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature for holding is 59°F to 60°F (NMFS 1997). Similarly, successful spawning for Chinook salmon occurs at water temperatures below 60°F (NMFS 1997). Prior to 1997, during some years, water temperatures below Keswick Dam began exceeding 60°F in May and during July and August, water temperatures were frequently above 60°F (NMFS 1997). In 1997, a temperature control device (TCD) was installed at Shasta Dam allowing better management of water temperatures in the Sacramento River. CDFG (2004) reported that the TCD was working well and that very low egg loss occurred as a result of adverse water temperatures in 2002 and 2003.

During much of the 1980s and 1990s, the winter-run population was at a precariously low level. Since the late 1990s the population abundance has had an upward trend up to nearly 20,000 fish. This slight upward trend, after nearly two decades of dangerously low numbers, is likely a response to a number of factors, including wetter than normal winters, operation of Livingston Stone Fish Hatchery, changes in ocean harvest regulations since 1995 that have significantly reduced harvests, changes in operations at RBDD, improved water temperature management on the upper Sacramento River (including installation of a cold-water release device on Shasta Dam in 1997), improved ocean conditions, water quality improvements due to remediation of Iron Mountain Mine discharges, changes in the State and Federal water projects, and a variety of other habitat improvements.

2.1.5 Critical Habitat

Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. The primary constituent elements considered essential for the conservation of listed

Central Valley salmonids are: (1) freshwater spawning sites; (2) freshwater rearing sites; (3) freshwater migration corridors; (4) estuarine areas; (5) nearshore marine areas; and (6) offshore marine areas.

On August 14, 1992, NMFS published a proposed critical habitat designation for winter-run Chinook salmon (57 FR 36626 (August 13, 1992)). The habitat proposed for designation included: (1) the Sacramento River from Keswick Dam, Shasta County (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; (2) all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; (3) all waters of San Pablo Bay westward of the Carquinez Bridge; and (4) all waters of San Francisco Bay to the Golden Gate Bridge (NMFS 1997).

On June 16, 1993, NMFS issued the final rule designating critical habitat for winter-run Chinook salmon (58 FR 33212 (June 16, 1993)). The habitat identified in the final designation is identical to that in the proposed ruling except that critical habitat in San Francisco Bay is limited to those waters north of the San Francisco-Oakland Bay Bridge. **Figure 2-3** depicts the designated critical habitat for Sacramento River winter-run Chinook salmon.

2.1.6 Reasons for Listing/Threats Assessment

Several factors have contributed to the decline of winter-run Chinook salmon through degradation of spawning, rearing, and migration habitats. The primary factors include blockage of historical habitat by Shasta and Keswick dams, warm water releases from Shasta Dam, juvenile and adult passage constraints at RBDD, water exports in the southern Delta, heavy metal contamination from Iron Mountain Mine, high ocean harvest rates and entrainment in a large number of unscreened or poorly screened water diversions (NMFS 1997). Other factors include smaller water manipulation facilities and dams, loss of rearing habitat in the lower Sacramento River and Delta from levee construction, marshland reclamation, interaction with and predation by introduced species, adverse flow conditions, high summer water temperatures and vulnerability to drought (NMFS 1997).

Presumably, there were several independent populations of winter-run Chinook salmon in the Pitt, McCloud, and Little Sacramento rivers and various tributaries to these rivers, such as Hat Creek and the Fall River. These populations merged to form the present single population. If populations ever existed in Battle Creek and the Calaveras River, they have been extirpated (Good *et al.* 2005).

The spatial distribution of spawners has not expanded. The primary reason is that the naturally-spawning population is artificially maintained by cool water releases from Shasta/Keswick dams, and the spatial distribution of spawners is largely governed by water year type and the ability of the CVP to manage water temperatures in the upper Sacramento River. The fact that this ESU is comprised of a single population with very limited spawning and rearing habitat increases its risk of extinction due to local catastrophe or poor environmental conditions. There are no other natural populations in the ESU to buffer it from natural fluctuations. A single catastrophe with effects persisting for four or more years could extirpate the entire Sacramento River winter-run Chinook salmon ESU, which puts the population at a high risk of extinction over the long run (Lindley *et al.* 2007). Such potential catastrophes include volcanic eruption of Lassen Peak, prolonged drought which depletes the cold water pool in Shasta Reservoir or some related failure to manage cold water storage, a spill of toxic materials with effects that persist for four years, or a disease outbreak. The risk associated with a prolonged drought should be emphasized as Shasta Reservoir is operated to maintain only one year of

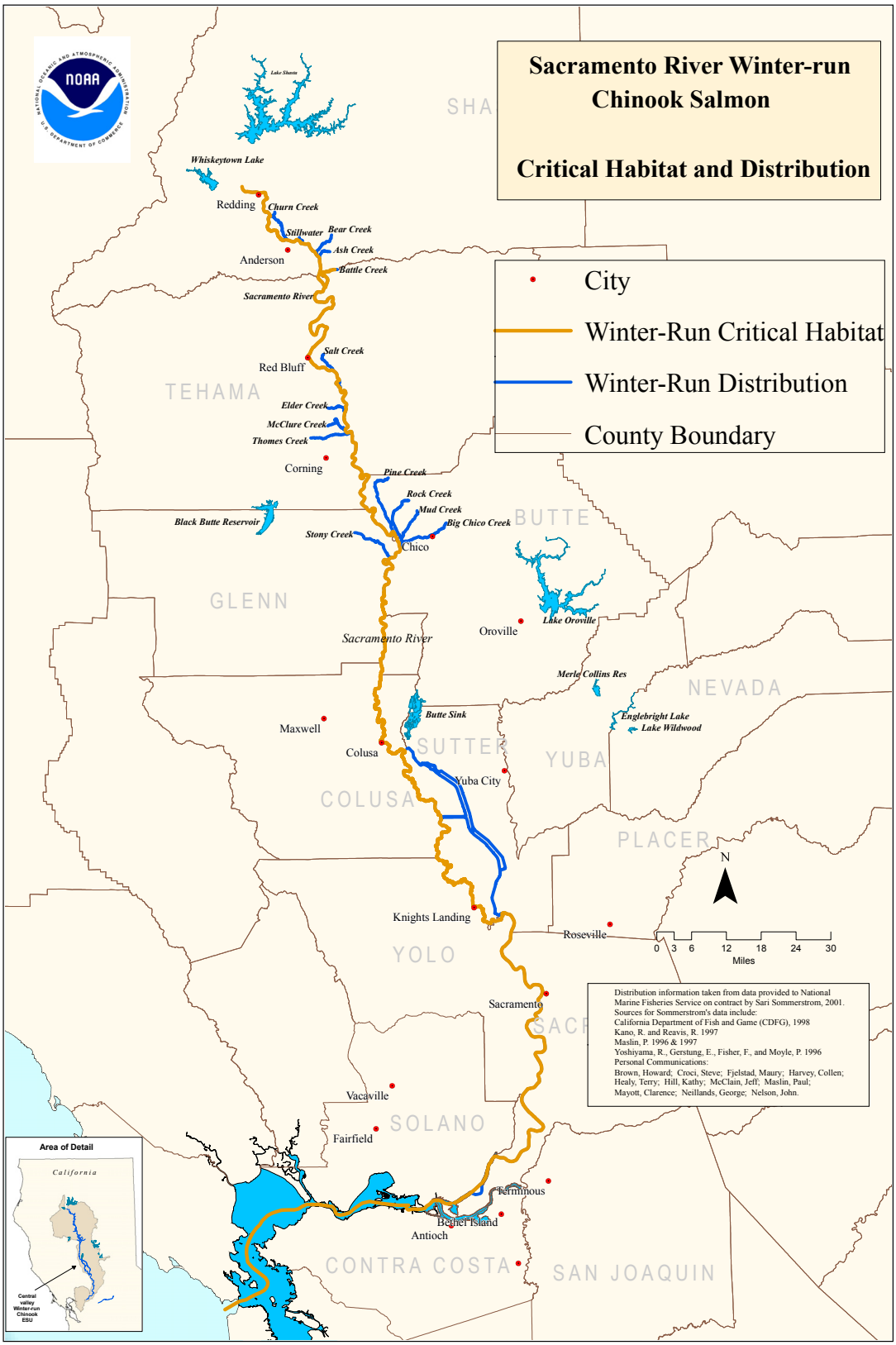


Figure 2-3. Sacramento River Winter-run Chinook Salmon Designated Critical Habitat and Distribution

carry-over storage. After two years of drought, Shasta Reservoir storage would be insufficient to provide cold water throughout the winter-run Chinook salmon spawning and embryo incubation season, resulting in complete year-class failure. A drought lasting several years would likely result in the extinction of winter-run Chinook salmon.

Another vulnerability to an ESU that is represented by a single population is the limitation in life history and genetic diversity that would otherwise increase the ability of individuals in the population to withstand environmental variation. A second naturally-spawning population is considered critical to the long-term viability of this ESU, and plans are underway to eventually establish a second population in the upper Battle Creek watershed. However, establishment of a second population of winter-run Chinook in Battle Creek has yet to be implemented because of the need to complete habitat restoration efforts in that watershed (Good et al. 2005).

A threats matrix has been developed and prioritized in Appendix B. Chief among the threats facing winter-run Chinook salmon is small population size—escapement fell below 200 fish in the 1990s. In 1989, the CDFG estimated that the winter-run Chinook salmon size was only 547 fish. This unexpectedly small return represented nearly a 75 percent decline from the consistent, but low, run size of 2,000 to 3,000 fish that had occurred since 1982. The final run size estimate made by the CDFG for 1991 was 191 fish. Population size declined from highs of near 100,000 fish in the late 1960s, indicating a sustained period of poor survival (Good *et al.* 2005).

The genetic integrity of winter-run Chinook salmon has been compromised due to having passed through several "bottlenecks" in the 20th century. Construction of Shasta Dam merged at least four independent winter-run Chinook populations into a single population, representing a substantial loss of genetic diversity, life history variability, and local adaptation. Episodes of critically low abundance, particularly in the early 1990s, for the single remaining population imposed ''bottlenecks'' that further reduced genetic diversity (Good *et al.* 2005).

The use of a hatchery program to supplement winter-run Chinook salmon populations in the Central Valley raises concerns about the genetic integrity and fitness of the population. There is a strong perception that hatchery fish may negatively affect the genetic constitution of wild fish (Allendorf *et al.* 1997; Hindar *et al.* 1991; Waples 1991). One of the main factors contributing to this perception is the observation of a reduction in wild fish populations following the initiation of a hatchery release program (Hilborn 1992; Washington and Koziol 1993). An explanation offered for this observation is that hatchery fish are adapted to the hatchery environment; therefore, natural spawning with wild fish reduces the fitness of the natural population (Taylor 1991). Researchers from the University of California at Davis have documented that hatchery Chinook salmon were more vulnerable to predation by Sacramento pikeminnow as they pass RBDD than were wild Chinook salmon (Lufkin 1996). To minimize hatchery effects in the population, LSNFH preferentially collects wild winter-run adults for the program. A maximum of 15 percent of the estimated winter-run Chinook salmon run, but no more than 120 natural-origin winter-run Chinook salmon per broodyear may be collected for broodstock use. If necessary, up to 10 percent (a maximum of 12 fish) of the LSNFH broodstock may be composed of hatchery adult returns. To ensure that hatchery production does not overwhelm the recovering population, annual hatchery releases are kept within the 200,000 to 250,000 range and the effects of the program are well-monitored.

Recently, NMFS (NMFS 2007b) reports that the rising proportion of hatchery fish among returning adults threatens to shift the population from a low to moderate risk of extinction. Lindley *et al.* (Lindley *et al.* 2007) recommend that in order

to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally-spawning population should be composed of hatchery fish. Since 2001, hatchery origin winter-run Chinook salmon have made up more than five percent of the run, and in 2005 the contribution of hatchery fish exceeded 18 percent (Lindley *et al.* 2007). Potential consequences to wild fish stocks from hatchery production include hybridization and genetic introgression, competition, predation, and increasing fishing pressure (Waples 1991).

Because LSNFH is a conservation hatchery using best management practices, a more appropriate tool to determine associated genetic risk may be the Proportionate Natural Influence (PNI). PNI is an index of gene flow rates between hatchery and natural populations that can be calculated by using the following formula:

$$PNI_{Approx} = pNOB/(pNOB+pHOS)$$

Where pNOB is defined as the Proportion of Natural Origin Brood Stock, and pHOS as the Proportion of Hatchery Origin In-River Spawners.

The Hatchery Scientific Review Group (HSRG), an independent scientific review panel for the Pacific Northwest Hatchery Reform Project, developed guidelines as minimal requirements for minimizing genetic risks of hatchery programs to naturally spawning populations. One of those guidelines is that PNI must exceed 0.5 in order for the natural environment to have a greater influence than the hatchery environment on the genetic constitution of a naturally-spawning population. A second guideline is that PNI should be greater than 0.67 for natural populations considered essential for the recovery or viability of an ESU/DPS.

The average PNI for LSNFH winter-run from 2003 through 2008 is 0.91, which satisfies the HSRG guidelines for minimizing the genetic effects of hatchery programs on natural populations (Bob Null, pers. comm. 2008).

In summary, LSNFH is one of the most important reasons that Sacramento River winter-run Chinook salmon still persist and the hatchery is beneficial to the ESU over the short term. However, if the continued existence of the ESU depends on LSNFH, it by any reasonable definition cannot be characterized as having a low risk of extinction, and therefore the ESU should not be delisted on that basis. The winter-run Chinook salmon ESU cannot be delisted until there are at least two viable populations (e.g., Battle Creek and Sacramento River above Shasta Dam). If the status of the ESU improves such that it one day has a high likelihood of persistence without LSNFH, then the LSNFH winter-run Chinook program should be phased out and eventually terminated. To obtain long-term sustainability, ESUs need to have some low-risk populations with essentially no hatchery influence in the long run; they could have additional populations with some small hatchery influence, but there needs to be a core of populations that are not dependent on hatchery production. The LSNFH winter-run program is intended to be evaluated for its benefits and risks periodically (every 5 years).

A detailed threats assessment was conducted for the Sacramento River winter-run Chinook salmon ESU (Appendix B). The threats/stressors affecting each winter-run Chinook salmon life stage are described in that appendix. A stressor matrix[3], in the form of a single Microsoft Excel worksheet, was developed to structure the winter-run Chinook salmon population, life stage, and stressor information into hierarchically-related tiers so that stressors to the ESU could be prioritized. The individual tiers within the matrix, from highest to lowest, are: (1) population; (2) life stage; (3) primary stressor category; and (4) specific stressor. These individual tiers were

[3] For winter-run Chinook salmon, a single stressor matrix was developed corresponding to the mainstem upper Sacramento River population, whereas for spring-run Chinook salmon and steelhead, multiple individual stressor matrices were developed corresponding to each of the extant populations for these species.

related hierarchically so that each variable within a tier had several associated variables at the next lower tier, except at the lowest (i.e. fourth) tier.

The general steps required to develop and utilize the winter-run stressor matrix are described as follows:

- Each life stage within the population was weighted so that all life stage weights in the population summed to one
- Each primary stressor category within a life stage was weighted so that all primary stressor category weights in a life stage summed to one
- Each specific stressor within a primary stressor category was weighted so that all specific stressor weights in a primary stressor category summed to one
- A composite weight for each specific stressor was obtained by multiplying the product of the population weight, the life stage weight, the primary stressor weight, and the specific stressor weight by 100
- A normalized weight for each specific stressor was obtained by multiplying the composite weight by the number of specific stressors within a particular primary stressor group
- The stressor matrix was sorted by the normalized weight of the specific stressors in descending order

Specific information explaining the individual steps taken to generate this prioritized list are provided in Appendix B.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. Each life stage of winter-run Chinook salmon is affected by stressors of "Very High" importance. These stressors include:

- The barriers of Keswick and Shasta dams, which block access to historic staging and spawning habitat
- Flow fluctuations, water pollution, water temperature impacts in the upper Sacramento River during embryo incubation
- Loss of juvenile rearing habitat in the form of lost natural river morphology and function, and lost riparian habitat and instream cover
- Predation during juvenile rearing and outmigration
- Ocean harvest
- Entrainment of juveniles at the C.W. Jones and Harvey O. Banks pumping plants

The complete prioritized list of life stage-specific stressors to the Sacramento River winter-run Chinook salmon ESU is presented in Appendix B.

2.1.7 Conservation Measures

The CVP Section 7 consultations with Reclamation likely contributed to habitat improvements benefiting the Sacramento River winter-run Chinook salmon ESU. Implementation of the 1992 reasonable and prudent alternative has provided substantial benefits to this ESU by improving habitat and fish passage conditions in the Sacramento River and the Delta. Such improvement likely has contributed to increases in abundance and productivity over the past decade through actions such as maintenance of minimum water flows during fall and winter months, establishment of temperature criteria to support spawning and rearing upstream of RBDD (coupled with water releases from Shasta Dam),

operation of the RBDD gates for improved adult and juvenile fish passage, and constraints on Delta water exports to reduce impacts on juvenile outmigrants.

In addition, two large, ongoing comprehensive conservation programs in the Central Valley provide a wide range of ecosystem and species-specific protective efforts potentially benefiting Chinook salmon – the CALFED Bay/Delta Program) and the CVPIA. CALFED is a cooperative effort of more than 20 State and Federal agencies working with local communities to improve water quality and reliability for California's water supplies, and has made efforts to restore the Bay/Delta. Though not fully implemented, CALFED's Ecosystem Restoration Program has funded projects involving habitat restoration, floodplain restoration and protection, instream and riparian habitat restoration and protection, fish screening and passage, research on non-native species and contaminants, research and monitoring of fishery resources, and watershed stewardship and outreach. CALFED established the Environmental Water Account (EWA) to offset losses of juvenile fish at the Delta pumps and to provide higher instream flows in the Yuba, Stanislaus, American, and Merced rivers to benefit native fish, including salmon.

The CVPIA balances the priorities of fish and wildlife protection, restoration, and mitigation with irrigation, domestic water use, fish and wildlife enhancement, and power augmentation. Reclamation and USFWS have conducted studies and implemented hundreds of actions, including modifications of CVP operations, management and acquisition of water for fish and wildlife needs, flow management for fish migration and passage, increased water flows, replenishment of spawning gravels, restoration of riparian habitats, and screening of water diversions. Actions in the Sacramento River tributaries have focused on riparian and shaded riverine aquatic habitat restoration, improved access to available upstream habitat, improved instream flows, and reduced loss of juveniles at diversions. Habitat restoration includes water acquisition for instream flows, channel restoration and enhancement, removal of dams and blockages to migration, gravel replenishment, and construction or modifications of devices to improve instream habitat and to improve access or reduce fish mortalities during migrations (such as fish ladders and screening diversions).

Harvest protective measures benefiting winter-run Chinook salmon include seasonal constraints on sport and commercial fisheries south of Point Arena. In addition, the State has listed winter-run Chinook under the CESA, and has thus established specific in-river fishing regulations and no-retention prohibitions designed to protect this ESU (e.g., management measures for time and area closures, gear restrictions, and zero bag limits in the Sacramento River).

2.1.8 Biological Constraints and Needs

As winter-run Chinook salmon historically were dependent on access to spring-fed tributaries to the upper Sacramento River that remained cool during summer and early fall, the most obvious impact to this ESU was the construction of Shasta Dam. The dam blocked access to the ESU's entire historic spawning habitat. With coldwater releases from Shasta creating conditions suitable for winter-run Chinook salmon 100 feet below the dam, this species was able to survive habitat alteration, but experienced significant impacts. Presumably, there were several independent populations of winter-run Chinook salmon in the Pitt, McCloud, and Little Sacramento Rivers, and in various tributaries to these rivers, such as Hat Creek and the Fall River. These populations merged to form the current single population. Any populations that may have existed in Battle Creek and the Calaveras River have since been extirpated. This ESU continues to be threatened by having only one extant population, low population size (compared to historic levels), vulnerability to drought, inadequately screened or unscreened water diversions, predation at

artificial strictures and by non-native species, pollution (e.g., Iron Mountain Mine), adverse flow conditions, high summer water temperatures, unsustainable harvest rates, and passage problems at various structures.

Another potential threat to the winter-run Chinook salmon population is the possible effects of long-term climate change. California's Central Valley is located at the extreme southern limit of Chinook salmon distribution. The southern limit of Chinook salmon distribution is likely a function of climate. In California, observations reveal trends in the last 50 years toward warmer winter and spring temperatures, a smaller fraction of precipitation falling as snow, a decrease in the amount of spring snow accumulation in lower and middle elevation mountain zones and an advance in snowmelt of 5 to 30 days earlier in the spring (Knowles *et al.* 2006). Given this trend, it is likely that most species, currently at the southern extent of their range, including Chinook salmon will experience less desirable environmental conditions in the future.

If air temperatures in California rise significantly, it will become increasingly difficult to maintain appropriate water temperatures in order to manage coldwater fisheries, including winter-run Chinook salmon. A reduction in snowmelt and increased evaporation could lead to decreases in reservoir levels and, perhaps more importantly, coldwater pool reserves (California Energy Commission 2003). As a result, water temperatures in rivers supporting anadromous salmonids, including winter-run Chinook salmon, could potentially rise and no longer be able to support over-summering life stages (i.e., winter-run Chinook salmon embryo incubation, fry emergence and juvenile emigration). The California Department of Water Resources (DWR) (DWR 2006) suggests that under a warmer climate scenario, water temperature standards in the upper Sacramento River likely could not be maintained. The potential adverse effects of long-term climate change are more thoroughly discussed in Chapter 7.

2.2 Spring-run Chinook Salmon

2.2.1 Brief Overview/Status of the Species

Central Valley spring-run Chinook salmon (*O. tshawytscha*), currently listed as threatened, were proposed as endangered by NMFS on March 9, 1998. NMFS (NMFS 1998) concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction because native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represented a large portion of the historic range and abundance of the ESU as a whole. Moreover, the only streams considered to have wild spring-run Chinook salmon at that time were Mill and Deer creeks, and possibly Butte Creek (tributaries to the Sacramento River). These populations were considered relatively small with sharply declining trends. Hence, demographic and genetic risks due to small population sizes were considered to be high. NMFS (NMFS 1998) also determined that habitat problems were the most important source of ongoing risk to this ESU.

On September 16, 1999, NMFS listed the Central Valley ESU of spring-run Chinook salmon as a "threatened" species (64 FR 50394 (September 16, 1999)). Although in the original Chinook salmon status review and proposed listing it was concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction (Myers *et al.* 1998), in the status review update, the BRT majority shifted to the view that this ESU was not in danger of extinction, but was likely to become endangered in the foreseeable future. A major reason for this shift was data indicating that a large run of spring-run Chinook salmon on Butte Creek in 1998 was naturally produced, rather than strays from the FRFH (Good *et al.* 2005).

NMFS (64 FR 50394 (September 16, 1999)) determined that the Central Valley spring-run Chinook salmon ESU are at risk of becoming endangered in the foreseeable future throughout all or a significant portion of their range after

reviewing the best available information, including public and peer review comments, biological data on the species' status, and an assessment of protective efforts. On March 11, 2002, pursuant to a January 9, 2002 rule issued by NMFS under Section 4(d) of the ESA (15 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply to the Central Valley ESU of spring-run Chinook salmon (67 FR 1116 (January 9, 2002)). On June 14, 2004, following a five-year species status review, NMFS proposed that the Central Valley spring-run Chinook salmon remain a threatened species based on the BRT strong majority opinion that the Central Valley spring-run Chinook ESU is ''likely to become endangered within the foreseeable future.'' The BRT based its conclusions on the greatly reduced distribution of Central Valley spring Chinook ESU and hatchery influences on natural population. In addition, the BRT noted moderately high risk for the abundance, spatial structure, and diversity Viable Salmonid Population (VSP) criteria, and a lower risk for the productivity criterion reflecting positive trends. On June 28, 2005, NMFS reaffirmed the threatened status of the Central Valley spring-run Chinook salmon ESU (70 FR 37160 (June 28, 2005)). **Figure 2-4** depicts the Central Valley spring-run Chinook salmon ESU.

2.2.2 Species Description and Taxonomy

The Chinook salmon, also largely referred to as king salmon in California, are the largest of the Pacific salmon. The following physical description of the species is provided by Moyle (Moyle 2002). Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fins, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. Parr have 6 to 12 parr marks, each equal to or wider than the spaces between them and most centered on the lateral line. The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear. Life History

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998), and enter the Sacramento River between March and September, primarily in May and June (Moyle 2002; Yoshiyama *et al.* 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Spawning normally occurs between mid-August and early October, peaking in September (Moyle 2002).

The length of time required for embryo incubation and emergence from the gravel is dependant on water temperature. For maximum embryo survival, water temperatures reportedly must be between 41°F and 55.4°F and oxygen saturation levels must be close to maximum (Moyle 2002).

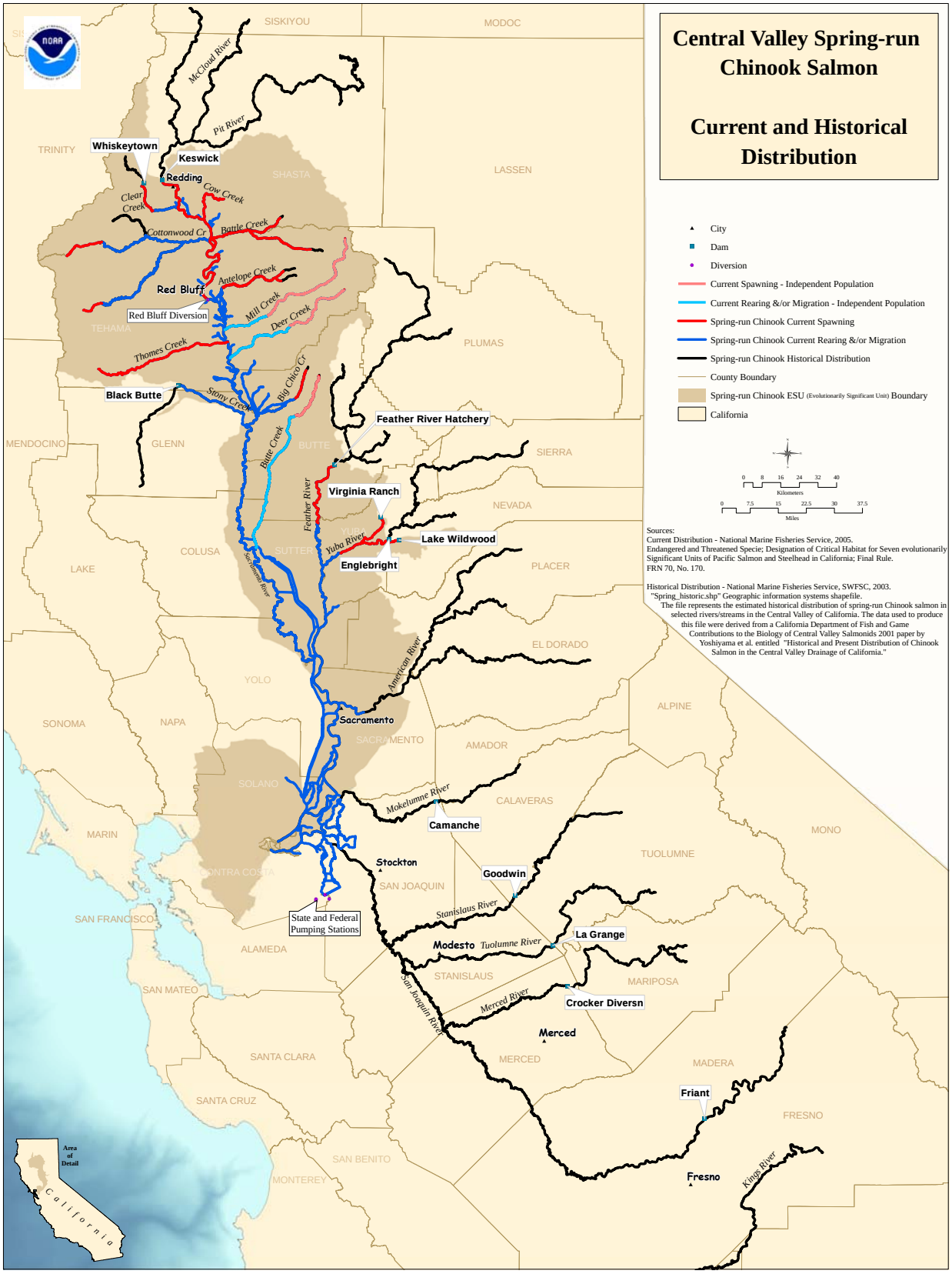


Figure 2-4. Central Valley Spring-run Chinook Salmon ESU, and Current and Historical Distribution.

Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins (the life stage between hatching and egg sack absorption) for another 4 to 6 weeks before emerging as fry (Moyle 2002).

Spring-run fry emerge from the gravel from November to March (Moyle 2002). Juveniles may reside in freshwater for 12 to 16 months, but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000b). The average size of fry migrants (approximately 40 mm between December and April in Mill, Butte, and Deer creeks) reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2004). By contrast, studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily during December, January, and February, and that these movements appeared to be influenced by flow. Small numbers of spring-run juveniles remained in Butte Creek to rear and migrate as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004). By contrast, data collected on the Feather River suggests that the bulk of juvenile emigration occurs during November and December (DWR and Reclamation 1999; Painter *et al.* 1977). Seesholtz *et al.* (Seesholtz *et al.* 2003) speculate that because juvenile rearing habitat in the Low Flow Channel of the Feather River is limited, juveniles may be forced to emigrate from the area early due to competition for resources. **Table 2-3** depicts the temporal occurrence of spring-run life stages in the Sacramento River.

2.2.3 Abundance Trends and Distribution

The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). More than 500,000 Central Valley spring-run Chinook salmon were caught in the Sacramento-San Joaquin commercial fishery in 1883 (Yoshiyama *et al.* 1998).

Before construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River (Fry 1961). The San Joaquin populations essentially were extirpated by the 1940s, with only small remnants of the run persisting through the 1950s in the Merced River (Yoshiyama *et al.* 1998). Since 1970, Central Valley spring-run Chinook salmon run size estimates have fluctuated significantly from highs near 30,000 to lows near 3,000. **Figure 2-5** depicts the estimated spring-run Chinook salmon spawning run size from 1970 through 2008.

Although spring-run Chinook salmon were probably the most abundant salmonid in the Central Valley under historic conditions, large dams eliminated access to almost all historical habitat and the spring-run has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River Basin (Fisher 1994).

Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley where natural barriers to migration were absent. Beginning in the 1880s, harvest, water development, construction of dams that prevented access to headwater areas and habitat degradation significantly reduced the number and range of spring-run Chinook salmon.

The only known streams that currently support viable populations of spring-run Chinook salmon in the Central Valley are Mill, Deer and Butte creeks (CDFG 1998). Each of these populations is small and isolated. **Figure 2-6** depicts the combined annual run size estimates for these populations. Additionally, these populations are genetically distinct from other

populations classified as spring-run in the Central Valley (e.g., Feather River) (DWR 2004). Banks *et al.* (Banks *et al.* 2000) suggest the spring-run phenotype in the Central Valley is actually shown by two genetically distinct subpopulations, Butte Creek, and Deer and Mill creeks. Lindley *et al.* (Lindley *et al.* 2007) report that the current distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters lie within the debris and pyroclastic flow radii of Lassen Peak, an active volcano that USGS views as highly dangerous.

Table 2-3. Temporal Occurrence of Adult and Juvenile Sacramento River Spring-run Chinook Salmon in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River Basin[1,2]												
Sacramento River[3]												
Mill Creek[4]												
Deer Creek[4]												
Butte Creek[4]												
Juvenile												
Sacramento River Tributaries[5]												
Upper Butte Creek[6]												
Mill, Deer, Butte Creeks[4]												
Sacramento River at RBDD[3]												
Sacramento River at KL[7]												
Chipps Island (Trawl)[8*]												

Sources: [1]Yoshiyama et al. 1998; [2]Moyle 2002; [3]Myers et al. 1998; [4]Lindley et al. 2006a; [5]CDFG 1998; [6]McReynolds et al. 2005; Ward et al. 2002, 2003; [7]Snider and Titus 2000, [8]USFWS 2001

Relative Abundance: = High = Medium = Low

* Note: By the time yearly spring-run Chinook salmon reach Chipps Island they cannot be distinguished from fall-run yearlings.

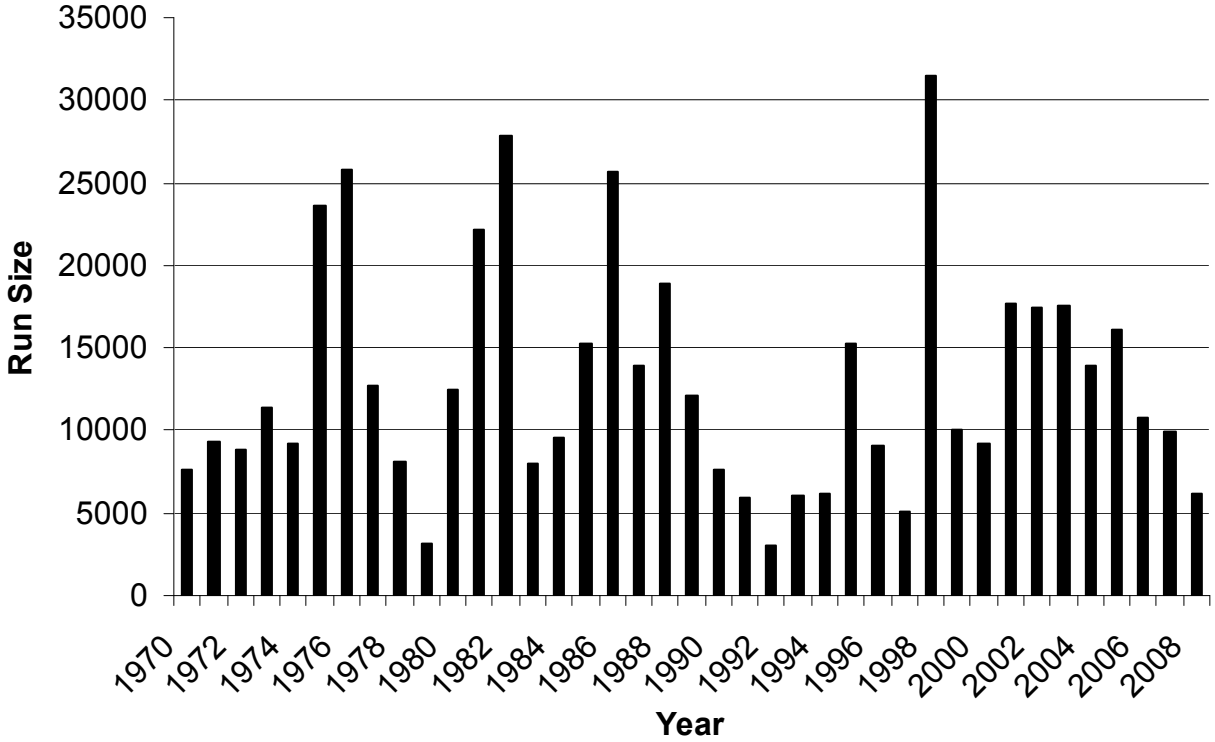


Figure 2-5. Central Valley Spring-run Chinook Salmon Run Size Estimates (1970–2008)

Source: (CDFG GRANDTAB 2009)

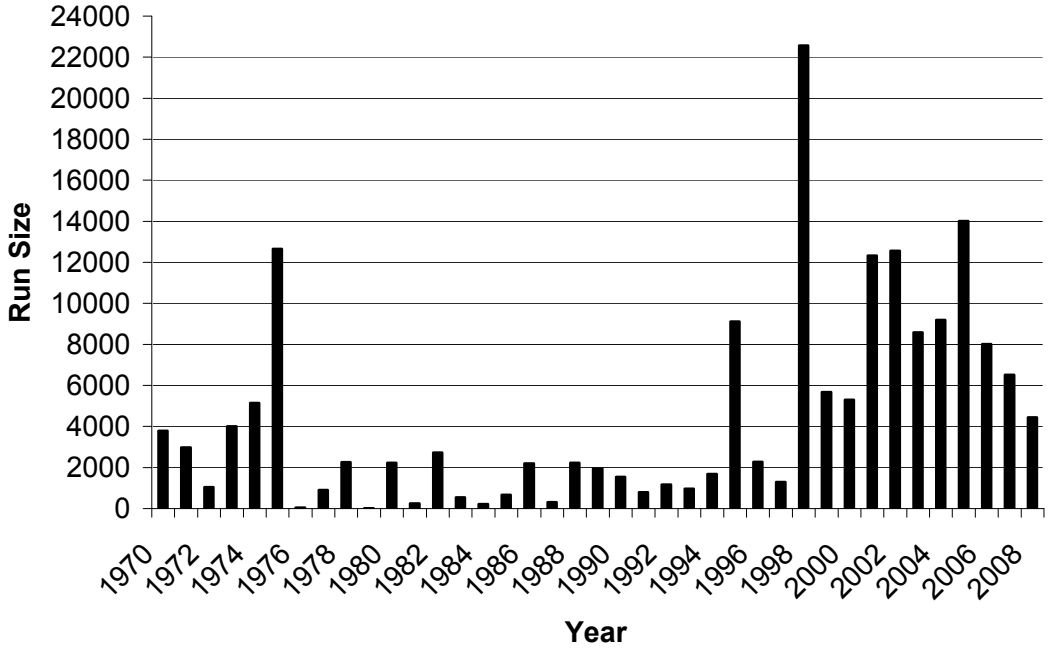


Figure 2-6. Mill, Deer, and Butte Creek Combined Spawning Run Size Estimates for Central Valley Spring-run Chinook Salmon (1970–2008). Source: (CDFG GRANDTAB 2009)

Additionally, a fire with a maximum diameter of 30 km, big enough to burn the headwaters of Mill, Deer, and Butte creeks simultaneously, has roughly a 10 percent chance of occurring somewhere in the Central Valley each year.

The FRFH was constructed in the mid 1960s by DWR to mitigate for the loss of Chinook salmon and steelhead spawning habitat by construction of Oroville Dam. The FRFH was opened in 1967 (DWR 2002) and is operated by CDFG. The FRFH is the only hatchery in the Central Valley producing spring-run Chinook salmon. The current production target for spring-run Chinook salmon at the FRFH is 2 million smolts.

Prior to 2004, FRFH hatchery staff differentiated spring-run from fall-run by opening the ladder to the hatchery on September 1. Those fish ascending the ladder from September 1 through September 15 were assumed to be spring-run Chinook salmon while those ascending the ladder after September 15 were assumed to be fall-run (Kastner 2003). This practice led to considerable hybridization between spring- and fall-run Chinook salmon (DWR 2004). Since 2007, the fish ladder remains open for 9.5 months of the year (September 15 through June 30) and those fish ascending the ladder are marked with an external tag and returned to the river. This practice allows FRFH staff to identify those previously marked fish as spring-run when they re-enter the ladder in September reducing the potential for hybridization between the spring and fall runs (DWR 2004).

The FRFH also releases a significant portion of its spring-run production into San Pablo Bay (1,000,000 juvenile smolts). This practice increases the chances that these fish will stray into other Central Valley streams when they return as adults to spawn. This straying has the potential for genetic hybridization to occur between FRFH spring-run with local spring-run and fall-run populations, increasing the risk of genetic introgression and subsequent homogeneity among Central Valley Chinook salmon runs. In addition, this straying has the potential to transfer genetic material from hatchery fish to wild naturally-spawning fish and is generally viewed as an adverse hatchery impact. Of particular concern would be the straying of hatchery fish into Deer, Mill, or Butte creeks, affecting the genetic integrity of the only significantly distinct spring-run Chinook salmon in the Central Valley (DWR 2004). **Figure 2-7** shows the total Central Valley spring-run Chinook salmon spawning run size estimates broken down by constituent component for the years 1970 through 2008. The figure indicates that since about 1982, the proportion of the spring-run in the Central Valley comprised of FRFH fish has substantially increased. The current and historical distribution of Central Valley spring-run Chinook salmon is presented in **Figure 2-4**.

2.2.4 Habitat Requirements

The habitat requirements for spring-run Chinook salmon are the same as those described above for winter-run Chinook salmon. The primary differences in the habitat requirements between the two runs are the duration and the time of year that the different life stages of the species utilize the habitat.

2.2.5 Critical Habitat

Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. The primary constituent elements considered essential for the conservation of listed Central Valley salmonids are: (1) freshwater spawning sites; (2) freshwater rearing sites; (3) freshwater migration corridors; (4) estuarine areas; (5) nearshore marine areas; and (6) offshore marine areas.

NMFS proposed new critical habitat for Central Valley spring-run Chinook salmon on December 10, 2004, (FR Vol. 69, No. 237) December 10, 2004)) and published a final rule designating critical habitat for this species on September 2, 2005 (FR Vol. 70, No. 170 (Friday, September 2, 2005)). **Figure 2-8** depicts the designated critical habitat for Central Valley spring-run Chinook salmon.

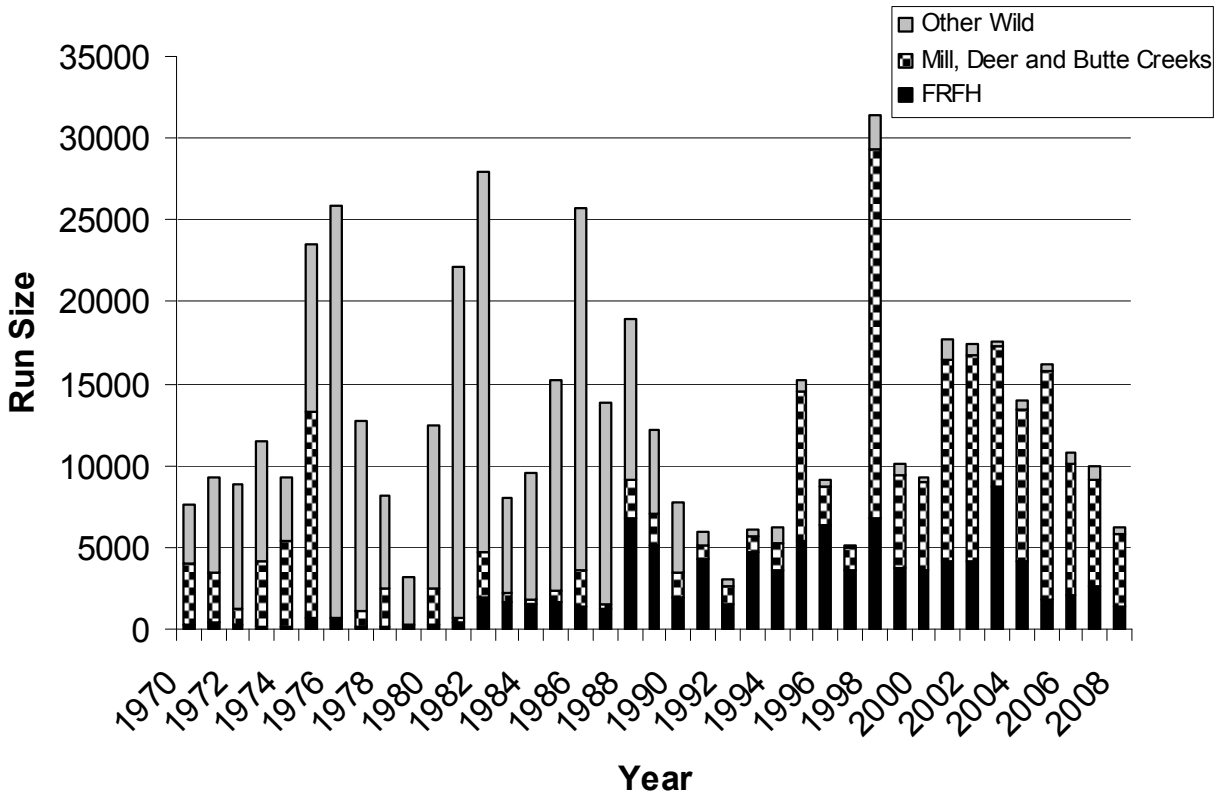


Figure 2-7. Central Valley Spring-run Chinook Salmon Spawning Run Size Composition (1970–2008)

Source: (CDFG GRANDTAB 2009)

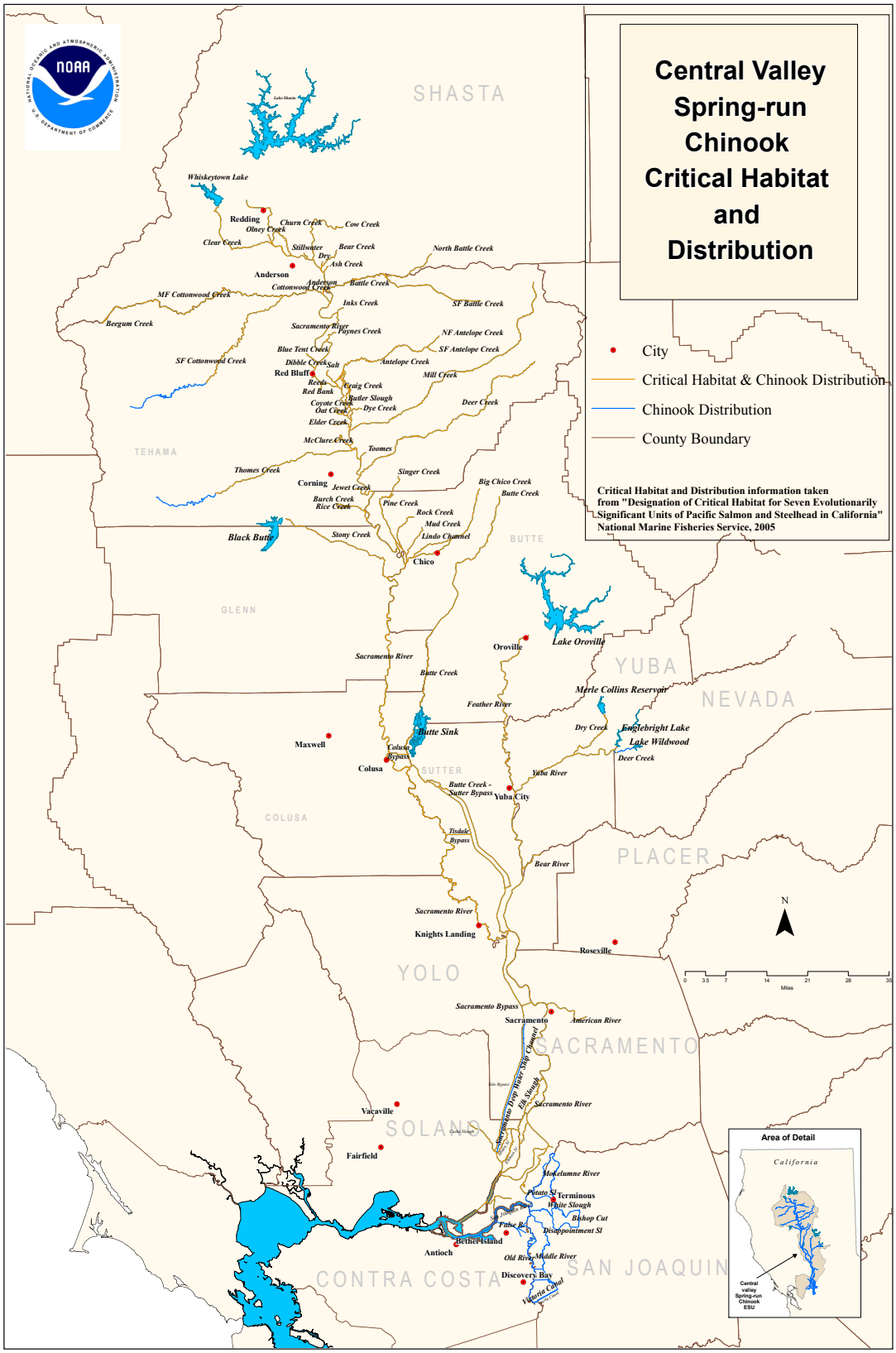


Figure 2-8. Central Valley Spring-run Chinook Salmon Designated Critical Habitat and Distribution

2.2.6 Reasons for Listing / Threats Assessment

Threats to Central Valley spring-run Chinook salmon fall into three broad categories: (1) loss of historical spawning habitat; (2) degradation of remaining habitat; and (3) threats to the genetic integrity of the wild spawning populations from the FRFH spring-run Chinook salmon production program. The construction of dams in the Central Valley has eliminated virtually all historic spawning habitat of spring-run Chinook salmon in the basin. Native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represents a large portion of the historic range and abundance of the ESU. Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998). Most of these populations are relatively small. The Feather River population depends on FRFH production, and is likely hybridized with fall-run Chinook salmon. Little is known about the status of the spring-run Chinook salmon population in the lower Yuba River, although the relatively recent installation of a VAKI Riverwatcher system at Daguerre Point Dam is beginning to provide more accurate estimates of population size. The upper Sacramento River may support a small spring-run Chinook salmon population, but the degree of hybridization with fall-run Chinook salmon is likely high, however, population status is poorly documented.

The construction of Shasta and Keswick dams on the Sacramento River and Oroville Dam on the Feather River and subsequent blocking of upstream migration has eliminated the spatial separation between spawning fall-run and spring-run Chinook salmon. Reportedly, spring-run Chinook salmon migrated to the upper Feather River and its tributaries from mid-March through the end of July (CDFG 1998). Fall-run Chinook salmon reportedly migrated later and spawned in lower reaches of the Feather River than spring-run Chinook salmon (Yoshiyama *et al.* 2001). The same pattern likely also existed on the Sacramento River. Restricted access to historic spawning grounds currently causes spring-run Chinook salmon to spawn in the same lowland reaches that fall-run Chinook salmon use as spawning habitat. The overlap in spawning site locations, combined with an overlap in spawning timing (Moyle 2002) with temporally adjacent runs, may be responsible for interbreeding between spring-run and fall-run Chinook salmon in the lower Feather River (Hedgecock *et al.* 2001) and in the Sacramento River below Keswick Dam.

In the upper Sacramento River, lower Feather River, and lower Yuba River, spring-run Chinook salmon spawning may occur a few weeks earlier than fall-run spawning, but currently there is no clear distinction between the two because of the disruption of spatial segregation by Shasta and Keswick dams on the Sacramento River, Oroville Dam on the Feather River, and Englebright Dam on the Yuba River. Thus, spring-run and fall-run Chinook salmon spawning overlap temporally and spatially. This presents difficulties from a management perspective in determining the proportional contribution of total spawning escapement by the spring- and fall-runs. Because of unnaturally high densities of spawning, particularly in the in the Low Flow Channel of the Feather River, spawning habitat is likely a limiting factor. Intuitively, it could be inferred that the slightly earlier spawning Chinook salmon displaying spring-run behavior would have better access to the limited spawning habitat, although early spawning likely leads to a higher rate of redd superimposition. Redd superimposition occurs when spawning Chinook salmon dig redds on top of existing redds dug by other Chinook salmon. The rate of superimposition is a function of spawning densities and typically occurs in systems where spawning habitat is limited (Fukushima *et al.* 1998). Redd superimposition may disproportionately affect early spawners and, therefore, potentially affect Chinook salmon exhibiting spring-run life history characteristics.

In general, spring-run Chinook salmon habitat has been degraded through elevated water temperatures, agricultural and municipal diversions and returns, restricted flows, entrainment of migrating juveniles into unscreened or poorly screened diversions, predation by non-native species and the poor quality and quantity of remaining habitat. Habitat problems remain one of the most important sources of ongoing risk to the Central Valley spring-run Chinook salmon (NMFS 1998). Like most spring-run Chinook salmon, Central Valley spring-run Chinook salmon require cool freshwater while they mature over the summer. In the Central Valley, summer water temperatures are reportedly suitable for Chinook salmon only above 150 to 500-m elevations, and most such habitat is now upstream of impassable dams (NMFS 2005). Current spawning is restricted to the mainstem and a few river tributaries in the Sacramento River, where the habitat is severely degraded (NMFS 1998).

General degradation of rearing and migrating habitat includes elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, predation by nonnative species, and the poor quality and quantity of remaining habitat (NMFS 1998). Hydropower dams and water diversions in some years have greatly reduced or eliminated in-stream flows during spring-run migration periods (NMFS 1998b).

In addition, hatchery programs in the Central Valley may pose threats to spring-run Chinook salmon stock genetic integrity (NMFS 1998). Much of the Central Valley Chinook salmon production is of hatchery origin, and naturally-spawning populations may be interbreeding with both fall-run and spring-run Chinook salmon hatchery fish. This problem has been exacerbated by the continued practice of trucking juvenile Chinook salmon to the Delta for release, contributing to the straying of returning adults throughout the Central Valley, especially in light of reports suggesting a high degree of mixing between spring- and fall- broodstock in the hatcheries. In the 1940s, trapping of adult Chinook salmon that originated from areas above Keswick and Shasta dams may have resulted in stock mixing, and further mixing with fall-run Chinook salmon apparently occurred with fish transferred to the CNFH. Deer Creek, one of the locations generally believed most likely to retain essentially native spring-run Chinook salmon, was a target of adult outplants from the 1940s trapping operation, but the success of those transplants is uncertain (NMFS 2005).

The FRFH spring-run Chinook salmon program releases half its production near the hatchery and the other half is released far downstream of the hatchery (CDFG 2001a). Given the large number of juveniles released off station, the potential contribution of straying adults to rivers throughout the Central Valley is considerable (NMFS 2005). The varying low rate of CWT marking for hatchery-derived spring-run fish and the absence of spring-run carcass surveys for most river systems prevented the accurate estimation of the contribution of naturally-spawning hatchery strays (NMFS 2005). Cramer (1996) reported that up to 20 percent of the Feather River spring-run Chinook salmon are recovered in the American River sport fishery. Furthermore, the use of a fixed date to distinguish returning spring- and fall-run fish at the FRFH may have resulted in considerable hybridization between the two runs (Campbell and Moyle 1990 *in* NMFS 2005).

Additionally, hatchery production of spring-run Chinook salmon may threaten the genetic integrity of naturally-spawning populations. Cramer and Demko (Cramer and Demko 1997) reported that half of the hatchery reared spring-run Chinook salmon returning to the Feather River did not return to the hatchery, but spawned naturally in the river. Hatchery straying is considered to be an increasing problem due to current practices of offsite releases. Given the large numbers of juveniles released offsite (1,000,000 spring-run),

the potential for straying to rivers throughout the Central Valley is high.

A detailed threats assessment was conducted for the Central Valley spring-run Chinook salmon ESU, and followed the same general procedure previously described for winter-run Chinook salmon. The threats/stressors affecting each spring-run Chinook salmon diversity group and population are described in Appendix B.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. For spring-run Chinook salmon, threats were prioritized within each diversity group, as well as within each population. Specific information explaining the individual steps taken to generate these prioritized lists are provided in Appendix B.

Some major stressors to the entire Central Valley spring-run Chinook salmon ESU include passage impediments/barriers, ocean harvest, warm water temperatures for holding and rearing, limited quantity and quality of rearing habitat, predation, and entrainment. The complete prioritized list of life stage-specific stressors to this ESU is presented in Appendix B.

Some of the most important specific stressors to each diversity groups within the ESU are described below.

Northern Sierra Nevada Diversity Group

- Agricultural diversions, diversion dams, and/or weirs on Deer, Mill, Antelope, and Butte creeks impeding or blocking access to upstream spawning habitat;
- Warm water temperatures in Antelope, Butte, and Big Chico creeks during the adult immigration and holding life stage, especially in dry or extreme years;
- Englebright Dam blocking access to habitat historically used by Yuba River spring-run Chinook salmon;
- Oroville Dam blocking access to habitat historically used by Feather River spring-run Chinook salmon;
- Entrainment in Antelope Creek resulting from terminal diversions and loss of channel connectivity;
- Loss of rearing habitat in the lower and middle sections of the Sacramento River and in the Delta;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

Basalt and Porous Lava Diversity Group

- Keswick and Shasta dams blocking access to habitat historically used by spring-run Chinook salmon in the upper Sacramento River watershed;
- Passage impediments and flow fluctuations resulting from hydropower operations on the North and South Forks of Battle Creek;
- Loss of rearing habitat in the Sacramento River and Delta;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

Northwestern California Diversity Group

- Warm water temperatures in all three watersheds during the adult immigration and holding life stage;
- Limited spawning habitat availability in all three watersheds;

- Loss of rearing habitat in the lower and middle sections of the Sacramento River and in the Delta;
- Whiskeytown Dam blocking access to habitat potentially historically used by Clear River spring-run Chinook salmon;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

2.2.7 Conservation Measures

During 2004 through 2006, progress was made in addressing some of the limiting factors and threats to this ESU, largely through ESA Section 7 consultations and other ESA-related conservation efforts in the Central Valley. The CVP Section 7 consultation with Reclamation has likely contributed to habitat improvements benefiting the Central Valley spring-run Chinook salmon ESU, such as flow and temperature improvements.

In addition, CALFED and CVPIA actions in the Sacramento River tributaries have focused on riparian and shaded riverine aquatic habitat restoration, improved access to available upstream habitat, improved instream flows, and reduced loss of juveniles at diversions, particularly for spring-run Chinook salmon and steelhead. For a description of CALFED, CVPIA and other actions, refer to the previous discussion of Conservation Measures for winter-run Chinook salmon.

The Delta Pumping Plant Fish Protection Agreement was intended to mitigate for SWP and pumping plant impacts through screening of unscreened water diversions, enhanced law enforcement efforts to reduce illegal fish harvest, installation of seasonal barriers to guide fish away from undesirable spawning habitat or migration corridors, salmon habitat restoration, and removal of four dams to improve fish passage on Butte Creek for Chinook and steelhead. Approximately one-third of the approved funding for salmon projects specifically targeted spring-run Chinook salmon and steelhead in the upper Sacramento River tributaries.

Harvest protective measures benefiting spring-run Chinook salmon include seasonal constraints on sport and commercial fisheries south of Point Arena. In addition, the State has listed spring-run Chinook under the CESA, and has thus established specific in-river fishing regulations and no-retention prohibitions designed to protect this ESU (e.g., fishing method restrictions, gear restrictions, bait limitations, seasonal closures, and zero bag limits), particularly in primary tributaries such as Deer, Big Chico, Mill, and Butte creeks, which support spring-run Chinook salmon. The CDFG has implemented enhanced enforcement efforts in spring-run tributaries and adult holding areas, which may significantly reduce illegal harvest, although there is no direct evidence that this is the case. The level of enforcement varies with funding.

2.2.8 Biological Constraints and Needs

The Central Valley spring-run Chinook salmon ESU is currently faced with three primary limiting factors and threats: (1) loss of most historic spawning habitat; (2) degradation of the remaining habitat; and (3) genetic introgression with the FRFH spring-run Chinook salmon strays. Spring-run Chinook require cool freshwater in summer, most of which is upstream of impassable dams. The ESU is currently limited to independent populations in Mill, Deer, and Butte creeks, persistent and presumably dependent populations in the Feather and Yuba rivers and in Big Chico, Antelope, and Battle creeks, and a few ephemeral or dependent populations in the Northwestern California region (e.g., Beegum, Clear, and Thomes creeks). This ESU continues to be threatened by habitat loss, degradation and modification, small hydropower dams and water diversions that reduce or eliminate instream flows

during migration, unscreened or inadequately screened water diversions, excessively high water temperatures, and predation by non-native species.

The potential effects of long-term climate change also may adversely affect spring-run Chinook salmon and their recovery. These effects are summarized above for winter-run Chinook salmon, and more thoroughly discussed in Chapter 7.

2.3 Steelhead

2.3.1 Brief Overview/Status of the Species

NMFS proposed to list the Central Valley steelhead (*Oncorhychus mykiss*), which is currently listed as threatened, as endangered on August 9, 1996. NMFS (61 FR 41541 (August 1996)) concluded that the Central Valley steelhead ESU was in danger of extinction because of habitat degradation and destruction, blockage of freshwater habitats, water allocation problems, the pervasive opportunity for genetic introgression resulting from widespread production of hatchery steelhead and the potential ecological interaction between introduced stocks and native stocks. Moreover, NMFS (71 FR 834 (January 5, 2006)) proposed to list steelhead as endangered because steelhead had been extirpated from most of their historical range.

On March 19, 1998, NMFS listed the Central Valley steelhead as a threatened species (63 FR 13347 (March 19, 1998)). NMFS (63 FR 13347 (March 19, 1998)) concluded that the risks to Central Valley steelhead had diminished since the completion of the 1996 status review based on a review of existing and recently implemented State conservation efforts and Federal management programs (e.g., CVPIA AFRP, CALFED) that address key factors for the decline of this species. In addition, NMFS (63 FR 13347 (March 19, 1998)) asserted that additional actions benefiting Central Valley steelhead included efforts to enhance fisheries monitoring and conservation actions to address artificial propagation.

On September 8, 2000, pursuant to a July 10, 2000, rule issued by NMFS under Section 4(d) of the ESA (16 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply to Central Valley steelhead (65 FR 42421 (July 10, 2000)). On January 5, 2006, NMFS reaffirmed the threatened status of the Central Valley steelhead and applied the DPS policy to the species because the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a separate DPS (71 FR 834 (January 5, 2006)). NMFS (1998) based its conclusion on conservation and protective efforts that, *"mitigate the immediacy of extinction risk facing the Central Valley steelhead DPS."* **Figure 2-9** depicts the Central Valley steelhead DPS.

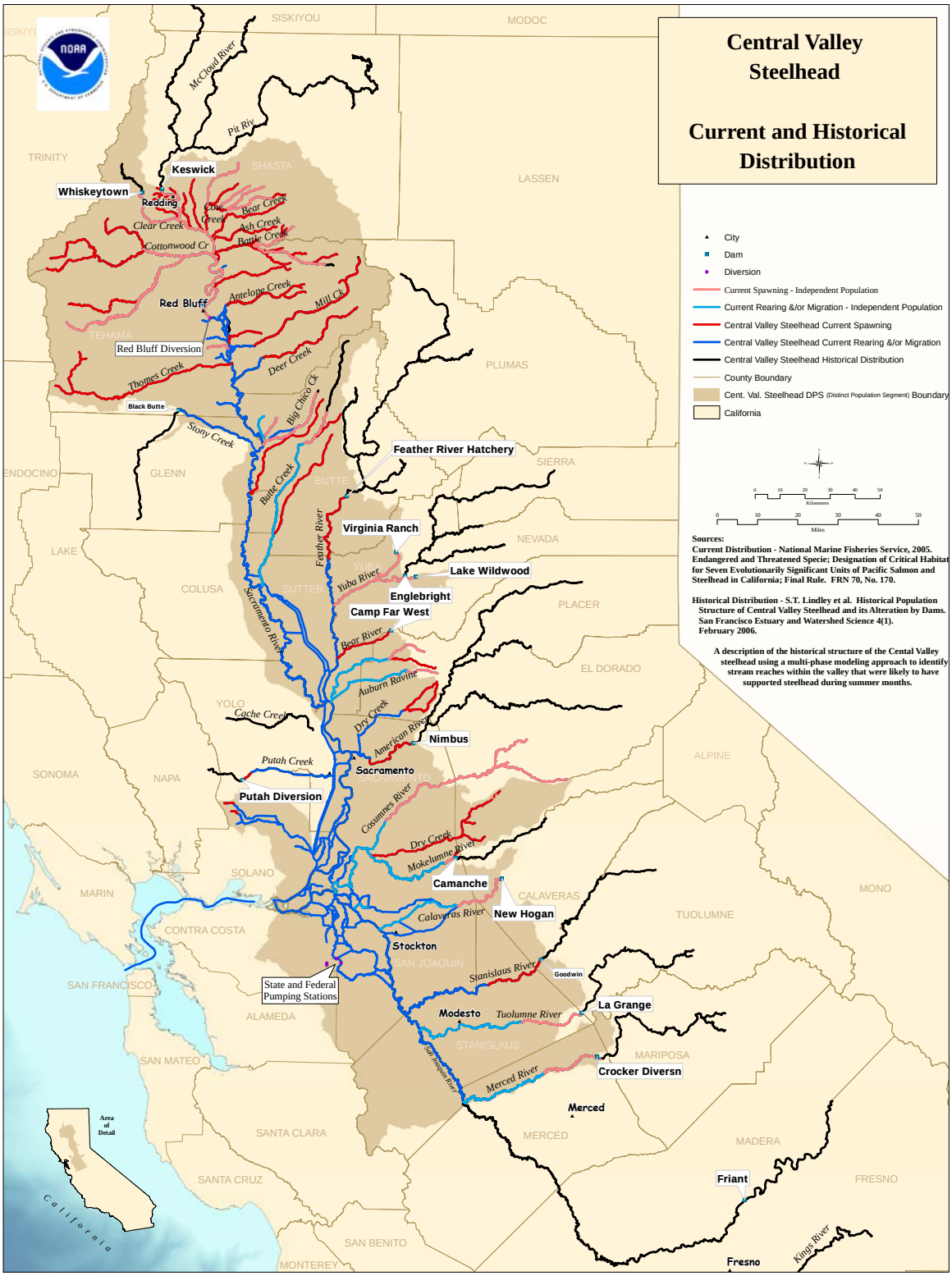


Figure 2-9. Central Valley Steelhead Distinct Population Segment, and Current and Historical Distribution. See Lindley et al. 2006 (Table 1) in Appendix D for a list of the 81 historic independent steelhead populations in the Central Valley.

2.3.2 Species Description and Taxonomy

Steelhead and rainbow trout are the same species. In general, steelhead refers to the anadromous form of the species. Normally, adult steelhead reach a larger size than resident rainbow trout. Sacramento River Basin steelhead immigrants range in size from 12 to 18 inches (30.5 to 45.7 cm) FL for adults returning after 1 year in the ocean, to 18 to 23 inches (45.7 to 58.4 cm) FL for adults returning after 2 years in the ocean (S.P. Cramer & Associates 1995).

Steelhead can be identified by the numerous black spots on the caudal fin, adipose fin, dorsal fin and back (Moyle 2002). When in freshwater, steelhead often display the pinkish to red lateral band and cheeks typical of resident rainbow trout. The back is normally an iridescent blue to brown, the sides and belly are silver, white or yellowish (Moyle 2002). The resident forms are usually darker than the sea-run. Juvenile coloration is similar to adults except that juveniles often have 8 to 13 widely spaced parr marks centered on the lateral line, 5 to 10 dark marks on the back between the head and dorsal fin, white to orange tips on the dorsal and anal fins, and few, if any, dark spots on the tail (Moyle 2002).

2.3.3 Life History

Oncorhychus mykiss may exhibit anadromy or freshwater residency. Resident forms are usually referred to as ''rainbow'' trout, while anadromous life forms are termed ''steelhead.'' Zimmerman et al. (2008) demonstrated that resident rainbow trout can produce anadromous smolts and anadromous steelhead can produce resident rainbow trout in the Central Valley. That study indicated that the proportion of resident rainbow trout to anadromous steelhead in the Central Valley is largely in favor of the resident form with 740 of 964 O. mykiss examined being the progeny of resident rainbow trout (Zimmerman et al. 2008).

Steelhead typically migrate to marine waters after spending two years in fresh water. They reside in marine waters for typically two or three years prior to returning to their natal stream to spawn as four- or five-year-olds. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002).

Currently, Central Valley steelhead are considered "ocean-maturing" (also known as winter) steelhead, although summer steelhead may have been present prior to construction of large dams (Moyle 2002). Ocean maturing steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. Central Valley steelhead enter fresh water from August through April. They hold until flows are high enough in tributaries to enter for spawning (Moyle 2002). Steelhead adults typically spawn from December through April, with peaks from January though March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961; McEwan 2001). Depending on water temperature, steelhead eggs may incubate in redds for 1.5 to 4 months before hatching as alevins. Following yolk sac absorption, alevins emerge from the gravel as young juveniles or fry and begin actively feeding (Moyle 2002).

In the Sacramento River, juvenile steelhead generally migrate to the ocean in spring and early summer at 1 to 3 years of age and 10 to 25 cm FL, with peak migration through the Delta in March and April (Reynolds *et al.* 1993). Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River Basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall.

Steelhead may remain in the ocean from one to four years, growing rapidly as they feed in the highly productive currents along the continental shelf (Barnhart 1986). Oceanic and climate conditions such as sea surface temperatures, air

temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of subarctic water, and increased sea levels (Pearcy 1997). For juvenile steelhead, warmer water and weakened upwellings are possibly the most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead would need to migrate more actively offshore through possibly stressful warm waters with numerous inshore predators.

Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1997). **Table 2-4** depicts the temporal occurrence of steelhead life stages in the Sacramento River.

2.3.4 Abundance Trends and Distribution

Prior to dam construction, water development and watershed perturbations, Central Valley steelhead were distributed throughout the Sacramento and San Joaquin rivers (Busby *et al.* 1996; NMFS 1996b, McEwan 2001). Steelhead were found from the upper Sacramento and Pit rivers (now inaccessible due to Shasta and Keswick dams) south to the Kings and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). Lindley *et al.* (Lindley *et al.* 2006) estimated that historically there were at least 81 independent Central Valley steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin rivers (**see Appendix D**). Presently, impassable dams block access to 80 percent of historically available habitat, and block access to all historical spawning habitat for about 38 percent of historical populations (Lindley et al. 2006). Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill creeks and the Yuba River. Populations may exist in Big Chico and Butte creeks, and a few wild steelhead are produced in the American and Feather rivers (McEwan 2001).

Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good et al. 2005). Because of the large resident O. mykiss population in Clear Creek, steelhead spawner abundance has not been estimated.

Until recently, CV steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001).

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good et al. 2005).

Naturally spawning populations of steelhead also occur in the Feather, Yuba, American, and Mokelumne rivers, but these populations have had substantial hatchery influence and their ancestry is not clear (Busby et al. 1996). Steelhead runs in the Feather and American rivers are sustained largely by the FRFH and Nimbus Hatchery (CDFG 1996). Steelhead also currently occur in the Stanislaus, Calaveras, Merced, and

Tuolumne rivers. The current and historical distribution of Central Valley steelhead is presented in **Figure 2-9**.

Table 2-4. The Temporal Occurrence of Adult and Juvenile Sacramento River Steelhead in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River[1,3]												
Sacramento River at Red Bluff[2,3]												
Mill, Deer Creeks[4]												
Sacramento River at Fremont Weir[6]												
Sacramento River at Fremont Weir[6]												
San Joaquin River[7]												
Juvenile												
Sacramento River[1,2]												
Sacramento River at Knights Landing[2,8]												
Sacramento River at KL[9]												
Chipps Island (Wild)[10]												
Mossdale[8]												
Woodbridge Dam[11]												
Stanislaus River at Caswell[12]												
Sacramento River at Hood[13]												

Sources: [1]Hallock et al. 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [5](Hallock et al. 1957); [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2003; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980

Relative Abundance:		= High		= Medium		= Low

Note: NMFS recognizes that CDFG Steelhead Report Card Data provides a small sample size and involves some known sampling bias, but these data represent the best information available for the temporal distribution of adult steelhead in the San Joaquin River.

Historic Central Valley steelhead run sizes are difficult to estimate because of the lack of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 (CDFG 1996). Over the last 30 years the steelhead populations in the upper Sacramento River have declined substantially. In 1996, NMFS estimated the Central Valley total run size based on dam counts, hatchery returns, and past spawning surveys was probably fewer than 10,000 fish. Both natural and hatchery runs have declined since the 1960s. Counts at RBDD averaged 1,400 fish from 1991 to 1996, compared to counts in excess of 10,000 fish in the late 1960s (CDFG 1996). American River redd surveys and associated monitoring from 2002 through 2007 indicate that only a few hundred steelhead spawn in the river and a portion of those spawners originated from Nimbus Hatchery (Hannon and Deason 2008).

In analyzing flow-habitat relationships for anadromous salmonids in the upper Sacramento River upstream of the Battle Creek confluence and downstream of Keswick Dam, USFWS (2003) reported that it was not possible to differentiate between steelhead and resident rainbow trout. Specific information regarding steelhead spawning within the mainstem Sacramento River is limited due to lack of monitoring (NMFS 2004). Currently, the number of steelhead spawning in the Sacramento River is unknown because redds cannot be distinguished from a large resident rainbow trout population that has developed as a result of managing the upper Sacramento River for coldwater species.

2.3.5 Habitat Requirements

A description of freshwater habitat requirements for steelhead is presented in the following sections. Habitat requirements are organized by the species life stage.

Adult Immigration and Holding

Adult steelhead immigration into Central Valley streams typically begins in August and continues into March (McEwan 2001; NMFS 2004). Steelhead immigration generally peaks during January and February (Moyle 2002). Optimal immigration and holding temperatures have been reported to range from 46°F to 52°F (CDFG 1991b).

Central Valley steelhead are known to use the Sacramento River as a migration corridor to spawning areas in upstream tributaries. Historically, steelhead likely did not utilize the mainstem Sacramento River downstream from the Shasta Dam site except as a migration corridor to and from headwater streams. The number of steelhead that spawn in the Sacramento River is unknown, but it is probably low (DWR 2003). Likewise, the Feather River below the current site of Oroville Dam was likely used only as a migration corridor to upstream reaches.

Adult Spawning

Central Valley steelhead spawn downstream of dams on every major tributary within the Sacramento and San Joaquin River systems. The female steelhead selects a site with good intergravel flow, digs a redd with her tail, usually in the coarse gravel of the tail of a pool or in a riffle, and deposits eggs while an attendant male fertilizes them. Water velocities over redds are typically 20 to 155 cm/sec, and depths are 10 to 150 cm (Moyle 2002). The preferred water temperature range for steelhead spawning is reported to be 30°F to 52°F (CDFG 2000).

Embryo Incubation

Following deposition of fertilized eggs in the redd, they are covered with loose gravel. Central Valley steelhead eggs can reportedly survive at water temperature ranges of 35.6°F to 59°F (Myrick and Cech 2001). However, steelhead eggs reportedly have the highest survival rates at water temperature ranges of 44.6°F to 50.0°F (Myrick and Cech 2001). The eggs hatch in three to four weeks at 50°F to 59°F, and fry emerge from the gravel four to six weeks later (Shapovalov and Taft 1954).

Juvenile Rearing and Outmigration

Regardless of life history strategy, for the first year or two of life rainbow trout and steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002). The smallest fish are most often found in riffles, intermediate size fish in runs, and larger fish in pools. Steelhead can be found where daytime water temperatures range from nearly 32°F to 81°F in the summer, although mortality may result at extremely low (i.e., <39°F) or extremely high (i.e., > ~73°F) water temperatures if the fish have not been gradually acclimated (Moyle 2002). Juvenile steelhead in northern California rivers reportedly exhibited increased physiological stress, increased agonistic activity, and a decrease in forage activity after ambient stream temperatures exceeded 71.6°F (Nielsen et al. 1994).

When water temperatures become stressful in streams, juvenile steelhead are faced with the increased energetic costs of living at high water temperatures. Hence, juvenile steelhead will move into fast flowing riffles to feed because of the increased abundance of food, even though there are costs associated with maintaining position in fast water. At higher water temperatures, steelhead are more vulnerable to stress which can be fatal (Moyle 2002). Predators also have a strong effect on microhabitats selected by steelhead. Small steelhead select places to live based largely on proximity to cover in order to hide from predators.

Optimal water temperatures for growth of steelhead have been reported to be 59°F to 64.4°F (Moyle 2002). Many factors affect choice of water temperatures by steelhead, including the availability of food. As steelhead grow, they establish individual feeding territories. Some juvenile steelhead utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the ocean.

2.3.6 Critical Habitat

Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. The primary constituent elements considered essential for the conservation of listed Central Valley salmonids are: (1) freshwater spawning sites; (2) freshwater rearing sites; (3) freshwater migration corridors; (4) estuarine areas; (5) nearshore marine areas; and (6) offshore marine areas.

NMFS proposed critical habitat for Central Valley steelhead on February 5, 1999 (FR Vol. 64, No. 24 (Friday, February 5, 1999)), in compliance with Section 4(a)(3)(A) of the ESA, which requires that, to the maximum extent prudent and determinable, NMFS designates critical habitat concurrently with a determination that a species is endangered or threatened (NMFS 1999). On February 16, 2000 (FR Vol. 65, No. 32 (Wednesday, February 16, 2000)), NMFS published a final rule designating critical habitat for Central Valley steelhead. Critical habitat was designated to include all river reaches accessible to listed steelhead in the Sacramento and San Joaquin rivers and their tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

In response to litigation brought by the National Association of Homebuilders (NAHB) on the grounds that the agency did not adequately consider economic impacts of the critical habitat designations (NAHB v. Evans, 2002 WL 1205743 No. 00–CV–2799 (D.D.C.)), NMFS sought judicial

approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)). NMFS proposed new critical habitat for Central Valley steelhead on December 10, 2004 (FR Vol. 69, No. 237 (Friday, December 10, 2004)) and published a final rule designating critical habitat for this species on September 2, 2005. **Figure 2-10** depicts the designated critical habitat for Central Valley steelhead.

2.3.7 Reasons for Listing / Threats Assessment

Extensive extirpation of historical populations has placed the Chinook salmon ESUs in jeopardy of extinction. The remaining populations are at low or moderate risk of extinction. The proximate problem afflicting these ESUs and the Central Valley steelhead DPS is that their historical spawning and rearing areas are largely inaccessible. For Central Valley steelhead, there are insufficient data to assess the risk of any but a few populations and, therefore, the Central Valley TRT could not assess the viability of this DPS using the quantitative approach. However, qualitative information does suggest that the Central Valley steelhead DPS is at a moderate or high risk of extinction, especially considering that most habitat is inaccessible. Threats to Central Valley steelhead are similar to those for Chinook salmon and fall into three broad categories: loss of historical spawning habitat; degradation of remaining habitat; and threats to the genetic integrity of the wild spawning populations from hatchery steelhead production programs in the Central Valley.

Historically, steelhead occurred naturally throughout the Sacramento and San Joaquin River basins; however, stocks have been extirpated from large areas in both basins. The California Advisory Committee on Salmon and Steelhead (1988) reported a reduction in Central Valley steelhead habitat from 6,000 miles historically to 300 miles at present. Reynolds *et al.* (1993) reported that 95 percent of salmonid habitat in California's Central Valley has been lost, largely due to mining and water development activities. They also noted that declines in Central Valley steelhead stocks are *"due mostly to water development, inadequate instream flows, rapid flow fluctuations, high summer water temperatures in streams immediately below reservoirs, diversion dams which block access, and entrainment of juveniles into unscreened or poorly screened diversions."* Other problems related to land use practices (agriculture and forestry) and urbanization also have certainly contributed to stock declines.

The major threat to genetic integrity for Central Valley steelhead comes from past and present hatchery practices. Overlap of spawning hatchery and natural fish within this DPS exists resulting in genetic introgression. Also, a substantial problem with straying of hatchery fish exists within this DPS (Hallock 1989). Currently, four hatcheries in the Central Valley produce steelhead to supplement the Central Valley wild steelhead population. The hatcheries and their current production targets are listed in Table 2-5. Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

Potential adverse effects to wild steelhead populations associated with hatchery production are similar to those described above for winter-run Chinook salmon. However, recent research has indicated that approximately 63 to 92 percent of steelhead smolt production is of hatchery origin (NMFS 2003) More importantly, these data suggest that the relative proportion of wild to hatchery smolt production is decreasing (NMFS 2003).

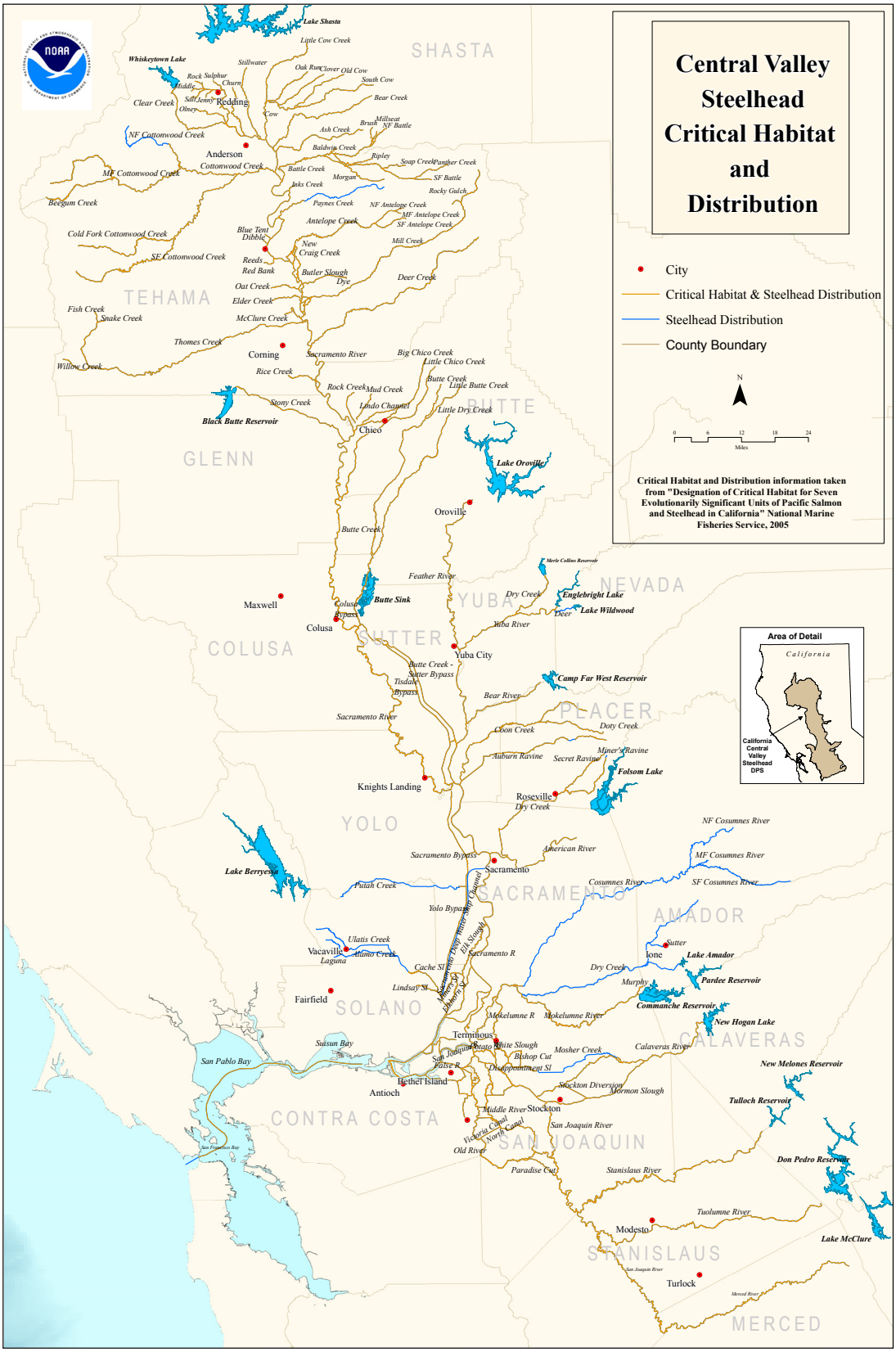


Figure 2-10. Central Valley Steelhead Designated Critical Habitat and Distribution

Potential adverse effects to wild steelhead populations associated with hatchery production are similar to those described above for winter-run Chinook salmon. However, recent research has indicated that approximately 63 to 92 percent of steelhead smolt production is of hatchery origin (NMFS 2003), which is a higher percentage than winter-run Chinook salmon estimates. More importantly, these data suggest that the relative proportion of wild to hatchery smolt production is decreasing (NMFS 2003).

Table 2-5. Hatcheries Producing Steelhead in the Central Valley

Hatchery	Production Target
Coleman National Fish Hatchery	600,000
Feather River Fish Hatchery	500,000
Nimbus Hatchery	430,000
Mokelumne Fish Hatchery	100,000

There is still significant local genetic structure to Central Valley steelhead populations. Hatchery effects appear to be localized – for example, Feather River and the FRFH steelhead are closely related, as are American River and Nimbus Hatchery fish (DWR 2002). Leary *et al.* (1995) report that hatchery straying has increased gene flow among steelhead populations in the Central Valley, and that a smaller amount of genetic divergence is observed among Central Valley populations compared to wild British Columbia populations largely uninfluenced by hatcheries. Currently, natural annual production of steelhead smolts in the Central Valley is estimated at 181,000 and hatchery production is 1,340,000, for a ratio of 0.148 (Good *et al.* 2005).

In general, although structure was found, all naturally-spawned O. mykiss populations within the Central Valley basin were closely related, regardless of whether they were sampled above or below a known barrier to anadromy. This is due to some combination of preimpoundment historic shared ancestry, downstream migration and, possibly, limited, anthropogenic upstream migration. However, lower genetic diversity in above-barrier populations indicates a lack of substantial genetic input upstream and highlights lower effective population sizes for above-barrier populations. Above-barrier populations clustered with one another and below-barrier populations are most closely related to populations in far northern California, specifically the genetic groups that include the Eel and Klamath Rivers. Since Eel River origin broodstock were used for many years at Nimbus Hatchery on the American River, it is likely that Eel River genes persist there and have also spread to other basins by migration, and that this is responsible for the clustering of the below-barrier populations with northern California ones. This suggests that the below-barrier populations in this region appear to have been widely introgressed with hatchery fish from out of basin broodstock sources. The consistent clustering of the above-barrier populations with one another, and their position in the California-wide trees, indicate that they are likely to most accurately represent the ancestral population genetic structure of steelhead in the Central Valley (Garza and Pearse 2008).

A significant transfer of genetic material has occurred among hatcheries within the Central Valley, as well as some transfer from systems outside the Central Valley. For example, an Eel River strain of steelhead was used as the founding broodstock for the Nimbus Hatchery (DWR 2002). Additionally, eyed eggs from the Nimbus Hatchery were transferred to the FRFH several times in the late 1960s and early 1970s (DWR 2002). There have also been transfers of steelhead from the FRFH to the Mokelumne Hatchery. In the late 1970s, a strain of steelhead was brought in from Washington State for the FRFH (DWR 2002).

In 1998, NMFS continued to identify long-term declines in abundance, small population sizes in the Sacramento River, and the high risk of interbreeding between hatchery and naturally spawned steelhead as major concerns for Central Valley steelhead. The significant loss of historic habitat, degradation of remaining habitat from water diversions, reduction in water quality and other factors, harvest impacts, and the lack of monitoring data on abundance also were identified as other important risk factors for this DPS. Nevertheless, NMFS concluded that the risks to Central Valley steelhead had diminished based on a review of existing and recently implemented State conservation efforts and Federal management programs that address key factors for the decline of this species. NMFS stated that Central Valley steelhead were benefiting from two major conservation initiatives, being simultaneously implemented: (1) the CVPIA, which was passed by Congress in 1992; and (2) the CALFED Program, a joint State/Federal effort implemented in 1995.

In 2005 and 2006, NMFS affirmed that risk factors for Central Valley steelhead include extirpation from most of the historical range, a consistent decline in the single available time series of abundance, declining proportion of wild fish in spawning runs, substantial opportunity for deleterious interactions with hatchery fish (including out-of-basin-origin stocks), various habitat problems, and lack of ongoing population assessments. In addition, harvest impacts have been identified. According to CDFG creel census surveys, the majority (93 percent) of steelhead catches occur on the American and Feather rivers, sites of steelhead hatcheries (CDFG 2001d). Creel census surveys conducted during 2000 indicated that 1,800 steelhead were retained, and 14,300 were caught and released. The total number of steelhead contacted might be a significant fraction of basin-wide escapement, so even low catch-and-release mortality may pose a problem for wild populations. Additionally, NMFS (2005) asserted that steelhead fisheries on some tributaries and the mainstem Sacramento River may affect some steelhead juveniles.

A detailed threats assessment was conducted for the Central Valley steelhead DPS. The threats and stressors affecting each steelhead diversity group and population are described in Appendix B.

Some major stressors to the entire Central Valley steelhead DPS include passage impediments and barriers, warm water temperatures for rearing, hatchery effects, limited quantity and quality of rearing habitat, predation, and entrainment. The complete prioritized list of life stage-specific stressors to the DPS is presented in Appendix B.

Many of the most important stressors specific to the steelhead diversity groups correspond to the diversity group-specific stressors described for the spring-run Chinook salmon ESU on page 43. The only diversity group (i.e., area) unique to the steelhead DPS, relative to the diversity groups in the spring-run Chinook salmon ESU is the southern Sierra Nevada diversity group. Some of the most important stressors to steelhead in the southern Sierra Nevada diversity group include:

- Friant Dam blocking access to habitat historically used by San Joaquin River steelhead;
- Passage impediments on Calaveras River including Bellota Weir and flash board dams;
- Limited habitat availability in each watershed and in the mainstem San Joaquin River for spawning and juvenile rearing;
- La Grange and Don Pedro dams blocking access to habitat historically used by Tuolumne River steelhead;
- Goodwin and New Melones dams blocking access to habitat historically used by Stanislaus River steelhead;

- McSwain and Crocker Huffman dams blocking access to habitat historically used by Merced River steelhead;
- Camanche and Pardee dams blocking access to habitat historically used by Mokelumne River steelhead; and
- Entrainment at the Jones and Banks Pumping Plants and associated losses from predation
- Inadequate summer flow on the Tuolumne River

2.3.8 Conservation Measures

During 2004–2006, progress was made toward addressing some of the limiting factors and threats to this DPS, largely through ESA Section 7 consultations and other ESA-related conservation efforts in the Central Valley. The CVP Section 7 consultation with the Bureau of Reclamation likely contributed to habitat improvements benefiting the Central Valley steelhead DPS, such as flow and temperature improvements.

In addition, two large, comprehensive conservation programs in the Central Valley provide a wide range of ecosystem and species-specific protective efforts that potentially benefit steelhead–the CALFED Program and the CVPIA. For a description of CALFED, CVPIA, and other actions, refer to the previous discussion of Conservation Measures for Winter-run and Spring-run Chinook Salmon.

Other ongoing measures to protect steelhead in the State of California include 100 percent adipose fin-clipping of all hatchery steelhead, although they are not coded-wire tagged and, therefore, determination of hatchery of origin, as well as straying rates, remain problematic for stock identification. Zero bag limits for unmarked steelhead, gear restrictions, closures, and size limits designed to protect smolts are additional inland harvest measures designed to protect steelhead. The State also works closely with NMFS to review and improve inland fishing regulations.

2.3.9 Biological Constraints and Needs

The primary limiting factor to the Central Valley steelhead DPS is the inaccessibility of more than 95 percent of its historic spawning and rearing habitat due to impassable dams. Where steelhead are still extant, natural populations are subject to habitat degradation and various impacts from water development activities and land use activities. This DPS requires cool water found at higher elevations, now largely above impassable dams. The lack of adequate status and trend monitoring and research limits our understanding of the viability of this DPS and our ability to determine how steelhead populations may have interacted before the dams were built. The geographically wide stocking of hatchery fish has had deleterious effects on native wild trout populations. It is likely many of the threats affecting Chinook salmon are also negatively impacting steelhead, such as inadequately screened water diversions, excessively high water temperatures, and predation by non-native species.

The potential effects of long-term climate change also may adversely affect steelhead and their recovery. These effects are summarized above for winter-run Chinook salmon, and are more thoroughly discussed in Chapter 7.

3.0 Recovery Strategy

"The wide-ranging migration patterns and unique life histories of anadromous salmonids take them across ecosystem and management boundaries in an increasingly fragmented world, which creates the need for analyses and strategies at similarly large scales."

- Good *et al.* 2007. Recovery Planning for Endangered Species Act-listed Pacific Salmon: Using Science to Inform Goals and Strategies

3.1 Strategic Framework

A broad strategic framework is necessary to serve as a strategic planning guide to integrate the actions contributing to the overarching goal of recovery of the two Chinook salmon ESUs and the steelhead DPS, which contain a mixture of hatchery and wild fish, and resident and anadromous fish. Because of the complexity associated with the multi-faceted considerations for these recovery efforts within the Central Valley Domain, this strategic planning framework incorporates the concepts of viability at both the population and ESU/DPS levels.

3.1.1 Population Viability

Recovery planning seeks to ensure the viability of protected species. In the short term, viability of populations (and ESU/DPS) depends on the demographic properties of the population or ESU/DPS, such as population size, growth rate, the variation in growth rate, and carrying capacity (Tuljapurkar and Orzack 1980) all of which depend largely on the quality and quantity of habitat. In the longer term, genetic diversity, and the diversity of habitats that support genetic diversity, become increasingly important (McElhany *et al.* 2000; Kendall and Fox 2002; Williams and Reeves 2003). In determining the future viability or extinction risk of a population, it is important to consider observed and predicted impacts of climate change on populations.

NMFS has developed guidelines to use in applying the four VSP parameters of abundance, productivity, spatial structure and diversity to salmonid populations for determining whether a population is viable (McElhany *et al*. 2000). These four parameters and their associated attributes are presented in **Figure 3-1**.

As presented in Good *et al.* (2005), criteria for VSP are based upon measures of population characteristics that reasonably predict extinction risk and reflect processes important to populations. Abundance is critical, because small populations are generally at greater risk of extinction than large populations. Stage-specific or lifetime productivity (i.e., population growth rate) provides information on important demographic processes. Abundance and productivity data are used to asses the status of populations of threatened and endangered ESUs (Good *et al.* 2005). Genotypic and phenotypic diversity are important in that they allow species to use a wide array of environments, respond to short-term changes in the environment, and survive long-term environmental change. Spatial structure reflects how abundance is distributed among available or potentially available habitats and how it can affect overall extinction risk and evolutionary processes that may alter a population's ability to respond to environmental change.

ABUNDANCE

A population should be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.

A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic perturbation.

A population should be sufficiently large to maintain its genetic diversity over the long term.

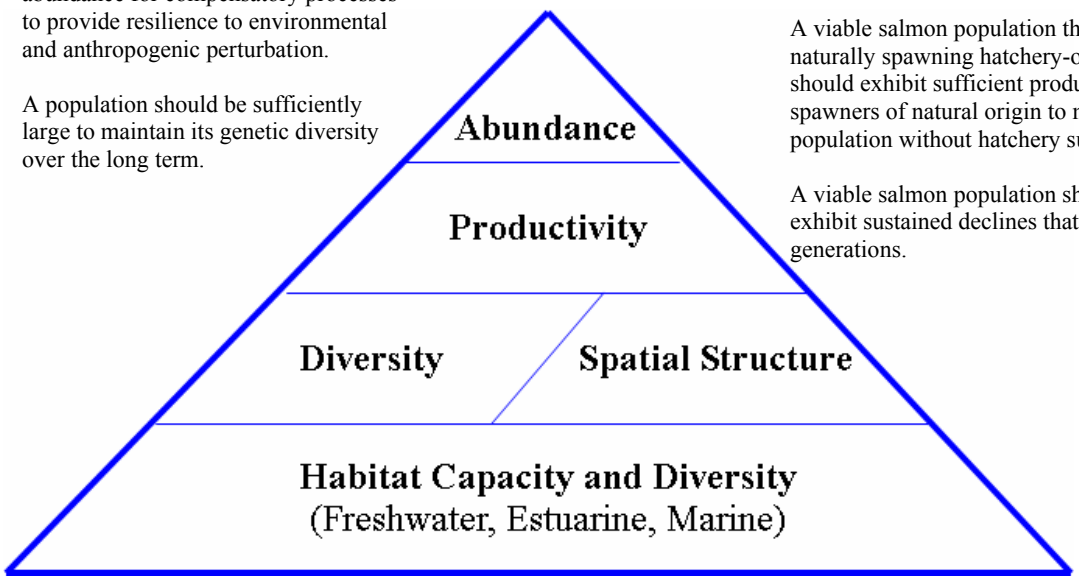
PRODUCTIVITY (POPULATION GROWTH RATE)

Natural productivity should be sufficient to reproduce the population at a level of abundance that is viable.

Productivity should be sufficient throughout freshwater, estuarine, and nearshore life stages to maintain viable abundance levels, even during poor ocean conditions.

A viable salmon population that includes naturally spawning hatchery-origin fish should exhibit sufficient productivity from spawners of natural origin to maintain the population without hatchery subsidy.

A viable salmon population should not exhibit sustained declines that span multiple generations.



DIVERSITY

Human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity (birth rate), morphology, behavior, and genetic characteristics.

The rate of gene flow among populations should not be altered by human caused factors.

Natural processes that cause ecological variation should be maintained.

SPATIAL STRUCTURE

Habitat patches should not be destroyed faster than they are naturally created.

Human activities should not increase or decrease natural rates of straying among salmon sub-populations.

Habitat patches should be close enough to allow the appropriate exchange of spawners and the expansion of population into underused patches.

Some habitat patches may operate as highly productive sources for population production and should be maintained.

Due to the time lag between the appearance of empty habitat and its colonization by fish, some habitat patches should be maintained that appear to be suitable, or marginally suitable, even if they currently contain no fish.

Figure 3-1. Viable salmonid population (VSP) parameters and their attributes. The quality, quantity and diversity of the habitat (habitat capacity and diversity) available to the species in each of its three main habitat types (freshwater, estuarine and marine environments) is a critical foundation to VSP. Salmon cannot persist in the wild and withstand natural environmental variations in limited or degraded habitats.

3.1.2 ESU Viability

Good *et al.* (2007) report that viability criteria for Pacific salmon ESUs rely on determining how many and which populations need to be at a particular status for the ESU as a whole to have an acceptably low extinction risk. In general, an assessment of an ESU as being viable will be more likely if it contains multiple populations (metapopulations), some of which meet viability criteria. Viability of the ESU is also more likely if: (1) populations are geographically widespread but some are close enough together to facilitate connectivity; (2) populations do not all share common catastrophic risks; and (3) populations display diverse life-histories and phenotypes (McElhany *et al*. 2000).

Considerations regarding the viability of an ESU are discussed in ISAB (2005), and are generally adopted herein for application to the two Chinook salmon ESUs and the steelhead DPS in the Central Valley Domain. To be viable, an ESU needs more than simple persistence over time; it needs to be in an ecologically and evolutionarily functional state. Evaluation of ESU viability should not only depend upon the numbers of component populations or on the abundance and productivity of those individual populations, but also should be based on the integration of population dynamics within the ecosystem as a whole. This concept of ESU viability does not accommodate the loss of populations or the anadromous or resident life history form from any given ESU, because that loss would represent a loss in diversity for the ESU that would put its long-term viability at risk. An ESU needs to contain viable populations inhabiting a variety of different habitats, interconnected as a metapopulation, if that ESU is to fulfill the entire complement of ecological and evolutionary interactions and functions (ISAB 2005).

A viable ESU consists of a group of populations existing together as a metapopulation that as an entity is self-sustaining for the foreseeable future. Populations within a viable ESU need to exhibit the abundance, productivity, diversity, and spatial distribution of natural spawners sufficient to accomplish the following: avoid the loss of genetic and/or life history diversity during short-term losses in abundance that are expected parts of environmental cycles; fulfill key ecological functions that are attributable to the species, such as nutrient cycling and food web roles; and provide for long-term evolutionary adaptability to changing environmental conditions. However, given the high uncertainty in prediction of future environmental conditions, as well as the uncertainty in interpretation of how genetic or other diversity metrics will be expressed in future environments, this Recovery Plan endeavors to avoid loss of currently small, peripheral, or in any way seemingly less valuable populations.

In addition to the considerations alliterated by ISAB (2005), the Central Valley TRT further addressed ESU viability for the Central Valley Domain using two different approaches. The goal of both approaches is to spread risk and maximize future potential for adaptation.

In the first approach, the Central Valley TRT assessed ESU viability by examining the number and distribution of viable populations across the landscape, and their proximity to sources of catastrophic disturbance. Risk-spreading is assessed by examining how viable populations are spread among geographically-defined regions within the ESU. As stated in Lindley *et al.* (2007), the Puget Sound, Williamette/Lower Columbia and Interior Columbia TRTs have used variations of the idea of dividing ESUs into subunits (Myers *et al.* 2003; Ruckelshaus *et al.* 2002; Interior Columbia Basin Technical Recovery Team 2003), and requiring representation of all subunits and redundancy within the subunits (which the Central Valley TRT referred to as the "representation and redundancy" rule). The ESU subunits are intended to capture important components of habitat, life history or genetic diversity that contribute to the viability of salmonid ESUs (Hilborn *et al.* 2003; Bottom *et al.* 2005). If extinction risks are not strongly correlated between populations, two populations,

each with low risk of extinction, would be extremely unlikely to go extinct simultaneously (McElhany *et al.* 2003). Should one go extinct, the other could serve as a source of colonists to reestablish the extirpated population. In the second approach, the TRT attempted to account explicitly for the spatial structure of the ESU and the spatial structure of various catastrophic risks, including volcanoes, wildfires, and droughts.

Diversity Groups

As discussed in Lindley et al. (2004), drainages in the Central Valley Basin are characterized by a wide variety of climatological, hydrological, and geological conditions. The Central Valley TRT used the Jepson floristic ecoregions defined by Hickman (1993) as a starting point for salmon ecoregions, but modified them to account for the effect of springs, which are influential on salmonids, but less influential to upland plants. These salmonid ecoregions are referred to herein as "Diversity Groups". The Central Valley TRT defined a "basalt and porous lava" Diversity Group that comprises the streams that historically supported winter-run Chinook salmon. All of these streams receive large inflows of cold water from springs through the summer, upon which winter-run Chinook salmon depended. This region excludes streams south of Battle Creek, but would include the part of the Upper Sacramento drainage used by winter-run, and part of the Modoc Plateau region. The southern part of the Cascades region (i.e., the drainages of Mill, Deer, and Butte creeks) is added to the Sierra Nevada region, but the Sierra Nevada region is divided into northern and southern parts (split somewhat arbitrarily south of the Mokelumne River). This split reflects the greater importance of snowmelt runoff in the southern part, and distinguishes tributaries to the Sacramento and San Joaquin rivers. The Central Valley steelhead DPS has two additional salmonid ecoregions: the Suisun Bay region which consists of tributaries to or near Suisun Bay, where summer temperatures are moderated by the marine influence of nearby San Francisco Bay and the Pacific Ocean; and the Central Western California ecoregion, which contains west-side San Joaquin Valley tributaries. A more detailed discussion of diversity group establishment and differentiation is presented in Lindley et al. (2004, 2007). The historic diversity group structure is presented in **Figure 3-2** for the Chinook salmon ESUs, and in **Figure 3-3** for the steelhead DPS in the Central Valley Domain.

Diversity and Population Requirements

A diversity group is a special unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery of the entire listed entity (i.e., are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, and other features necessary for long-term sustainability of the entire listed entity).

As such, the diversity groups contain multiple population sources in a dynamic ecosystem subject to unpredictable stochastic events, such as pyroclastic events or wild fires.

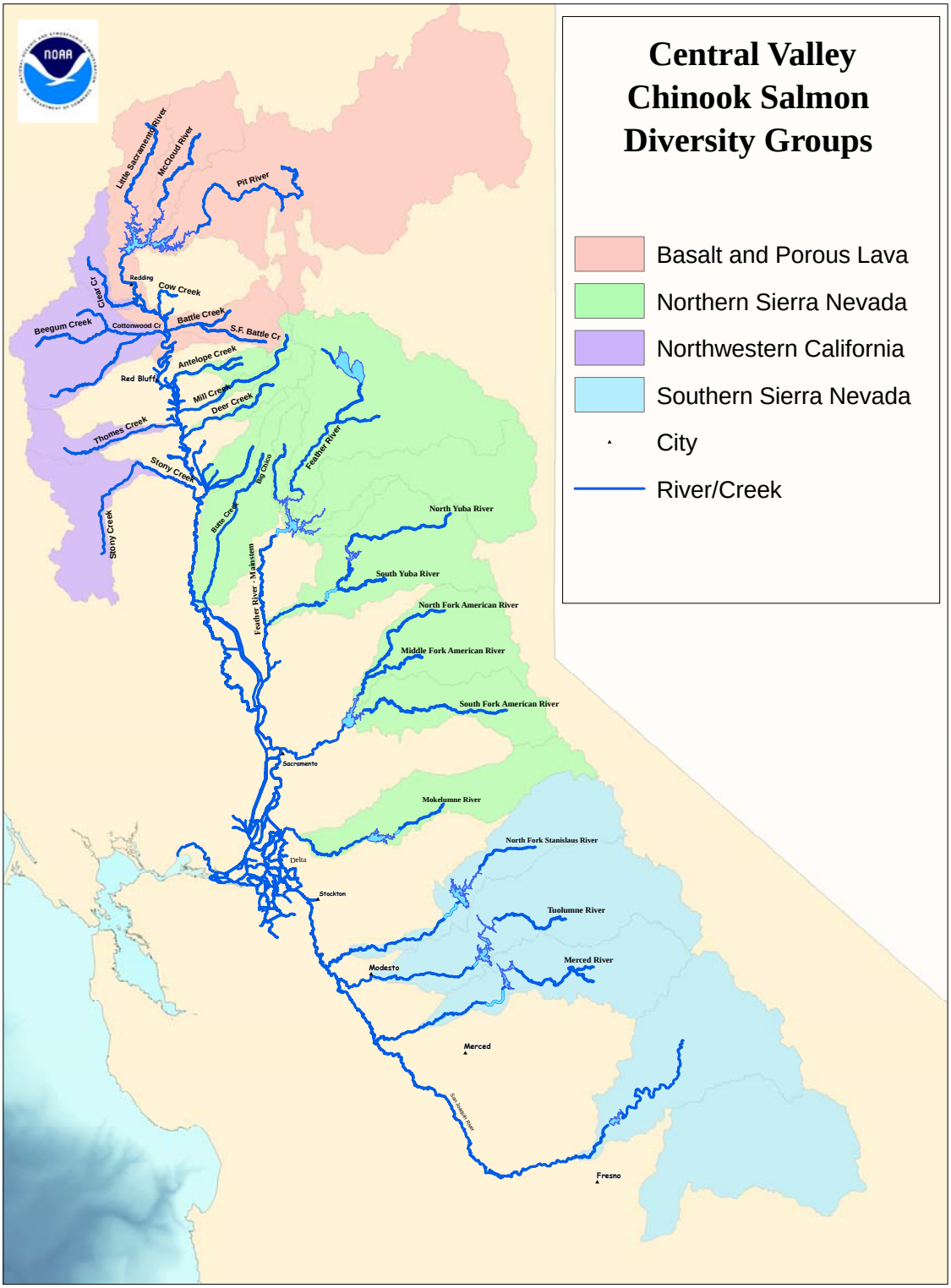


Figure 3-2. Diversity Groups for the Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon ESUs in the Central Valley Domain. The Sacramento River Winter-run Chinook Salmon ESU Historically Occurred in the Basalt and Porous Lava Diversity Group, while Spring-run Chinook Salmon Occurred in all of the Diversity Groups Shown.

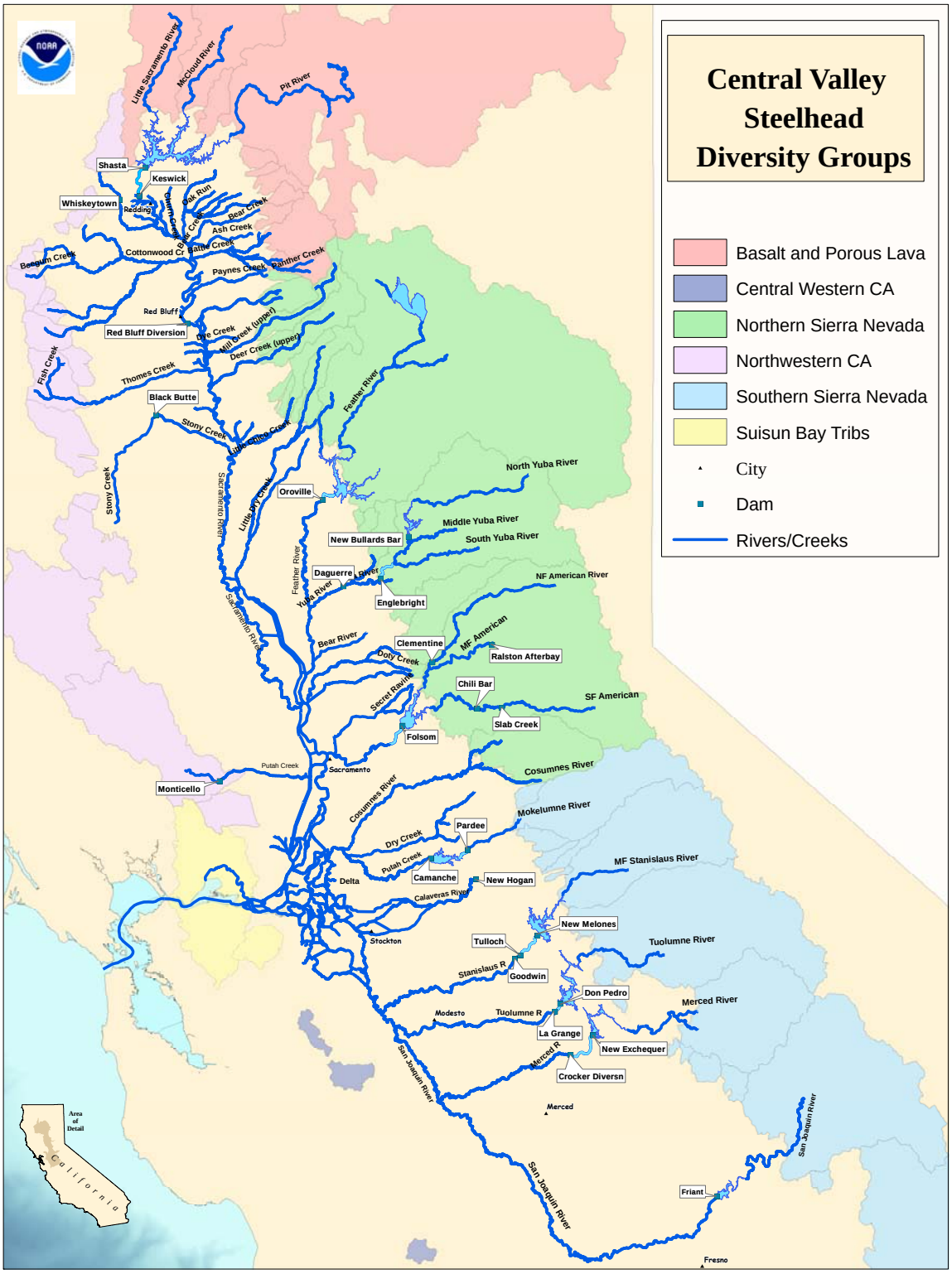


Figure 3-3. Diversity Groups for the Central Valley Steelhead DPS in the Central Valley Domain.

Each diversity group is necessary for the long-term health and stability of the overall listed entities and each must be recovered before the species can be delisted.

Individual populations possibly require different management than diversity groups that might be managed by different entities. Also, each population is not necessarily essential to the conservation of the species, as is the case for each diversity group.

Within the Central Valley Domain, therefore, a single diversity group encompasses multiple individual populations. Each Diversity Group must be conserved to ensure the long-term viability of the species. To achieve recovery within each Diversity group, only a subset of the populations might have to reach certain abundance estimates and threats-based criteria to be considered for de-listing.

3.1.3 Strategy for Success

This Recovery Plan establishes a strategic approach to recovery. Because recovery of the two Chinook salmon ESUs and the steelhead DPS will require implementation over an extended period of time, this Recovery Plan adopts a stepwise strategy which first addresses more urgent near-term needs, upon which to build toward full recovery. As this Recovery Plan is implemented over time, additional information will become available to help determine whether the threats have been abated, to further develop understanding of the linkages between threats and Chinook salmon and steelhead population responses, and to evaluate the viability of Chinook salmon and steelhead in the Central Valley Domain. In addition, there may also be new threats that arise. As such, periodic reviews of threats could occur to determine whether new threats and recovery action identification and prioritization processes should occur.

The Central Valley recovery strategy is based on foundational principles and the reliance on stakeholder cooperation, local initiatives, and public support for implementation.

Foundational Principles

Foundational principles, as used in this Recovery Plan, are generally analogous to conceptual models or conceptual foundations reported elsewhere (e.g., ISG 2000; CALFED 1999), and are fundamental to the guidance of recovery actions for anadromous salmonids in the Central Valley Domain. The following foundational principles are those presented in Williams (2006) as modified critical elements of the conceptual foundation described for the Columbia River Basin (ISG 2000):

- Restoration of Central Valley anadromous salmonids must address the entire natural and cultural ecosystem, which encompasses the continuum of freshwater, estuarine, and ocean habitats where salmonid fishes complete their life histories. This consideration includes human developments, as well as natural habitats.

- Sustained salmonid productivity requires a network of complex and interconnected habitats, which are created, altered, and maintained by natural physical processes in freshwater, the estuary, and the ocean. These diverse and high-quality habitats, which have been extensively degraded by human activities, are crucial for salmonid spawning, rearing, maintenance of food webs, migration, and predator avoidance. Ocean conditions, which are variable, are important in determining the overall patterns of productivity of salmon populations.

- Life history diversity, genetic diversity, and metapopulation organization are ways that salmonids adapt to their complex and connected habitats. These factors are the basis of salmonid productivity and contribute to the ability of salmonids to cope with environmental

variation that is typical of freshwater and marine environments.

Implementation Approach

The approach of this Recovery Plan for winter-run Chinook salmon, spring-run Chinook salmon and steelhead in the Central Valley Domain includes stakeholder cooperation, local initiatives, public support, and adaptive management and monitoring components.

Stakeholder Cooperation

Individual entities alone cannot achieve recovery of winter-run Chinook salmon, spring-run Chinook salmon and steelhead in the Central Valley Domain. Partnerships and collaborations to achieve mutual goals and objectives will accelerate accomplishments, increase available resources, reduce duplication of efforts, encourage innovative solutions, improve communication, and increase public involvement and support through shared authority and ownership of habitat restoration actions (USFWS 2001). Both the Department of the Interior AFRP and the CALFED ERP plans contain processes for the building of partnerships to pursue restoration actions. Both the AFRP and the ERP continue to build partnerships and provide funds to local agencies and watershed groups, as well as other Federal and State agencies, to implement specific restoration actions throughout the Central Valley Domain. NMFS is actively engaged in both of these efforts, as well as with local agency and stakeholder efforts, and recognizes and encourages the need for the furtherance of partnerships to achieve the goals of the Recovery Plan. Achievement of these goals requires partnerships and depends upon the cooperation of all stakeholders and regulatory entities.

Local Initiatives

NMFS encourages local agencies and stakeholder groups to share or take the lead in implementing recovery and habitat restoration actions. Influences on individual fish populations are related to specific watersheds and locally controlled water management and land use. Local development and implementation of recovery actions is essential to the success of the Recovery Plan. NMFS supports, and therefore will participate in, locally-led collaborative efforts to develop and implement recovery actions within the Central Valley Domain.

Public Support

In addition to local, State and other Federal agencies, public support is necessary for the acceptance and successful implementation of the Recovery Plan for the Central Valley Domain. As stated by USFWS (2001), public sentiment is an indicator of perceived economic and social effects of restoration actions, and public support for an action will facilitate implementation and attract partners for future actions. NMFS will continue to provide and seek additional opportunities for the public to assist in identifying, planning and implementing recovery and habitat restoration actions.

Adaptive Management and Monitoring

NMFS' implementation of the Recovery Plan includes an adaptive management and monitoring component to increase the effectiveness of, and to address the scientific uncertainty associated with, specific restoration actions. The adaptive management component allows NMFS, as well as local water agencies and irrigation districts, municipal and county governmental agencies, watershed groups, and State and other Federal agencies, to learn from past experiences through experimentation or by altering actions based on their measured effectiveness. There will be a thorough review of the recovery actions implemented and their effectiveness reflected by population and habitat condition responses at the 5-year status reviews of the Chinook salmon ESUs and the steelhead DPS.

Within the framework of the Recovery Plan, NMFS has the flexibility to work with partners to

develop and implement recovery actions to address specific problems as they arise, intensify, or as additional information becomes available regarding threats abatement, the linkages between threats and population responses, and the viability of Chinook salmon and steelhead in the Central Valley Domain. The adaptive management and monitoring component provides a framework to obtain the appropriate types and amounts of data to evaluate the effectiveness of recovery actions and the progress toward recovery. Therefore, the adaptive management and monitoring program needs to address system-wide, watershed, population and action-specific scales.

System-wide, Watershed and Population Monitoring

Several monitoring programs and studies have been developed and implemented on the system-wide, watershed and population scales by a variety of agencies and organizations. CDFG has conducted numerous monitoring programs and activities dating back to the 1940s and 1950s. These programs and activities have included spawning stock escapement (from carcass counts), creel census and inland harvest surveys, ocean harvest records, juvenile emigration (RST) surveys, snorkel surveys and redd counts, among others. The Interagency Ecological Program (IEP) continues to conduct long-term and real time monitoring programs, coordinates monitoring and manages data with particular emphasis on the Bay/Delta system. Pursuant to the CVPIA, the Comprehensive Assessment and Monitoring Program (CAMP) was prepared using a watershed-specific approach to evaluate long-term trends in anadromous fish. The AFRP has funded and implemented several watershed-specific and population-specific monitoring programs, including spawning stock escapement programs (e.g., VAKI Riverwatcher infrared and photo documentation monitoring) and instream flow evaluations, as well as site-specific habitat restoration actions. CALFED developed the Comprehensive Monitoring Assessment and Research Program (CMARP) to describe general monitoring, assessment and research needs for all of the CALFED programs. However, CMARP has not yet been implemented, and CALFED has not yet determined a way to monitor program effectiveness.

Although each of these programs and monitoring activities provide important information to the overall status of the specific resources and their habitats of the Bay/Delta and its watersheds, they can be generally characterized as being implemented on a project-by-project basis, and the need persists for more coordinated and comprehensive system-wide watershed and population monitoring. Moreover, several streams and associated populations within the Chinook salmon ESUs and the steelhead DPS within the Central Valley Domain have no existing monitoring surveys or programs.

Existing adult Chinook salmon escapement monitoring programs in the Central Valley are currently inadequate to estimate population status and evaluate population trends in a statistically valid manner for the following management purposes: (1) providing a sound basis for assessing recovery of listed stocks; (2) monitoring the success of restoration programs; (3) evaluating the contribution of hatchery fish to Central Valley populations; and (4) managing sustainable ocean and inland harvest (Allen 2005).

The need is even greater for the development and implementation of a comprehensive monitoring plan for steelhead populations throughout the Central Valley Domain. The Central Valley Domain TRT was unable to assess the status of the Central Valley steelhead DPS because nearly all of its approximately 80 populations are classified as data deficient, with a few exceptions that are closely associated with a hatchery (Lindley *et al.* 2007).

Until recently, hatchery marking programs for Central Valley anadromous salmonids have been inadequate to evaluate hatchery contributions to Central Valley populations. CDFG and USFWS have been adipose fin-clipping all steelhead hatchery production since the late 1990's, however there has been no real effort to recover any information from this, except through the

Steelhead Report Card program. CDFG has also initiated efforts to implement a constant fractional marking and tagging program for hatchery-produced Chinook salmon within the Central Valley. The efficacy of this program depends, in part, on the tag recovery rates in the adult escapement surveys in order to determine hatchery contribution or straying rates among populations.

In addition to population status and trend evaluation, accurate estimation of adult Chinook salmon and steelhead spawner escapement is a necessary component of harvest management. Age and run-specific escapement data in the Central Valley are necessary to utilize more accurate models associated with ocean harvest management.

CALFED recently funded, as an ERP directed action, the development of a comprehensive Central Valley adult Chinook salmon escapement monitoring plan. The objective of this plan is to develop a long-term monitoring program to estimate the population status and trends in abundance of Central Valley Chinook salmon at the watershed level, in a statistically valid manner. The plan will include statistical review of current monitoring methods, recommendations for the improvement of existing programs, and will develop comprehensive databases linking escapement, hatchery production, and coded-wire tag data. The framework for the plan was developed by the Interagency Ecological Program's Central Valley Salmonid Escapement Project Work Team (CVSEPWT). Agencies involved in the development of the framework for the plan include CDFG, DWR, NMFS, USFWS, Reclamation, Pacific States Marine Fisheries Commission, Yuba County Water Agency, and East Bay Municipal Utility District. Implementation of this monitoring plan is essential to evaluate Central Valley Chinook salmon viability at the system-wide, watershed, and population levels. Although providing essential contributions to meeting the needs of this Recovery Plan, the CVSEPWT monitoring plan most likely will need to be expanded or augmented in order to address the broad expanse of populations, watersheds and Diversity Groups associated with the Chinook salmon ESUs and the steelhead DPS throughout the Central Valley Domain. In addition, the Central Valley Steelhead Monitoring Plan is currently under development, which will provide the data necessary to evaluate threats abatement, the linkages between threats and population responses, and the viability of steelhead populations in the Central Valley Domain.

Watershed-level monitoring is necessary to evaluate the overall effects of multiple restoration actions within a single watershed. Monitoring at the watershed level should address population and/or life stage-specific attributes of target populations and of selected habitat variables. Watershed-specific monitoring evaluations will contribute to the assessment of threats abatement and population responses.

In addition to monitoring necessary to evaluate population status, trends and progress toward recovery, the long-term effects of habitat restoration actions need to be assessed throughout the Central Valley Domain. Components that require monitoring include long-term changes in the characteristics of aquatic habitat, riverine channel configuration, riparian vegetation, floodplain structure and function, and other targeted recovery/restoration components.

Action-Specific Monitoring

In addition to the multi-agency led comprehensive escapement monitoring plans, NMFS will be actively engaged with local agencies and stakeholder groups in developing and implementing watershed-specific, population-specific, and habitat restoration action-specific monitoring plans. NMFS believes that it is critically important to participate in locally-led collaborative efforts of local communities, State and Federal entities, and other stakeholder groups in order to provide input to the development and implementation of monitoring plans to help ensure that they are conducted within the adaptive management and monitoring framework of this Recovery Plan.

3.2 Applied Strategic Framework

For the Central Valley Domain, the TRT applied the strategic framework components of population and ESU viability to winter-run Chinook salmon, spring-run Chinook salmon and steelhead. The following is largely taken from the TRT report (Lindley *et al.* 2007).

3.2.1 Sacramento River Winter-run Chinook Salmon

All four historical populations of Sacramento River winter-run Chinook salmon are "extinct" in their historical spawning range. The upper Sacramento, McCloud and Pit River populations had spawning and rearing habitat far upstream of impassable Keswick and Shasta dams, although these populations were apparently in poor condition even before the construction of Shasta dam in the 1940s (Moffett 1949). Winter-run Chinook salmon no longer inhabit Battle Creek as a self-sustaining population.

The population of Sacramento River winter-run Chinook salmon that now spawns below Keswick Dam is at moderate extinction risk according to the Population Viability Analyses (PVA), and at low risk according to the other criteria. From roughly the mid-1990s until 2006, this population grew. A drop in abundance from the 2006 (17,304) run size was observed in 2007 (2,542) and 2008 (2,850). Even with the relatively low run sizes in 2007 and 2008, the population satisfies the low-risk criteria for population size, population decline, and catastrophe, but hatchery influence is a concern.

The Sacramento River winter-run Chinook salmon ESU does not currently satisfy representation and redundancy needs because it has only one population, and that population spawns outside of the ecoregion where it evolved. For the Sacramento River winter-run Chinook salmon ESU to have sufficient representation and redundancy, at least two populations would need to be re-established in the basalt-and-porous-lava region.

Obviously, an ESU represented by a single population at moderate risk of extinction is at high risk of extinction over the long run. A single catastrophe could extirpate the entire Sacramento River winter-run Chinook salmon ESU, if its effects persisted for four or more years.

3.2.2 Central Valley Spring-run Chinook Salmon

Perhaps 15 of the 18 or 19 historical populations of Central Valley spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various impassable dams (Lindley *et al.* 2007). Butte Creek and Deer Creek spring-run Chinook salmon are at low risk of extinction, satisfying both the PVA and other viability criteria. Mill Creek is at moderate extinction risk according to the PVA, but appears to satisfy the other viability criteria for low-risk status. Lindley *et al.* (2004) were uncertain whether Mill and Deer creek populations were each independent, or two parts of a single larger population. If viewed as a single population, Mill and Deer Creek spring-run Chinook salmon are at low extinction risk. Early-returning Chinook salmon persist within the FRFH population and spawn in the Feather River below Oroville Dam and the Yuba River below Englebright Dam. The current status of these fish is not assessable due to insufficient data.

With demonstrably viable populations in only one of at least three Diversity Groups that historically contained them, Central Valley spring-run Chinook salmon fail the representation and redundancy rule for ESU viability. Historically, the Central Valley spring-run Chinook salmon ESU spanned four ecoregions: the region used by winter-run Chinook salmon plus the northern and southern Sierra Nevada and the northwestern California region. There are two or three viable populations in the northern Sierra Nevada (Mill, Deer and Butte creeks). A few ephemeral or dependent populations are found in the Northwestern California region (e.g., Beegum and perhaps Clear creeks). Spring-run Chinook salmon have been almost entirely extirpated from both the basalt and porous lava region and the southern

Sierra Nevada region[4]. A small population persists on Battle Creek. The current distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters lay within the debris and pyroclastic flow radii of Lassen Peak. The current ESU structure is vulnerable to drought and wildfires, which pose a significant threat to the ESU in its current configuration.

3.2.3 Central Valley Steelhead

There are few data with which to assess the status of any of the 81 Central Valley steelhead populations described by Lindley *et al.* (2006). With few exceptions, therefore, Central Valley steelhead populations are classified as data deficient (Lindley *et al*. 2007). The exceptions are restricted to streams with long-running hatchery programs such as Battle Creek and the Feather, American and Mokelumne rivers. In all cases, hatchery-origin fish likely comprise the majority of the natural spawning run, placing the natural populations at high risk of extinction.

Data are lacking to suggest that the Central Valley steelhead DPS is at low risk of extinction, or that there are viable populations of steelhead anywhere in the DPS. Conversely, there is evidence to suggest that the Central Valley steelhead DPS is at moderate or high risk of extinction (McEwan 2001; Good *et al.* 2005). Clearly, most of the historical habitat once available to steelhead has been lost (Yoshiyama *et al.* 1996; McEwan 2001; Lindley *et al.* 2006). Furthermore, the observation that anadromous *O. mykiss* are becoming rare in areas where they were probably once abundant McEwan (2001) indicates that an important component of life history diversity is being suppressed or lost. It should be noted, however, that habitat fragmentation, degradation, and loss are likely having a strong negative impact on many resident as well as anadromous *O. mykiss* populations (Hopelain 2003).

[4] Observations of small numbers of Chinook salmon returning to the Stanislaus River in the spring have been reported, but their status as spring-run Chinook salmon has not been confirmed.

3.3 Recovery Plan Strategy

The Central Valley salmon and steelhead recovery strategy is similar to, and incorporates components of the strategic approaches adopted by NMFS for the three ESUs of salmon and steelhead within the Washington Lower Columbia Management Unit (NMFS 2005a), and for six ESUs of salmon and steelhead in the Willamette and Lower Columbia river basins (NMFS 2005b). This strategy identifies actions that address threats, and establishes an adaptive management framework to adjust actions and goals as understanding of the efficacy of certain actions and ESU (and DPS) status improves over time.

Recovery of the two Chinook salmon ESUs and the steelhead DPS within the Central Valley Domain will require implementation of the plan over an extended period of time. Recovery of individual Diversity Groups or even individual populations is likely to be a challenging and slow process (Lindley *et al.* 2007). Therefore, in order to achieve the overarching goal of recovery within the Central Valley Domain, this Recovery Plan adopts a stepwise strategy which first addresses more urgent near-term needs, upon which to build toward full recovery.

3.3.1 Near-term Strategic Approach

- *Secure all extant populations*. Both ESUs and the DPS are far short of being viable, and extant populations, even if not presently viable, may be needed for recovery. The Central Valley TRT recommends that every extant population be viewed as necessary for the recovery of the ESU and DPS. Wherever possible, the status of extant populations should be improved.

- *Begin collecting distribution and abundance data for O. mykiss in habitats accessible to anadromous fish*. This is fundamental to designing effective recovery actions and eventual delisting. Of equal importance is assessing the relationship of resident and anadromous forms of *O. mykiss*, including the role the resident fish play in population maintenance and persistence.

- *Minimize straying from hatcheries to natural spawning areas*. Even low levels of straying from hatchery populations to wild ones works against the goal of maximizing diversity within ESU/DPSs and populations. A number of actions could reduce straying from hatcheries to natural areas, including replacing off-site releases with volitional releases from the hatchery, allowing all fish that attempt to return to the hatchery to do so, marking or tagging programs that could be used to separate wild and hatchery stocks, and reducing the amount of fish released (see CDFG and NMFS (2001), for a review of hatchery issues).

- *Conduct critical research on fish passage above rim dams, reintroductions, and climate change*. Current climate change information suggests that the Central Valley will become warmer, a challenging prospect for Chinook salmon and steelhead – both of which are coldwater fish at the southern end of their distribution. To recover Central Valley salmon ESUs and the steelhead DPS, some populations will need to be established in cooler, high elevation areas now blocked by dams or insufficient flows. Assuming that most of these dams will remain in place for the foreseeable future, it will be necessary to facilitate the movement of fish around the dams in both directions. The near-term will include assessing habitat suitability and passage logistics.

- *Listed salmonid ESUs are likely to be conservation-reliant* (Scott *et al*. 2005). It seems highly unlikely that enough habitat can be restored in the foreseeable future such that Central Valley salmonid ESUs and DPS could be expected to persist without continued conservation management. Rather, it may be possible to restore enough habitat such that ESUs and DPS can persist with appropriate management, which should focus on maintaining ecological processes at the landscape level.

3.3.2 Long-term Strategic Approach

Strategies for Achieving Recovery at the ESU/DPS Level

- Every Diversity Group that historically existed should have a high probability of persistence (or a low risk of extinction).

- As a strategy for achieving recovery, until all ESU viability criteria have been achieved, no population should be allowed to decrease its probability of persistence.

- As a strategy for achieving recovery, high levels of recovery should be attempted in more populations than identified in the Diversity Group viability criteria because not all attempts will be successful.

Strategies for Achieving Recovery at the Diversity Group Level

- Individual populations within a Diversity Group should have persistence probabilities which together contribute to a high probability of Diversity Group persistence.

- Within a Diversity Group, the populations restored/maintained at viable status or above should be selected to:

- Allow for normative meta-population processes, including the viability of core populations, which are defined as the most productive populations.
- Allow for normative evolutionary processes.
- Minimize susceptibility to catastrophic events.

3.4 Core Populations

The TRT (Lindley *et al.* 2007) and almost all other salmon and steelhead restoration programs and plans in the Central Valley including the USFWS' AFRP and the Calfed ERP recognize that certain specific watersheds form the foundation of restoring and recovering the Chinook salmon ESU's and steelhead DPS. These watersheds exhibit the physical and hydrological characteristics (*e.g.,* appropriate water temperatures, stream flows, pool depths and spawning habitat availability) that are most likely to support viable populations – that is, independent populations that are critical for ensuring the viability of the ESU/DPS as a whole. Dependent populations may play a role in ESU/DPS viability by increasing biocomplexity (Hilborn et al. 2003), spreading risk, and maximizing future potential for adaptation (Lindley et al. 2004, 2007). As environmental conditions change over time, populations respond, providing the opportunity for a population's status to shift from dependent to independent, further suggesting that securing all extant populations of winter-run, spring-run, and steelhead will be critical to recovering those species. The spring-run population in Butte Creek provides an example of a population whose status has shifted considerably. From the mid-1960s through the mid-1990s, the estimated annual abundance of spring-run in Butte Creek fell into the moderate to high extinction risk categories, while following that period, the estimated annual abundance surpassed the low extinction risk abundance threshold (i.e., 2,500 fish) in all but one year. This population status shift was not anticipated and the factors causing it are not well understood, suggesting that a dependent population today may be a key independent population in the future.

In **Table 3-1**, existing populations are identified as Core 1, Core 2, or Core 3. The Core 1 populations are those populations identified as having the highest priority for recovery action implementation based on the known ability or significant immediate potential to support independent populations, thereby contributing to meeting the ESU/DPS-level recovery criteria. Core 1 populations form the foundation of the recovery strategy. In the Sacramento River Basin, Core 1 populations must meet the population-level biological recovery criteria for low risk of extinction set out in Table 4-1. In the San Joaquin River Basin, Core 1 populations also include areas the have a moderate potential to support viable populations, and must meet the population-level biological recovery criteria for a moderate risk of extinction. This is largely necessitated by the need to secure San Joaquin steelhead populations that are at very low levels, and currently face a high risk of extinction. NMFS believes that this set of Core 1 populations should be the first focus of an overall recovery effort. Core 2 population areas also form part of the recovery strategy by contributing to geographically diverse populations. Core 2 populations must have the potential to reach the biological recovery criteria for moderate risk of extinction set out in Table 4-1. These populations are of secondary importance in terms of recommended priority of recovery efforts, but provide an important role in ESU/DPS viability by increasing the diversity, spatial distribution and abundance of the species. Finally, the complete attainment of ESU/DPS-level biological recovery criteria may also require the presence of populations listed as Core 3. Similar to Core 2 populations, Core 3 populations may be present on an intermittent basis and are characterized as being dependent on other nearby independent populations for their existence, but are not expected to exceed the abundance criteria for high risk of extinction. The presence of these populations provides increased life history

diversity to the ESU/DPS and is likely to buffer against local catastrophic occurrences that could affect other nearby populations. Dispersal connectivity between populations and genetic diversity may be enhanced by working to recover Core 3 populations that serve as stepping stones for dispersal.

Populations identified as being Core 1 and 2 populations would be expected to meet the population recovery criteria either as a single population or a group of interacting trans-basin populations. Further research is needed to identify these interacting groups. In the interim, the population-level recovery criteria (Table 4-1) are proposed to apply to each core population.

Public and private groups should not be dissuaded from undertaking actions that alleviate threats to the species in Core 3 watersheds. While sufficient information regarding threats and the biology and ecology of the species is available to define an overall recovery strategy, there still remain questions regarding the ecology of the species (e.g., function of certain habitats in the life history of the species, relationship between the anadromous and resident forms, rate of dispersal between watersheds). In light of this uncertainty, a prudent approach is to define a recovery strategy based on the existing information on Core 1 and 2 watersheds while recovery opportunities in Core 3 watersheds continue to be actively pursued as a precaution to reduce the risk of extinction. Therefore, while the Core 1 and 2 watersheds form the foundation for recovery of the Central Valley Recovery Domain, recovery actions to alleviate threats should be undertaken in other watersheds to complement this recovery implementation strategy.

3.5 Reintroduction Priorities

Addressing the primary threats and risk factors for each of the ESUs and DPS will require reintroducing populations to historic, and currently unoccupied habitats. These areas include watersheds that are currently inaccessible because of existing dams (e.g., Little Sacramento River and McCloud River), and watersheds that are currently accessible, but not utilized (e.g., winter-run in Battle Creek). Candidate areas for reintroduction are identified in the Recovery Footprint maps of Chapter 5 (Recovery Scenarios). Efforts to reintroduce fish will be challenging, expensive, and will require unparalleled efforts to gain stakeholder support. Therefore we have prioritized these areas as either primary or secondary (**Table 3-2**). Rather than prioritize a third category, the Recovery Footprint maps have excluded from consideration the historically occupied, habitats that are so critically impaired by hydroelectric development and channel inundation that we felt addressing them was not reasonable. We prioritized areas based on information described in the Recovery Scenarios and Watershed Profiles sections of this plan. Primary priority watersheds were described in the Watershed Profile as having a high potential to support spawning populations of anadromous fish and either high quality existing conditions or a high restoration potential for anadromous fish. Secondary priorities were characterized in the Watershed Profiles as having a moderate potential to support spawning populations of anadromous fish based on existing habitat conditions and a moderate to unknown restoration potential. Secondary areas also include watersheds that historically supported large populations, but there is little existing information on habitat suitability, and further evaluation is needed to understand the reintroduction potential.

Table 3-1. Recovery Priorities for Central Valley Watersheds Currently Occupied by Winter-run, Spring-run, or Steelhead.

Diversity Group	Watershed/Population	Species	Recovery Focus
Northwestern California	Clear Creek	Spring-run Steelhead	**Core 1**
	Cottonwood/Beegum Creek	Steelhead	Core 2
		Spring-run	Core 2
	Thomes Creek	Steelhead	Core 2
		Spring-run	Core 3
Basalt and Porous Lava	Upper Sacramento River (Keswick to Red Bluff)	Winter-run	**Core 1**
		Spring-run Steelhead	Core 2
	Cow Creek	Steelhead	Core 2
	Redding Area Tributaries	Steelhead	Core 2
	Battle Creek	Spring-run Steelhead	**Core 1**
Northern Sierra Nevada	Antelope Creek	Steelhead	**Core 1**
		Spring-run	Core 2
	Mill Creek	Spring-run Steelhead	**Core 1**
	Deer Creek	Spring-run Steelhead	**Core 1**
	Big Chico Creek	Steelhead	Core 2
		Spring-run	Core 3
	Butte Creek	Spring-run	**Core 1**
		Steelhead	Core 2
	Lower Feather River	Spring-run Steelhead	Core 2
	Lower Yuba River	Spring-run Steelhead	**Core 1**
	Bear River	Spring-run Steelhead	Core 3
	Lower American River	Steelhead	Core 2
	Cosumnes River	Steelhead	Core 3
	Lower Mokelumne River	Steelhead	Core 3
Southern Sierra Nevada	Calaveras River	Steelhead	**Core 1**
	Lower Stanislaus River	Steelhead	Core 2
	Lower Tuolumne River	Steelhead	Core 2
	Lower Merced River	Steelhead	Core 2

Table 3-2. Reintroduction Priorities for Central Valley Watersheds.

Diversity Group	Watershed	Species	Focus for Recovery
Basalt and Porous Lava	Little Sacramento River	Winter-run Spring-run Steelhead	**Primary**
	McCloud River	Winter-run Spring-run Steelhead	**Primary**
	Battle Creek	Winter-run	**Primary**
Northern Sierra Nevada	NF Feather River	Spring-run Steelhead	Secondary
	Upper Yuba River	Spring-run Steelhead	**Primary**
	Upper American River	Spring-run	Secondary
		Steelhead	**Primary**
	Cosumnes River	Steelhead	Secondary
	Upper Mokelumne River	Steelhead	Secondary
Southern Sierra Nevada	Upper Stanislaus River	Steelhead	Secondary
	Upper Tuolumne River	Steelhead	Secondary
	Upper Merced River	Steelhead	Secondary
	San Joaquin River (Friant to Merced)	Spring-run	**Primary**

4.0 Recovery Goals, Objectives and Criteria

"Merely increasing a species' numbers, range and abundance does not ensure its long-term health and sustainability; only by alleviating threats can lasting recovery be achieved."

- Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2006)

4.1 Recovery Goals

The overarching goal of this Recovery Plan is the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and Central Valley steelhead DPS from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11). Recovery plans are not regulatory documents and successful implementation and recovery of listed species will require the support, efforts and resources of many entities, from Federal and state agencies to individual members of the public. Another goal will be to encourage and support effective partnerships with regional stakeholders to meet the objectives and criteria of the Recovery Plan. The objectives and criteria to accomplish this goal build upon the technical input and guidance provided by the Central Valley TRT, and other information provided during public workshops and co-manager reviews. Much of the technical recovery discussion in this section is taken directly from information developed by the TRT (Lindley *et al.* 2004; 2006; 2007).

The Endangered and Threatened Species Recovery Planning Guidance (NMFS 2006b) describes the recovery planning goal as recovery and long-term sustainability of an endangered or threatened species and, therefore, delisting of the species. Further, NMFS (2006b) states that goals usually can be subdivided into discrete component objectives which, collectively, describe the conditions (criteria) necessary for achieving the goal. Simply stated, recovery objectives are the parameters of the goal, and criteria are the values for those parameters. The objectives and related criteria, representing the components of the recovery goal, identify mechanisms for pursuing the goal (including necessary recovery actions) and allows confirmation when the goal has been reached.

According to NMFS (2006b), recovery and long-term sustainability of an endangered or threatened species require:

- Adequate reproduction for replacement of losses due to natural mortality factors (including disease and stochastic events)
- Sufficient genetic robustness to avoid inbreeding depression and allow adaptation
- Sufficient habitat (type, amount, and quality) for long-term population maintenance
- Elimination or control of threats (this may also include having adequate regulatory mechanisms in place)

4.2 Integrating TRT Products into Recovery Objectives and Criteria

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants. The recovery criteria constitute the standards upon which the decision to consider reclassifying or delisting a species will be based.

Evaluating a species for potential delisting requires an explicit analysis of population or demographic parameters (the biological recovery criteria) and also of threats under the five ESA listing factors in ESA section 4(a)(1) (threats criteria). Together, these make up the "objective, measurable criteria" required under section 4(f)(1)(B).

While this plan establishes some objective, measurable criteria specific to both population demographics and to threat abatement, measurable criteria has not been provided for all demographic and threat-based factors at this time. Therefore, qualitative delisting criteria are provided in such instances.

These criteria represent the best scientific analysis incorporating the most current understanding of the ESU and DPS and their populations. As this Recovery Plan is implemented, additional information will become available that can increase certainty about whether the threats have been abated, whether improvements in populations and ESU and DPS status have occurred, and whether linkages between threats and changes in Chinook salmon and steelhead status are understood. These recovery criteria will be assessed through the adaptive management program for this Recovery Plan, and there will be a review of the criteria every five years during status reviews of the Chinook salmon ESUs and the steelhead DPS. During these reviews, the criteria may be revised, if necessary. NMFS will apply the Recovery Plan's criteria when it makes a decision whether to delist the ESUs and DPS.

4.2.1 Biological Recovery Criteria

In order to delist the winter-run and spring-run Chinook salmon ESUs and the steelhead DPS, the TRT stated that there must be at least two viable populations within each historic diversity group (Lindley et al. 2007). This ESU/DPS-level recovery criterion addresses the representation and redundancy rule for ESU/DPS viability. Exceptions to the ESU/DPS-level criterion include diversity groups which likely did not historically contain viable populations, such as the Northwestern California diversity group for spring-run Chinook salmon and steelhead, and the Suisun Bay and Central Western California steelhead diversity groups. For the Northwestern California diversity group, the presence of at least two populations, but not necessarily viable ones, is required to recover spring-run Chinook salmon and steelhead

It is assumed that full recovery of Central Valley steelhead can be achieved without the presence of populations in either the Suisun Bay or Central Western California diversity groups. This assumption is based on the fact that the four Chinook salmon diversity groups, which did not include the Suisun Bay or Central Western California regions, supported abundant and diverse Chinook salmon populations for thousands of years. As such, the extent and diversity of habitats historically available in those four diversity groups would likely also support a viable steelhead DPS, if the quantity and quality of habitat currently available in those regions was sufficiently increased.

Whether or not the ESU/DPS-level criterion has been met requires application of population-level recovery criteria. The population-level criteria can be used to determine whether a population is viable or not. A viable population is one with a low extinction risk in the wild over the long-term (McElhany et al. 2000). The Central Valley TRT

assumed that a 5 percent or less risk of extinction in 100 years is an acceptably low extinction risk for populations.

The Central Valley TRT incorporated the four VSP parameters into assessments of population viability, and two sets of population viability criteria were developed, expressed in terms of extinction risk. Then, populations were classified into one of six categories, including "extinct", "extinct in the wild", "high", "moderate", and "low" extinction risk, or "data deficient" following the general approach of the IUCN (1994) as modified for Pacific salmonids by Allendorf *et al.* (1997). The first set of criteria deal with direct estimates of extinction risk from population viability models. If data are available and such analyses exist and are deemed reasonable for individual populations, such assessments may be efficient for assessing extinction risk. The Central Valley TRT used a population viability assessment based on the random-walk-with-drift model extended to account for observation error (Lindley *et al*. 2007). In addition, the Central Valley TRT also provided simpler criteria, both of which are presented in Table 4-1.

The simpler criteria include population size (and effective population size), population decline, catastrophic rate and effect, and hatchery influence. The effective population size criteria in the second row of Table 4-1 relate to loss of genetic diversity. Very small populations, for example with $Ne < 50$, suffer severe inbreeding depression (Franklin 1980; Soulé 1980 *in* Lindley *et al.* 2007), and normally outbred populations with such low *Ne* have a high risk of extinction from this inbreeding. Somewhat larger, but still small, populations can be expected to lose variation in quantitative traits through genetic drift faster than it can be replaced by mutation. With future research, it may be possible to define population size targets that conserve genetic variation and account for migration and genetic structuring within ESUs.

The population decline criteria are intended to capture demographic risks. The rationale behind the population decline criteria are fairly straightforward–severe and prolonged declines to small run sizes are strong evidence that a population is at risk of extinction.

The overall goal of the catastrophe criteria is to capture a sudden shift from a low risk state to a higher risk state. Catastrophes are defined as instantaneous declines in population size due to events that occur randomly in time, by contrast to regular environmental variation. A high risk catastrophic event is created by a 90 percent decline in population size over one generation. A moderate risk catastrophic event is one that is smaller but biologically significant, such as a year-class failure.

The spawning of hatchery fish in the wild is a potentially serious threat to the viability of natural populations. Population genetics theory predicts that fish hatcheries can negatively impact wild populations when hatchery fish spawn in the wild. In assessing the genetic impact of immigration on a population, considerations include the source of the immigrants, duration of the impact, the number of immigrants relative to the size of the recipient population, and how divergent the immigrants are from the recipient population. Definitions of the manner in which different immigration scenarios relate to extinction risk for natural populations are summarized in Figure 4-1. Application of these definitions can result in a low-risk classification even with moderate amounts of straying from best-practices hatcheries, as long as other risk measures area acceptable (Lindley *et al.* 2007).

Estimators for the various viability criteria are presented in Table 4-2 (from Lindley *et al.* 2007). The average run size is computed as the mean of up to the three most recent generations, if that much data are available. Mean population size is estimated as the product of the mean run size and the average generation time. Population growth (or decline) rate is estimated from the slope of the natural logarithm of spawners versus time for the

most recent 10 years of spawner count data. The fraction of naturally-spawning fish of hatchery origin is the mean fraction over one to four generations.

The TRT assessed the viability of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead populations by applying both the PVA modeling and the simpler demographic criteria described in Table 4-1. Detailed descriptions of those assessments are provided in the Recovery Strategy chapter. In general, the only Central Valley populations with enough demographic data available for the TRT to conduct the PVA modeling were mainstem Sacramento River winter-run Chinook salmon and spring-run Chinook salmon populations in Butte, Mill, and Deer creeks. That modeling suggested that the Sacramento River winter-run Chinook salmon population and Mill Creek spring-run Chinook salmon were at a moderate risk of extinction, while spring-run Chinook salmon in Butte and Deer creeks were at a low risk. Application of the criteria in Table 4-1 placed each of those four populations into the low risk (i.e., viable) category. The TRT categorized steelhead in the Feather River, Battle Creek, American River, and Mokelumne River each into the high risk category due to high hatchery influence. All other populations of the three species being assessed were considered to be either data deficient or extinct.

The low extinction risk criteria described in Tables 4-1 and 4-2 function were used to develop interim biological delisting criteria with following exceptions: (1) diversity groups that likely did not historically contain viable populations, including the Suisun Bay and Central Western California steelhead diversity groups; (2) diversity groups that likely did not historically contain viable populations but currently have the potential to support viable, independent populations of spring-run Chinook salmon due to water projects that create suitable conditions including Clear Creek in the Northwestern California diversity group; (3) the Northern Sierra Diversity Group, which serves as the centerpoint of the ESUs/DPS, and the biological hub in terms of interconnectivity of populations to the north and south; and (4) winter-run Chinook salmon, which are only present within one diversity group, thereby placing the ESU at a greater risk from exposure to catastrophic events or long-term events such as climate change, than other the spring-run ESU and steelhead DPS that were historically, and presently more widely distributed across several Diversity Groups.

One exception to this is that the population size recovery criterion (i.e., N>2,500) could be considered an interim criteria until population-specific abundance criteria are identified.

Healthy populations should be at or near carrying capacity in most years. As such, a detailed and thorough assessment of each watershed's carrying capacity should be conducted, and the recovery criterion for abundance should be based on that estimated carrying capacity. As recovery actions are implemented and habitats are restored and expanded, the low extinction risk abundance criterion (i.e., N>2,500) may be too low for large watersheds or for currently abundant populations. For example, Butte Creek has supported spring-run Chinook salmon populations well in excess of 2,500 since 1998, suggesting that the carrying capacity of that system may be greater than 2,500 adults. Similarly, in recognition that all extant populations are necessary for recovery, including relatively small ones that likely will not meet or exceed the low extinction risk abundance level (i.e., 2,500) even after habitat restoration, abundance recovery criteria that are based on carrying capacity analyses should be developed.

Table 4-1. Criteria for assessing the Level of Risk of Extinction for Populations of Pacific Salmonids, Applied to the Chinook Salmon ESUs and the Steelhead DPS in the Central Valley Domain (from Lindley et al. 2007)

	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction risk from PVA	> 20% within 20 years	> 5% within 100 years	< 5% within 100 years
	– or any ONE of –	– or any ONE of –	– or ALL of –
Population size[a]	$N_e \leq 50$	$50 < N_e \leq 500$	$N_e > 500$
	–or–	–or–	–or–
	$N \leq 250$	$250 < N \leq 2500$	$N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
[b] Decline within last two generations to annual run size $\leq$ 500 spawners, or run size > 500 but declining at $\geq$ 10% per year. Historically small but stable population not included.
[c] Run size has declined to $\leq$ 500, but now stable.
[d] Catastrophes occuring within the last 10 years.
[e] Decline < 90% but biologically significant.
[f] See Figure 1 for assessing hatchery impacts.

Table 4-2 Estimation Methods and Data Requirements for Population Metrics. S_t denotes the number of spawners in year t; g is mean generation time, assumed as three years for California salmon (from Lindley et al. 2007)

Metric	Estimator	Data	Criterion
$\hat{S}_t$	$\sum_{i=t-g+1}^{t} S_i/g$	$\geq$ 3 years spawning run estimates	Population decline
N_e	$N \times 0.2$ or other	varies	Population size
N	$\hat{S}_t \times g$	$\geq$ 3 years spawning run estimates	Population size
Population growth rate (% per year)	slope of $\log(S_t)$ v. time $\times 100$	10 years S_t	Population decline
c	$100 \times (1 - \min(N_{t+g}/N_t))$	time series of N	Catastrophe
h	average fraction of natural spawners of hatchery origin	mean of 1-4 generations	Hatchery influence

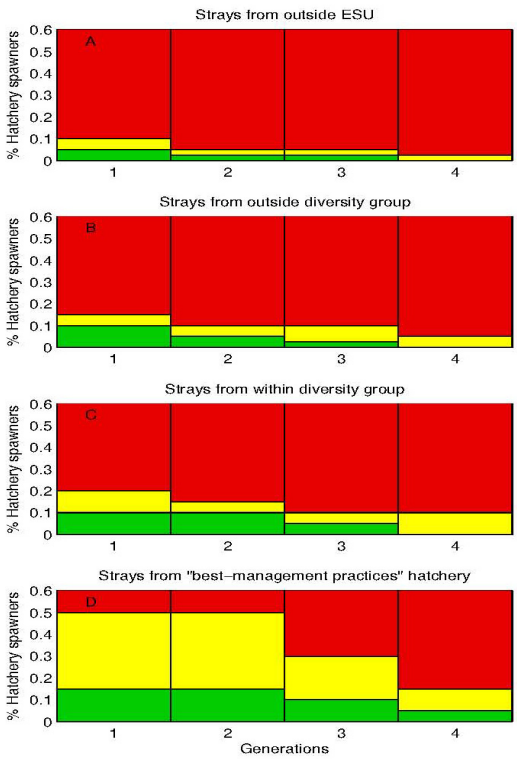


Figure 4-1. Extinction Risk Levels Corresponding to Different Amount, Duration and Source of Hatchery Strays. Green bars indicate the range of low risk, yellow bars moderate risk, and red areas indicate high risk. Which chart to use depends on the relationship between the source and recipient populations. (A) hatchery strays are from a different ESU than the wild population. (B) Hatchery strays are from the same ESU but from a different diversity group within the ESU. (C) Hatchery strays are from the same ESU and diversity group, but the hatchery does not employ "best management practices." (D) Hatchery strays are from the same ESU and diversity group, and the hatchery employs "best management practices." (from Lindley *et al.* 2007)

Such carrying capacity assessments could be accomplished by applying a consistent approach to measure habitat capacity throughout each ESU/DPS and then relating that capacity to assumed spawner density thresholds that correspond to varying levels of extinction risk (Williams et al. 2008). As habitats are restored and expanded, carrying capacity should increase and population-level recovery criteria for abundance will likely need to be adjusted periodically. Until such population-specific abundance recovery criteria are developed, the low and moderate extinction risk abundance criterion will serve as benchmarks for the developing population delisting criteria; (5) the Recovery Plan includes criteria for dependent, or core 2-level populations, recognizing that smaller interconnected metapopulation viability plays in important role in the Mediterranean climate of the Central Valley, when spring-run Chinook salmon and steelhead exploit habitats when they become periodically available during consecutive wet water years.

4.3 Biological Objectives and Criteria at the ESU/DPS and Diversity Group Level and Population Level

Implementation of the Recovery Plan is designed to ultimately achieve objectives for the ESUs/DPS at the Diversity Group level, and at the population level (i.e. watershed level) for the four VSP criteria of abundance, productivity, diversity, and spatial structure. Objectives addressing these requirements include demographic parameters, reduction or elimination of threats to the species (the listing factors), and any other particular vulnerability or biological needs inherent to the species. The Central Valley TRT described these objectives in a general sense, and NMFS expects that more detailed objectives and accompanying criteria will be developed over the next several years as part of recovery plan implementation.

4.3.1 ESU/DPS and Diversity Group Objectives

ESU/DPS viability depends on the number of populations within the ESU/DPS, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and diversity of the populations and their habitats. In the most general terms, ESU/DPS viability increases with the number of populations, the viability of these populations, the diversity of the populations, and the diversity of habitats that they occupy. Each of the Diversity Groups must individually achieve recovery in order for the ESUs and DPS to be considered as

having achieved recovery. Thus, an overall objective is to achieve recovery in each of the Diversity Groups.

In addition to population objectives, in order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, each Diversity Group must meet the following habitat objectives:

- The spatial distribution and productive capacity of freshwater, estuarine, and marine habitats should be sufficient to maintain viable populations identified for recovery
- The diversity of habitats for recovered populations should resemble historic conditions and provide sufficient resilience and redundancy to withstand expected natural disturbance regimes such as wildfires, floods, volcanic eruptions, etc. Historic conditions represent a reasonable template for a viable population; the closer the habitat resembles the historic diversity, the greater the confidence in its ability to support viable populations
- At a large scale, habitats should be protected and restored, with a trend toward an appropriate range of attributes for salmonid viability. Freshwater, estuarine, and marine habitat attributes should be maintained in a non-deteriorating state

ESU Level Downlisting Criteria for Endangered Winter-run Chinook

Criteria to downlist winter-run Chinook salmon from endangered to threatened include the following two criteria:

- The existing mainstem Sacramento River spawning population must meet each of the low extinction risk criteria described in Table 4-1, with the exception of the criterion related to hatchery influence. The hatchery influence criteria does not have to be met provided that the Livingston Stone National Fish Hatchery continues to operate as a conservation hatchery using best management practices;
- In addition to the mainstem Sacramento River population, the ESU must include one other spawning population that meets the moderate extinction risk criteria described in Table 4-1.

ESU/DPS Level Delisting Criteria

In addition to population criteria, in order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, each Diversity Group must meet the following DPS criteria:

Winter-run Chinook salmon

- Three populations in the Basalt and Porous Lava Flow Diversity Group at low risk of extinction

Spring-run Chinook salmon

- One population in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Flow Diversity Group at low risk of extinction
- Three populations in the Northern Sierra Diversity Group (because of their geographic proximity, Mill and Deer Creek are considered part of the same meta population at low risk of extinction

- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain Core 2 populations at moderate risk of extinction

Central Valley steelhead

- Two populations in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Flow Diversity Group at low risk of extinction
- Three populations in the Northern Sierra Diversity Group (because of their geographic proximity, Mill and Deer Creek are considered part of the same meta population at low risk of extinction
- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain Core 2 populations at moderate risk of extinction

4.3.2 Population Objectives

Consistent with the strategic approach to achieve recovery, this Recovery Plan establishes objectives for the viability of individual populations, similar to NMFS (2005b) and following the VSP parameters for productivity and abundance, population structure and diversity.

Productivity and Abundance Objectives

- In general, viable populations should demonstrate a combination of population growth rate and abundance that produces an acceptable probability of population persistence. Specifically, viable populations should meet the low extinction risk levels for the population decline and population size criteria described in Table 4-1.
- A population with non-negative growth rate and an average abundance approximately equivalent to estimated historic average abundance should be considered to be in the highest persistence category. The estimate of average historic abundance should be credible, the estimate of current abundance should be averaged over several generations, and the growth rate should be estimated with adequate statistical confidence

Within-Population Spatial Structure Objectives

The spatial structure of a population must support the population at the desired productivity, abundance, and diversity levels through short-term environmental perturbations, longer-term environmental oscillations, and natural patterns of disturbance regimes. The metrics and benchmarks for evaluating the adequacy of a population's spatial structure specifically address:

- Quantity: Spatial structure should be large enough to support growth and abundance, and diversity criteria
- Quality: Underlying habitat spatial structure should be within specified habitat quality limits for life-history activities such as spawning, rearing, migration, or a combination
- Connectivity: Spatial structure should have permanent or appropriate seasonal connectivity to allow adequate migration between spawning, rearing, and migration habitat
- Dynamics: The spatial structure should not deteriorate in its ability to support the population. The processes creating spatial structure are dynamic, so structure will be created and destroyed, but the rate of flux should not exceed the rate of creation over time

- Catastrophic Risk: the spatial structure should be geographically distributed in such a way as to minimize the probability of a significant portion of the structure being lost because of a single catastrophic event, either anthropogenic or natural

Because within-population spatial structure is so intricately linked to habitat quantity and quality, the threat abatement criteria described in the next section that are related to habitat act as a link between this objective and

Within-Population Diversity Objectives

Sufficient life-history diversity must exist to sustain a population through short-term environmental perturbations and to provide for long-term evolutionary processes. The metrics and benchmarks for evaluating the diversity of a population should be evaluated over multiple generations and include:

- Substantial proportion of the diversity of a life-history trait(s) that existed historically
- Gene flow and genetic diversity should be similar to historic (natural) levels and origins
- Successful utilization of habitats through-out the habitat
- Resilience and adaptation to environ-mental fluctuations

Population Level Delisting Criteria

Core 1 Populations (from Table 3-1) must meet low risk extinction criteria

- Census population size is >2500 adults -or- Effective population size is >500
- No productivity decline is apparent
- No catastrophic events occurring or apparent within the past 10 years

Core 2 Populations (from Table 3-1) must meet moderate risk extinction criteria

- Census population size is 250 to 2500 adults -or- Effective population size is 50 to 500 adults
- Productivity: Run size may have dropped below 500, but is stable
- No catastrophic events occurring or apparent within the past 10 years
- Hatchery influence is moderate or hatchery operates as a conservation hatchery using best management practices

4.4 Threat Abatement Criteria

It is imperative that threats to the species be controlled prior to delisting. This includes all threats identified at the time of listing, as well as any new factors identified since listing. Since listing, numerous additional threats have been identified and prioritized for the ocean, migratory corridors, and for each of the Diversity Groups and individual populations of the winter-run and spring-run Chinook salmon ESUs, and the steelhead DPS within the Central Valley Domain (Introduction, Appendix B).

NMFS proposes that, to determine that the affected ESU/DPS is recovered to the point that it no longer requires the protections of the ESA, the listing factors should be addressed according to specific criteria identified for each of them so that delisting is not likely to result in re-emergence of the threat. It is possible that current perceived threats will become insignificant in the future because of changes in the natural environment, changes in the way threats affect the entire life cycle of salmon, or the success of actions intended to ameliorate the threat. Consequently, NMFS expects that the significance of threats will change over time. It is also possible that new threats may be identified. During the status reviews, NMFS will evaluate and review the listing factor criteria under conditions at that time.

NMFS is providing the specific threat abatement criteria listed below for each of the relevant listing/delisting factors to help to ensure that underlying causes of decline have been addressed and mitigated prior to considering a species for delisting. These threat abatement criteria correspond to the listing factors identified for winter- and spring-run Chinook salmon and steelhead in this Recovery Plan, and to the stressors described in Appendix B.

Below each specific threat abatement criterion, actions and/or general goals related to eliminating or minimizing threats to winter- and spring-run Chinook salmon and steelhead are described. Unless otherwise specified, each of the individual threat abatement criteria listed below are applicable to all of the species addressed by this Recovery Plan. Although infrequent, there also are some circumstances where species-specific distinctions are required. Where these limited cases occur, a species-specific discussion is provided.

Listing Factors and Threats

Sacramento River Winter-run Chinook Salmon

Several factors have contributed to the decline of winter-run Chinook salmon through degradation of spawning, rearing, and migration habitats. The primary factors included in the listing of winter-run Chinook salmon were blockage of historical habitat by Shasta and Keswick dams, warm water releases from Shasta Dam, juvenile and adult passage constraints at RBDD, water exports in the southern Delta, heavy metal contamination from Iron Mountain Mine, high ocean harvest rates and entrainment in a large number of unscreened or poorly screened water diversions (NMFS 1997). Other factors include smaller water manipulation facilities and dams, loss of rearing habitat in the lower Sacramento River and Delta from levee construction, marshland reclamation, interaction with and predation by introduced species, adverse flow conditions, high summer water temperatures and vulnerability to drought (NMFS 1997). Since listing, some of these threats have been addressed, although numerous additional threats have been identified and prioritized (Appendix B).

Central Valley Spring-run Chinook Salmon

Listing factors and threats to Central Valley spring-run Chinook salmon fall into three broad categories: loss of historical spawning habitat; degradation of remaining habitat; and threats to the genetic integrity of the wild spawning populations from the FRFH spring-run Chinook salmon production program and from spawning with naturally- and hatchery produced fall-run Chinook salmon. A complete prioritized list of life stage-specific stressors to this ESU is presented in Appendix B. Each of the threats criteria described below is related to one or more of the major factors limiting recovery described and listed in the NMFS 2006 Report to Congress on the PCSRF.

Central Valley Steelhead

Threats to Central Valley steelhead are similar to those for Central Valley spring-run Chinook salmon: loss of historical spawning habitat, degradation of remaining habitat, and threats to the genetic integrity of the wild spawning populations from hatchery steelhead production programs in the Central Valley. A complete prioritized list of life stage-specific stressors to the DPS is presented in Appendix B. Each of the threats criteria described below is related to one or more of the major factors limiting recovery described and listed in the NMFS 2006 Report to Congress on the PCSRF.

Factor 1: Destruction, Modification, or Curtailment of Habitat or Range

Dams in the Central Valley have: (1) blocked access to historical spawning grounds; (2) modified natural flow regimes and altered water temperatures; and (3) reduced habitat quality and complexity.

To determine that the winter- and spring-run Chinook salmon ESUs and the steelhead DPS are recovered, threats to habitat and the risks posed to the abundance, productivity, and especially to the spatial structure and diversity of the ESU/DPS should be addressed through the following criteria.

Criterion 1.1: Address Threats to Spawning Habitat

1.1.A. As appropriate or necessary to support region-wide recovery goals, passage obstructions (e.g. dams) are removed or modified to restore fish access or improve passage to historically accessible spawning habitat

- Shasta and Keswick dams are modified or circumvented to restore winter-run and spring-run Chinook salmon, and steelhead into the Little Sacramento and McCloud rivers.
- Folsom and Nimbus dams are modified or circumvented to restore steelhead.
- Englebright Dam is modified (or circumvented) to restore steelhead and spring-run Chinook salmon.
- Primary reintroduction areas for modifying or circumventing dams in the San Joaquin River Basin are identified.

1.1.B. Instream flow conditions and programs are implemented that support anadromous salmonid spawning and embryo incubation needs to meet species-specific population targets

1.1.C. Projects or programs designed to improve or supplement available spawning habitat used by anadromous salmonids are implemented

1.1.D. Segregation during spawning where spring-run and fall-run Chinook salmon habitat overlap is provided

Criterion 1.2: Address Threats to Water Quality

1.2.A. Deleterious effects of stormwater runoff are eliminated or controlled so as not to impair water quality and quantity in salmonid streams or the riparian habitats supporting them

1.2.B. Agricultural practices are implemented and programs are in place to protect and restore riparian areas, floodplains and stream channels, and to protect water quality from sediment, pesticide, herbicide and fertilizer runoff, and thermal loading. Particularly in the Delta, mainstem Sacramento and San Joaquin rivers and their major tributaries.

1.2.C. Water temperature conditions that are contributing to water quality impairment are evaluated, and management actions designed to reduce, eliminate or avoid impairment are implemented

1.2.D. Ecological functions of salmon and steelhead, including their benefits in cycling ocean-derived nutrients into freshwater areas, are considered in fishery, hatchery, and habitat management

1.2.E. Nutrient enrichment programs to determine where additional nutrient inputs can provide significant benefits to juvenile salmonid food-producing areas are evaluated

1.2.F. Urban and rural development, including land use conversion from agriculture and forest land to developed areas, is restricted so as to not impair water

quality or result in dysfunctional stream conditions

1.2.G. The effects of toxic contaminants on salmonid fitness and survival in the Delta, mainstem rivers, and nearshore ocean are sufficiently limited, and programs are in place to ensure continued limitation of toxic contaminants so as not to affect recovery

1.2.H. Programs and/or measures are implemented to ensure continued protection and restoration of water quality in anadromous salmonid inhabited areas so as to promote recovery

1.2.I. Programs and/or measures are implemented to reduce instream sedimentation and turbidity in core 1 and 2 watersheds and in primary reintroduction areas.

Criterion 1.3: Address Threats to Habitat Quality and Complexity

1.3.A. Instream flow conditions and programs are implemented that support anadromous salmonid migration and rearing needs (in addition to spawning needs, see Criterion 1.1B) to meet species-specific population targets

1.3.B. In support of rearing, migration and spawning needs, coldwater resources are managed to reduce thermal stress to Chinook salmon and steelhead and to meet species-specific population targets

1.3.C. Channel function, including vegetated riparian areas, instream wood, streambank stability, off-channel and side-channel habitats, natural substrate and sediment processes, and channel complexity are restored to improve rearing, migration, and spawning habitat

- A continuous 100-mile stretch of ecologically viable riparian habitat to flood-prone lands along the Sacramento River between Colusa and Verana are restored

1.3.D. Floodplain and tidally-influenced habitats, including tidal swamp and marsh habitat in estuaries and the tidal freshwater portion of the lower rivers, are restored and protected as to promote recovery. Floodplain connectivity and impaired sediment delivery processes are restored in the lower portions of rivers and in estuaries.

1.3.E. Nearshore processes are protected and restored so that ecological inputs (of sediment, insects, leaves and wood) to rivers, and mudflats function properly to support anadromous salmonids and the species they prey upon

1.3.F. Activities that dredge, fill or harden streambanks and river beds are sufficiently mitigated as to support anadromous salmonids, and riparian restoration in core 1 and 2 areas and primary reintroduction areas.

1.3.G. Forest management practices that protect and restore watershed and stream functions are implemented on Federal, State, Tribal, and private lands and programs are in place to ensure continued mitigation in core 1 and 2 areas and primary reintroduction areas.

1.3.H. Stream surveys, habitat modeling, and other technical approaches are utilized to accurately assess the impacts of habitat management actions

1.3.I. Educational outreach programs are developed and conducted with

interested stakeholders or watershed groups to promote collaborative development, funding and implementation of habitat enhancement and protection projects, and to promote river stewardship among landowners

Factor 2: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Continue the assessment of the potential overutilization of winter- and spring-run Chinook salmon populations for commercial, recreational, scientific or educational purposes. Additionally, although there are no commercial fisheries for steelhead in the ocean, inland steelhead fisheries continue to be important tribal and recreational fisheries and, thus, continue to warrant assessment.

To determine that the winter- and spring-run Chinook salmon ESUs and the steelhead DPS are recovered, any utilization for commercial, recreational, scientific, or educational purposes should be addressed through the following criteria.

Criterion 2.1: Address Threats from Overutilization

2.1.A. Fishery management plans that address Chinook salmon ESUs and the steelhead DPS are implemented that: (a) accurately account for total fishery mortality (i.e., both landed catch and non-landed mortalities) and constrain mortality rates for individual populations to levels that are consistent with achieving ESU/DPS viability (i.e., provide for adequate spawning escapement given intrinsic productivity for populations representative of the life history and major regional divisions in the ESU/DPS); and (b) are implemented so that any effects on the abundance, productivity, diversity, and spatial structure of populations are consistent with the recovery of the ESU/DPS

2.1.B. Modeling and other technical tools, and adaptive management are used to accurately assess the potential impacts of fishery management actions

2.1.C. Rules and regulations for fishery management actions are effectively enforced, and additional regulations are implemented as necessary, as to promote recovery

Factor 3: Disease or Predation

Both naturally spawned and artificially propagated winter- and spring-run Chinook salmon and steelhead are susceptible to threats from: (1) disease outbreaks caused by naturally occurring pathogens; and (2) predation.

To determine that the winter- and spring-run Chinook salmon ESUs and the steelhead DPS are recovered, any disease or predation that threatens its continued existence should be addressed through the following criteria.

Criterion 3.1: Address Threats from Disease Outbreaks

3.1.A. Hatchery operations apply measures that reduce the risk that natural populations are adversely affected by fish diseases and parasites

3.1.B Coldwater resources are managed to avoid water temperature-related fish disease and parasite outbreaks in anadromous salmonids

Criterion 3.2: Address Threats from Predation

3.2.A. Suitable methods and levels of marine mammal control are identified and implemented to mitigate negative interactions with anadromous salmonids where predation poses significant risks to recovery

3.2.B. Populations of introduced game fish are managed such that competition with or predation on Chinook salmon and steelhead does not impede population recovery

3.2.C Predation of anadromous salmonids is minimized at diversions and other instream structures

3.2.D Predation from birds and mammals is minimized in areas of low flow management (stranding)

3.2.E. Quantitative estimates of predation on anadromous salmonids are developed

Factor 4: Inadequacy of Existing Regulatory Mechanisms

Despite Federal and non-Federal efforts and partnerships that have been implemented to help increase the abundance and productivity of anadromous salmonids over the past 10 to 15 years, the winter-run and spring-run Chinook salmon ESUs and steelhead DPS remain at risk of extinction because the existing regulatory mechanisms do not provide sufficient certainty that efforts to reduce threats to the ESUs/DPS will be fully funded or implemented. Existing conservation efforts, research and monitoring activities also do not occur at a scale that is adequate to protect the entire Chinook salmon ESUs or steelhead DPS.

To determine that the Chinook salmon ESUs and the steelhead DPS are recovered, inadequacy of existing regulatory mechanisms that threaten their continued existence should be addressed through the following criteria.

Criterion 4.1. Address Threats Resulting from Inadequacy of Existing Regulatory Mechanisms

4.1.A. Regulatory mechanisms are implemented to ensure that effects on the abundance, productivity, diversity, and spatial structure of populations are consistent with the recovery of the ESU/DPS

4.1.B. Technical tools (such as modeling) are used to accurately assess the potential impacts of regulatory actions

4.1.C. Rules and regulations related to habitat protection and restoration and water quality are effectively enforced

4.1.D. Fishery Management Plans are developed and implemented

4.1.E. Habitat conditions, watershed functions and nearshore processes are protected and restored through land-use planning that guides human population growth and development

4.1.F. Habitat conditions and watershed function are protected and restored through regulations that govern resource extraction such as timber harvest and gravel mining

4.1.G. Habitat conditions, watershed functions and nearshore processes are protected and restored through land protection agreements as appropriate, where existing policy or regulations do not provide adequate protection

4.1.H. Adequate resources, priorities, regulatory frameworks, and coordination mechanisms are established and/or maintained for effective enforcement of land and water use regulations that protect and restore habitats and marine and freshwater water bodies and for the effective management of fisheries

4.1.I. Regulatory, control, and education measures to prevent additional exotic species invasions are implemented

Factor 5: Other Natural and Manmade Factors Affecting Continued Existence

Winter-run and spring-run Chinook salmon and steelhead are susceptible to natural and man-made threats caused by the effects of: (1) artificial propagation ; (2) climate changes or El Niño ocean conditions and prolonged drought conditions; (3) unscreened water diversions; (4) migration obstructions and impediments; and (5) invasive aquatic species.

To determine that the Chinook salmon ESUs and the steelhead DPS are recovered, natural and man-made threats to their continued existence should be addressed through the following criteria.

Criterion 5.1. Address Threats Resulting from Artificial Propagation

5.1.A. Hatchery management plans are implemented to ensure that any effects on the abundance, productivity, diversity, and spatial structure of populations are consistent with the recovery of the ESU/DPS

5.1.B. Technical tools (such as modeling) are used to accurately assess the potential impacts of hatchery management actions

5.1.C. Rules and regulations for hatchery management and protection are developed and effectively enforced

5.1.D. Hatchery programs are operated in a manner that is consistent with individual watershed and region-wide recovery approaches; appropriate criteria are used for the integration of hatchery Chinook salmon and steelhead populations, and extant natural populations inhabiting watersheds where the hatchery fish return

5.1.E. Hatcheries operate using appropriate ecological, genetic, and demographic risk containment measures for: (1) hatchery-origin adults returning to natural spawning areas; (2) release of hatchery juveniles; (3) handling of natural-origin adults at hatchery facilities; (4) withdrawal of water for hatchery use; (5) discharge of hatchery effluent; and (6) maintenance of fish health during their propagation in the hatchery

5.1.F. All Hatchery Chinook salmon and steelhead are marked or tagged so that they can be differentiated from natural Chinook salmon and steelhead in fisheries, migratory areas, and as adults returning to hatcheries and natural spawning areas (currently all listed anadromous salmonids are marked prior to hatchery release; a constant fractional marking program is in place for fall-run Chinook salmon hatchery production, although consistent, long-term funding is not secured)

5.1.G. Stocking practices for put-and-take fisheries do not interfere with recovery

Criterion 5.2. Address Threats Resulting from Climate Change

5.2.A. Research that aids in predicting the effects of climate change on salmon recovery is funded, and Federal and State commitments to respond to findings from the research are obtained

Criterion 5.3. Address Threats Resulting from Water Diversions and other Instream Structures

5.3.A. Entrainment and mortality of anadromous salmonids during the screening, holding and transport operations associated with the Jones and Banks pumping facilities are reduced

5.3.B. Alternatives to conveyance of SWP and CVP water south of the Delta that minimize/eliminate entrainment at existing facilities are evaluated and the preferred alternative is implemented

5.3.C. Entrainment at individual prioritized unscreened diversions are minimized or eliminated

5.3.D. Rates of entrainment at individual diversions are monitored

Criterion 5.4. Address Threats Resulting from Migration Obstructions and Impediments

5.4.A. Anadromous salmonid migration obstructions and impediments (e.g. due to Yolo and Tisdale bypass weirs, Sacramento Deep Water Ship Channel lock gates, diversion dams, etc.) are addressed

Criterion 5.5. Address Threats Resulting Invasive Aquatic Species

5.5.A. Mechanisms are developed and implemented to reduce the incidence of, and impacts from, introduced, invasive, or exotic species

5.5.B. The management actions for addressing aquatic invasive species described in the California Aquatic Invasive Species Management Plan are implemented.

5.0 Recovery Scenarios

"An ESU with well-distributed viable populations will avoid the situation where populations succumb to the same catastrophic risk(s), will allow for a greater potential source of diverse populations for recovery in a variety of environments (i.e., greater options for recovery), and increases the likelihood of the ESU surviving rapid environmental changes"

- Ruckelshaus et al. (2002)

5.1 Overview

The recovery scenarios presented in this section provide initial examples of how to achieve the overarching goal of this Recovery Plan - the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and Central Valley steelhead DPS in the Central Valley Domain from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11). These ESU/DPS-level recovery scenarios identify a combination of populations and population status levels that meet recovery criteria for a viable ESU/DPS. The scenarios represent some of the many possible combinations of populations, restoration actions, risk minimization and threat abatement. Different scenarios may fulfill the biological requirements for recovery.

The conceptual recovery scenarios were developed with consideration of the biological significance and recovery feasibility of each population. Biological significance was based on current status, potential for improvement, historical significance, proximity to other selected populations with reference to catastrophic risks, and spatial distribution between independent and dependent populations. Feasibility of recovery was based on expected progress as a result of existing programs, absence of apparent impediments toward recovery, and other management considerations (e.g. fish passage potential).

As this Recovery Plan is implemented over time, additional information will become available to help determine whether the threats have been abated, to further develop understanding of the linkages between threats and Chinook salmon and steelhead population responses, and to evaluate the viability of Chinook salmon and steelhead in the Central Valley Domain. There will be a thorough review of the recovery actions implemented, and population and habitat condition responses, at the 5- and 10-year status reviews of the Chinook salmon ESUs and the steelhead DPS. Monitoring and adaptive management in the course of implementation of this Recovery Plan will provide more information on the feasibility of recovering the winter- and spring-run Chinook salmon ESUs and the steelhead DPS in the Central Valley Domain. Such information is expected to lead to adjustments in recovery expectations and restoration actions and, thus, recovery scenarios.

5.2 Recovery Scenario Considerations

5.2.1 ESU/DPS Level Considerations

The conceptual recovery scenarios incorporate the concepts of viability at both the population and ESU/DPS levels. ESU/DPS viability depends on the number of populations within the ESU/DPS, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and diversity of the populations and their habitats. In the most general terms, ESU/DPS viability increases with the number of populations, the viability of these populations, the diversity of the populations, and the diversity of habitats that they occupy (Lindley et al 2007).

The Central Valley TRT reviewed available data to develop ESU/DPS- and population-specific criteria that take into account the constraints that can influence viability (e.g., populations with less habitat available will need to have higher intrinsic growth rates or less variable growth, compared to populations with greater habitat availability, to achieve similar viability (Lindley et al. 2007)). Unfortunately, population-specific information is unavailable for many of the populations in the winter- and spring-run Chinook salmon ESUs, and particularly in the steelhead DPS. Thus, the Central Valley TRT developed biologically relevant criteria that are generic to Oncorhynchus species.

Taxonomically general criteria for identifying and prioritizing species in need of conservation have been modified for application to Pacific salmonids (Allendorf et al. 1997). The Central Valley TRT extended the criteria-based approach of Allendorf et al. (1997) to account for the effects of hatchery fish on the extinction risk of naturally-spawning populations, and explicitly define a "low" extinction risk category. This low-risk definition can serve as a default goal for recovering populations for which too little data exist for more detailed goals to be developed (Lindley et al. 2007).

The extinction risks of populations are correlated because normal environmental influences affecting the population dynamics of salmonids are spatially correlated. The effects of catastrophes (defined as rare environmental perturbations with very strong negative effects on afflicted populations) can be quite widespread and a single catastrophic event (e.g., a toxic spill) could affect all populations even though they are widely dispersed for most of their life cycle. Because it is unlikely that all possible sources of risk can be identified and anticipated, the Central Valley TRT adopted the dual approach of managing risk and maximizing diversity within each ESU/DPS (Lindley et al. 2007).

ESU/DPS viability is assessed by examining the number and distribution of viable populations across the landscape and their proximity to sources of catastrophic disturbance. The Central Valley TRT (Lindley et al. 2007) addressed ESU/DPS viability in two ways. In the first, risk-spreading is assessed by examining how viable populations are spread among geographically-defined regions within the ESU/DPS. In the second, they attempted to account explicitly for the spatial structure of the ESU/DPS and the spatial structure of various catastrophic risks, including volcanoes, wildfires, and droughts. Therefore, for the ESUs/DPS to be considered viable, they should at a minimum be able to persist if challenged by any one of these types of catastrophes.

The Central Valley TRT defined ESU/DPS viability as requiring representation of all Diversity Groups and redundancy within the Diversity Groups (which they termed the "representation and redundancy" rule). If extinction risks are not strongly correlated between populations, two populations, each with low risk of extinction, would be extremely unlikely to go extinct simultaneously (McElhany et al. 2000). Should one go extinct, the other

could serve as a source of colonists to re-establish the extirpated population.

The conceptual recovery scenarios incorporate these considerations and approaches by the Central Valley TRT, as well as definitions of ESU (and DPS) recovery and viability based on McElhaney et al. (2000), as follows.

ESUs should contain multiple populations. If an ESU (or DPS) is comprised of multiple populations, it is less likely that a single catastrophic event will cause it to become extinct. Also, ESUs (or DPS) may function as "metapopulations" over the long term and the existence of multiple populations would be necessary for the operation of sustainable population-level extinction/ re-colonization processes. In addition, multiple populations within an ESU (or DPS) increase the likelihood that a diversity of phenotypic and genotypic characteristics will be maintained, thus allowing natural evolutionary processes to operate and increase the ESU's (or DPS') viability in the long term.

Some populations in an ESU (or DPS) should be geographically widespread. Spatially correlated environmental catastrophes are less likely to drive a widespread ESU (or DPS) to extinction. This guideline also directly relates to the ESA mandate of protecting a species in a "significant portion of (its) range."

Efforts to establish viable populations should be attempted in more populations than identified in the Diversity Group viability criteria (2 viable, independent populations per diversity group) because some attempts may be unsuccessful; individual population viability can be highly variable within diversity groups; catastrophic threats can often affect more than one population at a time; and climate change and extended drought conditions that are frequent in California require that we increase spatial diversity so that there is even distribution of populations throughout diversity groups, especially in the Northern Sierra Diversity Group, which is geographically located in the middle of all other diversity groups and functions as a hub of population connectivity, and genetic flow, between populations and diversity groups that are located to the north and south.

Some populations should be geographically proximate. On long temporal scales, ESUs (or DPS) may function as "metapopulations". Populations geographically close to one another facilitate connectivity among existing populations. Thus, a viable ESU (or DPS) requires both widespread and spatially proximate populations.

Populations should not all share common catastrophic risks. An ESU (or DPS) containing populations that do not share common catastrophic risks is less likely to be driven to extinction by correlated environmental catastrophes. Maintaining geographically widespread populations is one way to reduce risk associated with correlated catastrophes, but spatial proximity is not the only reason why two populations could experience a correlated catastrophic risk.

Populations that display diverse life-histories and phenotypes should be maintained. When an ESU's (or DPS') populations have a fair degree of life-history diversity (or other phenotypic diversity), the ESU (or DPS) is less likely to go extinct as a result of correlated environmental catastrophes or changes in environmental conditions that occur too rapidly for an evolutionary response. In addition, assuming phenotypic diversity is caused at least in part by genetic diversity, maintaining diversity allows natural evolutionary processes to operate within an ESU (or DPS).

Some populations should exceed VSP guidelines. Larger and more productive ("resilient") populations may be able to recover from a catastrophic event that would cause the extinction of a smaller population An ESU (or DPS) that contains some populations in excess of

VSP threshold criteria for abundance and population growth rate is less likely to go extinct in response to a single catastrophic event that affects all populations.

Evaluations of ESU (or DPS) status should take into account uncertainty about ESU/DPS-level processes. Our understanding of ESU/DPS-level spatial and temporal process is very limited. ESUs (or DPS) are believed to have been historically self-sustaining and the historical number and distribution of populations serves as a useful "default" goal in maintaining viable ESUs (or DPS).

In consideration of the foregoing, the conceptual recovery scenarios require that, in general, each Diversity Group must be represented, and population redundancy within the groups must be met to achieve Diversity Group recovery. Therefore, the recovery scenarios include the following Diversity Group general objectives:

A minimum of two viable populations of winter-run Chinook salmon within the winter-run Chinook salmon Diversity Group.

A minimum of two viable populations of spring-run Chinook salmon within each of the four spring-run Chinook salmon Diversity Groups, with the exception of the Northwestern California Diversity Group which historically did not contain independent spring-run Chinook salmon populations. For the Northwestern California Diversity Group, observed occupancy will suffice rather than viability, as defined.

A minimum of two viable populations of steelhead within each of the four extant steelhead Diversity Groups (i.e., the Basalt and Porous Lava Diversity Group, the Northwestern California Diversity Group, the Northern Sierra Nevada Diversity Group and the Southern Sierra Nevada Diversity Group). The historical Central Valley steelhead DPS included the two additional ecoregions of the Suisun Bay Tributaries Diversity Group and the Central Western California Diversity Group. However, because: (1) the previously described historical Suisun Bay Tributaries Diversity Group presently is included in the Central California Coast Steelhead DPS and, therefore, is not further considered in the Central Valley Domain; and (2) steelhead have been entirely extirpated from the Central Western California Diversity Group and watersheds in this Diversity Group would require significant restoration actions, have low recovery potential, and are not considered candidate areas for reintroduction - particularly in consideration of long-term climate change. Therefore, the steelhead DPS conceptual recovery scenario does not include reestablishing viable populations of steelhead in the Central Western California Diversity Group.

5.2.2 Population Level Considerations

The Central Valley TRT described the historical populations of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon ESUs in the Central Valley (Lindley et al. 2004). They considered geography, migration rates, genetic attributes, life history diversity, population dynamics, and environmental characteristics in grouping the populations into independent populations and dependent populations. For the Central Valley steelhead DPS, Lindley et al. (2006) identified historical independent populations based on a model that identifies discrete habitat and interconnected habitat patches isolated from one another by downstream regions of thermally unsuitable habitat.

Independent populations of Chinook salmon were identified based on three criteria: (1) basin isolation; (2) basin size; and (3) substantial genetic differentiation within the basin. For the basin's isolation criterion, watersheds within a critical dispersal distance of at least 50 km in the same ecoregion were grouped together. For the basin size criterion, watersheds with an area greater than 500 km^2 were considered capable of supporting independent populations. For the genetic differentiation criterion, significant

environmental differences should exist among the basins inside of the distance criterion.

Populations of salmon and steelhead in the Central Valley Domain that have minimal demographic influence from adjacent populations and are viable in isolation have been classified as functionally independent populations. Dependent populations are populations that would not persist without immigration from neighboring populations. Dependent populations play a valuable role in the viability of the ESU/DPS by linking other populations, as well as containing valuable genetic traits. The presence and spatial distribution of dependent and independent populations are considered in the development of the conceptual recovery scenarios.

5.2.3 Ecological (Habitat) Restoration Considerations

In addition to ESU/DPS and population viability, structure and distribution considerations, the conceptual recovery scenarios incorporate ecological or habitat objectives for each Diversity Group:

- The recovery scenario must address the entire natural ecosystem (freshwater spawning, rearing and migration areas; estuarine habitats, and the Pacific Ocean)

- The recovery scenario should reflect that viable ESUs/DPSs and populations require a network of complex and interconnected habitats, which are created, altered, and maintained by natural physical process

- The spatial distribution and productive capacity of freshwater and estuarine habitats should be sufficient to maintain viable populations identified for recovery

- The diversity of habitats for recovered populations generally should resemble historic conditions given expected natural disturbance regimes (wildfire, flood, volcanic eruptions, etc.). Historic conditions represent a reasonable template for a viable population - the closer the habitat resembles the historic diversity, the greater the confidence in its ability to support viable populations

- At a large scale, habitats should be protected and restored, with a trend toward an appropriate range of attributes for salmonid viability

The conceptual recovery scenarios reflect NMFS' goal to restore and conserve the habitats that support the Federally-protected anadromous fish. Critical habitat is of great importance in conserving listed salmonids. Conservation and enhancement of habitat to sustain these fish should reflect consideration of habitat areas identified in NMFS' critical habitat designation, including information from the Critical Habitat Analytical Review Team (CHART) regarding PCEs and habitat rankings:

<u>Freshwater Spawning Sites</u>

- have good water quality and quantity
- have substrate for spawning, incubation, and larval development

<u>Freshwater Rearing Sites</u>

- have good water quality and quantity and floodplain connectivity to maintain habitat conditions
- have forage for juvenile development
- have natural cover to provide refuge (such as submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks or boulders, side channels, undercut banks, etc.)

<u>Freshwater Migration Corridors</u>

- are unobstructed
- have good water quality and quantity

- have natural cover to provide refuge to support juvenile and adult mobility and survival
- afford safe passage conditions for migrations

Estuarine Areas

- are unobstructed
- have good water quality and quantity, with salinity conditions to support juvenile and adult physiological transitions between freshwater and saltwater
- have natural cover to provide refuge to support migrations among systems
- have forage for juvenile and adult migrating fish

Nearshore Marine Areas (not included in critical habitat designation, but important to overall species lifecycle)

- are unobstructed
- have good water quality and quantity conditions
- have forage to support growth and maturation of fish
- have natural cover to provide refuge

Offshore Marine Areas

- have good water quality conditions
- have forage to support growth and maturation

The above critical habitat attributes in the Central Valley Domain were considered in the development of the conceptual recovery scenarios, although marine areas were not explicitly considered. Habitat restoration potential of freshwater habitats (see watershed profiles) were explicitly considered in the development of the conceptual recovery scenarios.

5.2.4 Threat Abatement

As described in this Recovery Plan, it is imperative that threats to the species be controlled prior to delisting. This includes all threats identified at the time of listing, as well as any new factors identified since listing. Since listing, numerous additional threats have been identified and prioritized for each of the Diversity Groups and individual populations of the winter-run and spring-run Chinook salmon ESUs, and the steelhead DPS within the Central Valley Domain, as previously described in Appendix B.

NMFS proposes that, to determine that the affected ESU/DPS is recovered to the point that it no longer requires the protections of the ESA, the listing factors should be addressed according to specific criteria identified for each of them so that delisting is not likely to result in re-emergence of the threat. The explicit listing factor (threats) criteria previously described in this Recovery Plan correspond to the listing factors identified for winter- and spring-run Chinook salmon and steelhead, and to the stressors described in Appendix B. Accordingly, NMFS expects that if this Recovery Plan's proposed actions (Chapter 6 and Appendix C) to address the threats and limiting factors are implemented, they will make substantial progress toward meeting the listing factor (threats) criteria specified herein. These threat abatement criteria are established to address threats to, or resulting from, spawning grounds, habitat quality and quantity, overutilization, disease or predation, inadequate regulatory mechanisms, artificial propagation, climate change, water diversions, and non-indigenous aquatic nuisance species.

The conceptual recovery scenarios consider the degree to which, in both the near-term and long-term, threat abatement is anticipated for the Diversity Groups and individual populations in the Central Valley Domain.

5.3 Process for Recovery Scenario Development

Information about the population structure and the distribution of the ESU/DPS is critical to guide restoration actions in the Central Valley, and in the development of the recovery scenarios. Recovering the ESU/DPS will likely require a mix of improved access to historically available habitat and restoration of degraded habitat, as previously identified in this Recovery Plan. Understanding the current and historical structure of the ESU/DPS is important for recovery and conservation purposes, and the development of the conceptual recovery scenarios. Current distribution provides an understanding of how to efficiently safeguard the existence of the ESU/DPS. Historical distribution provides an understanding of how the species might have survived catastrophic disturbances and how an altered ESU/DPS may or may not persist in the future. Genetically diverse populations within an ESU/DPS are important for the persistence of an ESU/DPS in the event of a catastrophic or gradual change in the local environment, and recolonization by neighboring populations that are adapted to similar environmental conditions. In the case of reintroductions of salmonids to an area where they have been extirpated, knowing which populations might have members that are ecologically exchangeable would help guide reintroductions into restored habitats.

For each ESU/DPS in the Central Valley Domain, conceptual recovery footprint maps have been developed to show the historical habitat, candidate areas for reintroduction and potential examples of anticipated lifestage-specific areas within each diversity group that would be needed to support recovered populations of Sacramento River winter-run and Central Valley spring-run Chinook salmon, and Central Valley steelhead.

5.4 Conceptual Recovery Scenarios

Multi-species recovery for wide-ranging migratory species that occur across a large number of different ecosystems and landscapes can be assisted by developing a foundational approach that describes a conceptual vision of what a recovered ESU or DPS should look.

5.4.1 Spatial Distribution and Abundance

In general, the populations within each ESU/DPS should reflect historic distribution, through representation and redundancy within Diversity Groups while taking into account that not all reintroduction efforts will be successful and that population viability at any point in time is likely to vary between populations. For winter-run Chinook salmon, this means that multiple populations need to be present within the Basalt and Porous Lava Diversity Group, including the persistence of the last remaining population in the Sacramento River, below Keswick and Shasta Dams, establishing a population in Battle Creek, and reintroducing populations to the Little Sacramento and McCloud Rivers. The low extinction risk criteria in Table 4-1 of this Recovery Plan should be used as viability targets for these populations.

For Central Valley spring-run Chinook salmon, the population distribution should vary by diversity group, based on current and historic distribution patterns and habitat availability. We envision that a recovered ESU would contain populations meeting the low extinction risk criteria presented in Table 4-1 in Clear Creek, for the Northern California Diversity Group; in the Little Sacramento and McCloud Rivers and Battle Creek for the Basalt and Porous Lava Diversity Group; in Deer, Mill, and Butte creeks, and in the Feather River below Oroville Dam, and the Yuba River, including habitats above Englebright Dam for the Northern Sierra Nevada Diversity Group;

and in the San Joaquin River, below Friant Dam, and within at least one tributary of the San Joaquin River, for the Southern Sierra Diversity Group. Of course, this is a conceptual description of distribution, and other areas that are identified in the Recovery Footprint maps as candidate areas may also prove feasible as information on habitat condition and reintroduction feasibility is developed.

For Central Valley steelhead, the population distribution should also vary by diversity group, based on current and historic distribution patterns and habitat availability. We envision that a recovered DPS would include independent populations with a low risk of extinction (see Table 4-1) in Thomes, Beegum and Clear creeks, for the Northwestern California Diversity Group; in the Little Sacramento and McCloud Rivers and Battle Creek for the Basalt and Porous Lava Diversity Group; in Deer, Mill, and Butte creeks, in the Feather River below Oroville Dam, in the Yuba River, including in habitats above Englebright Dam, and in the American River above Folsom Dam, for the Northern Sierra Nevada Diversity Group; and in the within at least two tributaries of the San Joaquin River, including the Calaveras River, for the Southern Sierra Diversity Group. Similar to spring-run, this is a conceptual description of distribution, and other areas that are identified in the Recovery Footprint maps as candidate areas may also prove feasible as information on historic habitat condition and reintroduction feasibility is developed.

The reintroduction of fish to historic habitats will require numerous efforts including short-term actions to trap and haul fish to conduct pilot reintroduction tests; source population selection; habitat evaluations, and habitat suitability and carrying capacity modeling; juvenile recapture pilot testing; and long-term efforts that may include developing more volitional passage mechanisms, and implementation of long-term reintroduction and monitoring programs.

5.4.2 Network of Complex and Interconnected Habitats

The ultimate purpose of the ESA is to conserve the ecosystems upon which threatened and endangered species rely so that they no longer require the protections of the ESA to persist. Viable ESUs/DPSs and populations will require a network of complex and interconnected habitats that are created, altered, and maintained by natural physical process. Central Valley salmonid ecosystems have been extensively altered. Dams have disconnected fish from their historic habitats and altered the flow regimes downstream by storing the naturally occurring high flow events of winter and spring months and releasing these flows during summer for agricultural and municipal uses. More than 1,600 miles of levee construction in the Central Valley has constricted river channels, disconnected floodplains from active river channels, reduced riparian habitat, and reduced natural channel function, particularly in lower reaches of the Sacramento and San Joaquin Rivers and the Delta. Finally, thousands of water diversions within the Central Valley reduce instream flows, and the State and Federal pumping facilities in the south Delta reverse natural river flows, disrupt natural tidal patterns, and alter the migration patterns and survival of salmonid individuals and populations.

Restoring the ecosystem of anadromous fish in the Central Valley will be a difficult and time intensive endeavor and will require: (1) establishing reliable passage and connectivity of fish to upstream habitats; (2) restoring the geomorphic function and natural habitat processes of the lower Sacramento and San Joaquin River and the Delta; (3) providing ecological flows and alternative Delta water diversion approaches that match the life history needs of fish including habitat development and maintenance processes of river systems; and (4) significantly reducing the abundance of non-native predatory fishes that inhabit the lower river reaches and the Delta. Floodplains are a

vital component of the salmon and steelhead ecosystem and floodplain reclamation and restoration is expected to be a key habitat improvement action that will be necessary to recover these fish.

Reintroduction of anadromous to historic habitats will require a new approach to watershed management, especially in regard to the operation and licensing of hydroelectric projects. Many of the keystone passage impediments to block access to upstream habitat are regulated by the Federal Energy Regulatory Commission (FERC). In many watersheds, FERC also regulates upstream hydroelectric projects and facilities, and in most cases the licenses issued by FERC expire on different schedules, making a coordinated watershed approach to relicensing difficult. There are numerous hydroelectric licenses that are up for renewal in the next 20 years. Reintroduction of fish to historic habitats will require a concerted effort by FERC and other interested parties to align license schedules and develop watershed approaches to developing new stream flow regimes and facilitate comprehensive fish passage plans. This approach is especially necessary in the McCloud, upper Yuba, upper Merced and other watersheds where upstream hydroelectric projects may influence areas identified for reintroduction, affect downstream habitats that are essential for recovery. Reintroduction will also require improved approaches to coordinating to resource agency coordination including joint filings under FERC proceedings, aligning regulatory schedules and products, and sharing biological, technical and policy expertise on high priority projects.

For all extant populations, small passage impediments such as low-head agricultural dams, recreation dams, fish ladders and road crossings should be evaluated and reconfigured to meet NMFS fish passage criteria for all life stages that encounter a structure. In no cases should passage impediments exist that restrict the passage of fish during their migration periods. All existing impediments should be evaluated over the next two years and upgraded within five years.

Due to the significant presence of levees in the Central Valley and their effects on river function and the creation and maintenance of anadromous salmonid habitat, achieving species recovery will require a long-term river restoration program that separates the levees from the active channels of the river systems; especially in the Sacramento River between the vicinity of Colusa and Verona California, and in the Delta. In many areas, significant urban infrastructure is present that may preclude the relocation of flood control structures. In these areas, actions that restore the habitat complexity within the river channel should be aggressively pursued. Levee designs and levee repairs should target establishing low-risk woody vegetation, instream woody material, and benches to create small engineered floodplain areas that will serve as critical refugia and growth areas for fish within urban corridors.

To assist with ecological restoration, comprehensive conservation strategies need to be developed for each of the inland biogeographic areas in this Recovery Plan (Delta, San Joaquin River, Sacramento River, and each of the Diversity Groups).

In the Delta, a strategic approach to restoring intertidal habitats along principle migration and rearing corridors should be applied. Many factions compete for the beneficial uses of the waters of the Delta ecosystem. Increasing year-round water demand, continuous drought years, and more recently, poor ocean conditions have contributed to reductions in the survival, abundance, and diversity of native Delta fish species. In order to restore the Delta ecosystem, we believe that the following actions, some of which have been recently recommended by the Governors Delta Vision Blue Ribbon Task Force are critical to undertake in the near future:

- A new system of water conveyance around the Delta to protect and restore

estuarine ecosystems and anadromous fish migration;

- An investment commitment and conservation strategy to restore and sustain a diverse Delta ecosystem;
- A monitoring and investment plan to protect and enhance unique and important characteristics of the Delta region;
- A plan to significantly improve and provide incentives for water conservation – through both wise use and reuse – in both urban and agricultural sectors throughout the state;
- A Delta levee policy with quantified objectives, based on science and peer review, that prioritizes and implements restoration projects and identifies levees that need to be maintained for priority flood control purposes, or that can be allowed to deteriorate or be decommissioned to restore intertidal and floodplain fish habitat.
- New anadromous fish flows that create positive flow conditions during essential migratory periods in order to optimize the survival of emigrants through the Delta.
- An improved, comprehensive governance system that has reliable funding, takes advantage of established and effective ecosystem restoration and science programs, and has clear authority to determine priorities and strong performance measures to ensure accountability to the new governing doctrine of the Delta.

The CDFG has recently completed the CALFED Ecosystem Restoration Program (ERP) Draft Conservation Strategy for Stage 2 Implementation in the Sacramento-San Joaquin Delta and Suisun Marsh and Bay Planning Area. This strategy proposes to address the critical environmental conditions in the Delta and Suisun Marsh/Bay during the first phase (Phase 1) of Stage 2 implementation (2009-2020). The spatial extent of the ERP includes the Sacramento and San Joaquin Valleys in addition to the Bay-Delta estuary, and the ERP implementing entities recognize how conditions in the estuary are directly influenced by the manner in which water and species are managed upstream. Conservation strategies for these upstream areas will be forthcoming as part of ongoing ERP implementation, and should incorporate this recovery plan strategy to assist with attaining recovery criteria.

5.4.3 Hatchery Management

In general, existing fish hatcheries should be managed to reduce and minimize the potential for hatchery influences on winter- and spring-run Chinook salmon and steelhead. Reviews and reform of Central Valley Hatcheries are currently being coordinated with CDFG, NMFS, and the USFWS through the development and implementation of Hatchery and Genetic Management Plans (HGMPs); which will include long-term function or purpose of each hatchery in the context of VSP criteria and recovery objectives for salmonids listed under the ESA. In addition, HGMPs will include a monitoring component. Hatcheries are expected to play a continued role in salmonid fisheries in the Central Valley, but their purposes and roles should change to assist with the conservation of listed populations. Over time, as viable, naturally produced populations increase in abundance and distribution according to the recovery criteria laid out in this plan, hatchery management should transition from meeting mitigation production goals to assisting with the recovery goals and criteria laid out in this plan. This transition should allow for consideration to sunset certain hatchery programs as viable, natural populations are re-established.

Livingston Stone National Fish Hatchery is expected to play a continuing role as a conservation hatchery for the protection, and enhancement of the existing winter-run population below Keswick and Shasta dams, but

also should play a role in re-establishing winter-run to habitats above Shasta Reservoir, and to Battle Creek. Coleman National Fish Hatchery should consider developing a spring-run Chinook salmon conservation program to assist with the reintroduction of fish to the upper Sacramento River above Keswick and Shasta Dams.

In the near term, the Feather River Fish Hatchery will continue to target mitigation production goals for spring-run Chinook salmon and steelhead, but the future management of anadromous fisheries in the Feather River will be guided by an aggressive adaptive management program that is expected to significantly affect the future of these fish. As natural and hatchery-spawned spring-run Chinook salmon are increasingly separated from fall-run, their life history and genetic diversity traits are likely to improve over time and individuals will become more fit, increasing the species natural production, abundance, diversity and resilience. Feather River spring-run Chinook salmon may be good candidates for consideration in fishery reintroduction programs throughout the Central Valley. Although the existing genetic structure of the Feather River spring-run population is largely similar to fall-run Chinook salmon, there are some significant differences, and the population continues to display spring-run phenotypic life history characteristics. The Feather River hatchery should play an increasing conservation role in the future of the Feather River natural population, but also for reintroduction purposes to areas such as the San Joaquin River. The development of HGMPs should anticipate these potential uses and develop appropriate best management practices.

Hatchery management practices in the San Joaquin River Basin will also be changed by HGMPs. Steelhead management and HGMPs should provide consideration for developing steelhead conservation hatchery practices to assist with the reintroduction of these fish both to available, and to currently inaccessible, unoccupied habitat.

5.4.4 Winter-run Chinook Salmon

Dams in the Central Valley have blocked access to the entire historical spawning grounds, altered water temperatures, and reduced habitat complexity, thus posing risks to the abundance, productivity, and especially to the spatial structure and genetic diversity of the winter-run Chinook salmon ESU. The construction and operation of Shasta Dam alone immediately reduced the winter-run Chinook salmon ESU from four independent populations to one dependent population. The remaining available habitat for natural spawners is currently maintained with cool water releases from Shasta and Keswick dams, thereby significantly limiting spatial distribution of this ESU.

The population of Sacramento River winter-run Chinook salmon that now spawns below Keswick Dam is at moderate extinction risk according to the Population Viability Analysis, and at low risk according to the other criteria (Lindley et al. 2007). At present, the population easily satisfies the low-risk criteria for population size, population decline, and catastrophe, but hatchery influence remains of concern. The continued persistence of the winter-run Chinook salmon population is dependent on hatchery production, and as such cannot be characterized as having a low risk of extinction. However, as discussed in the Background chapter, in the short-term, LSNFH does not appear to be a genetic risk to the naturally spawning population based on a high average PNI value from 2003 through 2008.

The Sacramento River winter-run Chinook salmon ESU does not currently satisfy the representation and redundancy rule because it has only one population, and that population spawns outside of the ecoregion where it evolved (Lindley et al. 2007). An ESU represented by a single population at moderate risk of extinction is at high risk of extinction over the long-term. A single catastrophe could extirpate the entire Sacramento River winter-run Chinook salmon ESU, if its effects persisted for four or more years.

The entire reach of the Sacramento River used by winter-run Chinook salmon is within the zone of influence of Mt. Lassen. Some other possible catastrophes include a prolonged drought that depletes the cold water storage of Shasta Reservoir or some related failure to manage cold water storage, a spill of toxic materials with effects that persist for four years, or a disease outbreak.

For the Sacramento River winter-run Chinook salmon ESU to satisfy the representation and redundancy rule, at least two viable, independent populations would need to be present in the Basalt and Porous Lava Diversity Group. Therefore, the conceptual recovery scenario for the winter-run Chinook salmon ESU (**Figure 5-1**) includes: (1) securing the extant population by implementing key habitat restoration actions, particularly in the near term; (2) establishment of at least one other viable independent population in the Basalt and Porous Lava Diversity Group (e.g., Battle Creek and/or in systems above Shasta Dam).

For currently occupied habitats between Keswick Dam and Red Bluff, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a population of Sacramento River winter-run Chinook can be improved and sustained with extensive long-term human intervention. In order to secure the extant population of winter-run Chinook salmon, particularly in the near term, several key habitat restoration actions have been identified, including the following:

- Achieve the daily average water temperature targets described in the Biological Opinion on the Long-Term Central Valley Project Operations Criteria and Plan (NMFS 2009)

- Implement a river flow management plan that balances carryover storage needs with instream flow needs for winter-run Chinook salmon based on runoff and storage conditions, including flow fluctuation and ramping criteria (USFWS 2001)

- Use the best available data regarding winter-run Chinook salmon spawning habitat availability as a key consideration for determining Keswick Dam releases

- Develop a long-term strategy for monitoring and regulating discharges from agricultural lands to protect waters within the Central Valley, including enforcing water quality regulations (SWRCB Website 2009)

- Conduct periodic (e.g., every 5 years) spawning gravel assessments in the upper Sacramento River (i.e., above RBDD) and implement gravel augmentation projects, as necessary

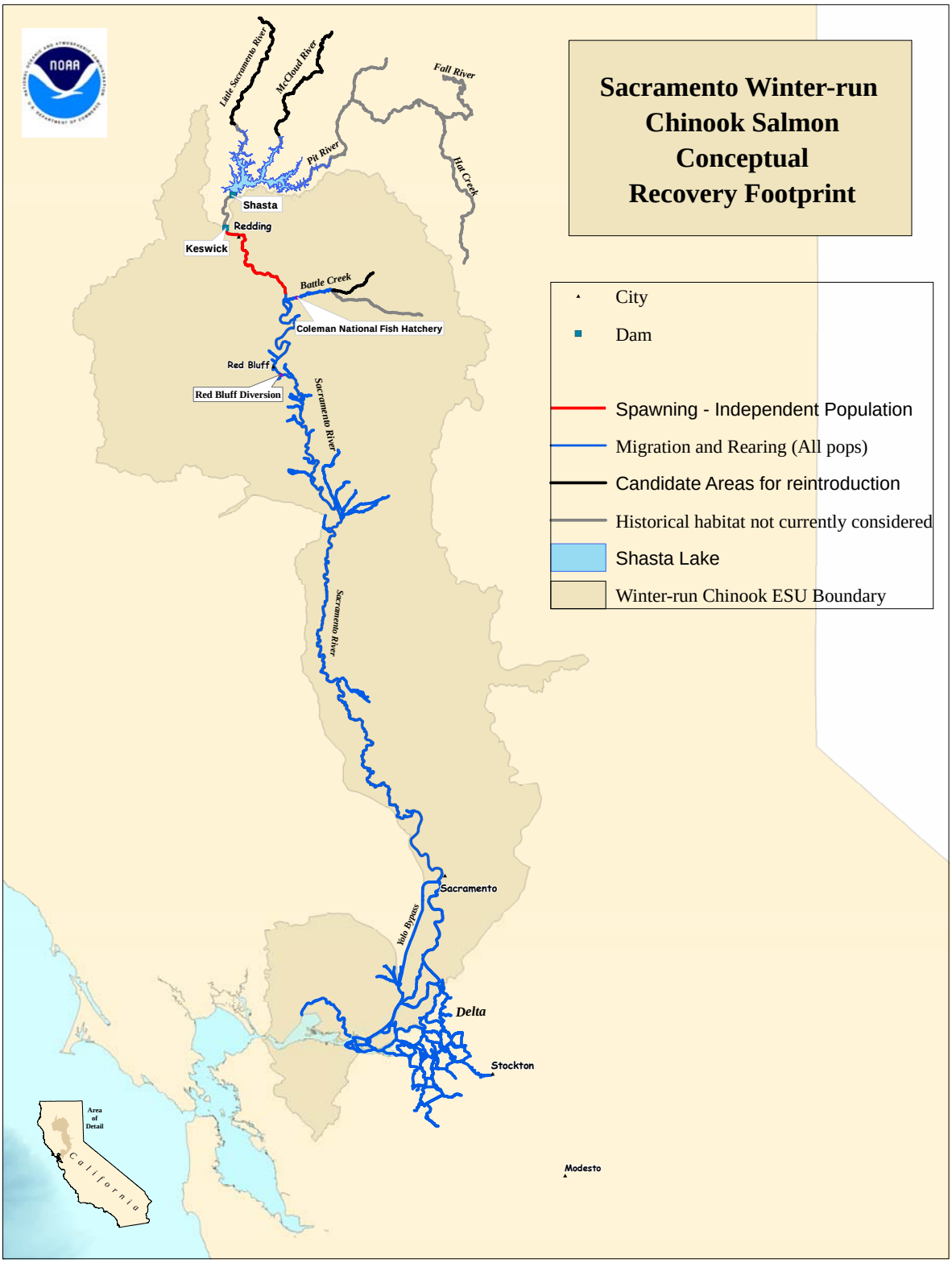


Figure 5-1. Sacramento River Winter-run Chinook Salmon ESU Conceptual Recovery Footprint. The candidate areas for reintroduction that are depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning, and rearing still exist or could be restored.

- Incorporate conservation measures in bank stabilization projects in the Sacramento River to provide more suitable seasonal habitat for juvenile salmon, and to reduce predation in the riprapped, leveed, or channelized sections of the Sacramento River

- Conduct feasibility studies on unscreened water diversions in the Sacramento River and at the State and Federal water project pumping plants to avoid or minimize the entrainment of juvenile salmon

- Conduct habitat evaluations and feasibility studies for reintroducing winter-run Chinook salmon to habitat above Shasta Dam, including assessing habitat suitability and passage logistics

- Design and conduct an experimental fish passage program evaluating adult distribution, survival, spawning, and production in habitats above Shasta Dam

- Develop habitat restoration / conservation and water project management operations actions in the Delta

Lindley et al. (2004) identifies four historically independent populations of Sacramento River winter-run Chinook salmon in the Central Valley, which met the two criteria for independence: basin isolation and minimum basin size. The historically independent populations were the Little Sacramento River, Pit-Fall-Hat Creek, McCloud River, and Battle Creek. The first three basins are blocked by Shasta and Keswick dams, and access to Battle Creek has been blocked by the Coleman National Fish Hatchery weir and various hydropower dams and diversions. The one independent population that presently inhabits the area of cool water between Keswick Dam and Red Bluff was not historically used by winter-run Chinook salmon for spawning.

The Basalt and Porous Lava Diversity Group comprises the streams that historically supported winter-run Chinook salmon. All of these streams receive large inflows of cold water from springs through the summer, upon which winter-run Chinook salmon depended.

A recovery scenario that ultimately results in re-establishing viable populations in at least two of the four historic winter-run Chinook salmon populations (i.e., Little Sacramento, Pit River, McCloud River, and Battle Creek) will be needed to recover the ESU. With the exception of Battle Creek, passage past Shasta and Keswick dams will be required to achieve the representation and redundancy criterion.

For currently unoccupied historic habitats, the Little Sacramento and McCloud rivers have a high potential to support spawning adults due to the number of connected miles of suitable spawning and rearing habitat. The Pit River has a low potential due to the extensive presence of hydroelectric facilities that inundate or substantially affect historic habitat.

In order to secure long-term populations in the winter-run Chinook salmon ESU, several key actions have been identified and include:

- If the near-term experimental fish passage program demonstrates that passage above Shasta Dam can substantively contribute to the long-term viability of the ESU, then develop and implement long-term fish passage programs

- Continue to achieve the daily average water temperature targets described in the Biological Opinion on the Long-Term Central Valley Project Operations Criteria and Plan (NMFS 2009)

- Continue to implement a river flow management plan that balances carryover storage needs with instream flow needs for winter-run Chinook salmon based on runoff and storage conditions, including flow fluctuation and ramping criteria (USFWS 2001)

- Implement a long-term strategy for monitoring and regulating discharges from agricultural lands to protect waters within the Central Valley, including enforcing the regulations (SWRCB Website 2009)

- Continue to use the best available data regarding winter-run Chinook salmon spawning habitat availability as a key consideration for determining Keswick Dam releases

- Incorporate conservation measures in bank stabilization projects in the Sacramento River to provide more suitable seasonal habitat for juvenile salmon, and to reduce predation in the riprapped, leveed, or channelized sections of the Sacramento River

- Implement fish screen improvement projects for unscreened water diversions in the Sacramento River and at the State and Federal water project pumping plants to avoid or minimize the entrainment of juvenile salmon

- Implement habitat restoration/ conservation and water project management operations in the Delta

Long-term climate change is an additional consideration regarding the viability of the winter-run Chinook salmon ESU and specific populations in the long-term. Global and localized climate changes, such as El Nino ocean conditions and prolonged drought conditions, may play an important role in the suitability of winter-run Chinook salmon habitat and, hence, viability. The Sacramento River winter-run Chinook salmon ESU is highly vulnerable to drought conditions. During dry years, less cold water is available for release from Shasta Dam, which is the sole provider of cold water on which the fish are dependent. During an extended drought, the potential increased water temperatures in the Sacramento River would be expected to reduce the availability of suitable spawning and rearing conditions.

Lindley et al. (2007), in a simplified analysis, postulated three different long-term climate change scenarios potentially occurring by the year 2100. Mean summer air temperatures are expected to rise by at least 2°C, are expected to increase by around 5°C (9°F), and the less likely but still possible scenario of an 8°C (14.4°F) warming. Under the expected warming of around 5°C, substantial habitat would be lost, with remnants of habitat for winter-run Chinook salmon remaining in the upper Sacramento, McCloud, and Pit rivers, and Battle Creek. However, the net result in the long-term is uncertain, and Lindley et al. (2007) cautioned that more research is needed to evaluate the details of how warming would influence individual populations and subbasins.

Long-term climate change considerations emphasize the importance of a recovery scenario that ultimately results in re-establishing multiple viable populations among the four historic winter-run Chinook salmon populations (i.e., Little Sacramento, Pit River, McCloud River, and Battle Creek). These streams in the Basalt and Porous Lava Diversity Group that historically supported winter-run Chinook salmon receive spring-fed cold water through the summer. These watersheds offer important cold water inputs for winter-run Chinook salmon populations that could provide protection against climate change effects.

5.4.5 Spring-run Chinook Salmon

Present risks to the abundance, productivity, and especially to the spatial structure and genetic diversity of the spring-run Chinook salmon ESU result from the construction of dams in the Central Valley that have blocked access to the entire historical spawning grounds, altered water temperatures, and reduced habitat complexity. Good et al. (2005) emphasized the loss of diversity in the ESU caused by the extirpation of spring-run Chinook salmon populations from most of the Central Valley, including the San Joaquin River tributaries, as well as the close proximity of the remaining independent populations in the Central Valley spring-run Chinook salmon ESU.

Lindley et al. (2004) identify 18 historical independent populations of Central Valley spring-run Chinook salmon:

Independent Populations

- Little Sacramento River
- Pitt-Fall-Hat Rivers
- McCloud River
- Battle Creek
- Butte Creek
- Mill and Deer Creeks
- North Fork Feather River
- West Branch Feather River
- South Fork Feather River
- Yuba River
- North and Middle Forks American River
- South Fork American River
- Mokelumne River
- Stanislaus River
- Tuolumne River
- Merced River
- San Joaquin River

Each of these independent populations meets two of the three criteria for independence: basin isolation and minimum basin size. Two populations additionally met the third criterion of substantial genetic differentiation: Butte Creek, and Mill and Deer creeks. Currently, there are only three independent populations of spring-run Chinook salmon, inhabiting Butte Creek, Mill Creek, and Deer Creek.

Lindley et al. (2004) also identified four historically dependent populations, grouped as follows:

Dependent Populations

- Kings River
- Big Chico, Antelope and Clear creeks
- Thomes and Cottonwood creeks
- Beegum and Stony creeks

The Kings River Basin is frequently inaccessible to anadromous fish. The other basins of dependent populations do not have enough habitat for spring-run Chinook salmon to persist in isolation. The following discussion regarding spring-run Chinook salmon population structure and viability is taken from Lindley et al. (2007).

Perhaps 15 of the 18 or 19 historical populations of Central Valley spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various impassable dams. Butte Creek and Deer Creek spring-run Chinook salmon are at low risk of extinction, satisfying both the PVA and other viability criteria. Mill Creek is at moderate extinction risk according to the PVA, but appear to satisfy the other viability criteria for low-risk status. Lindley et al. (2004) were uncertain whether Mill and Deer creek populations were each independent, or two parts of a single larger population. If viewed as a single population, Mill and Deer creek spring-run Chinook salmon are at low extinction risk. Early-returning Chinook salmon persist within the Feather River Hatchery population and spawn in the Feather River below Oroville Dam. Early-returning Chinook salmon also persist within the Yuba River and spawn below Englebright Dam. The current status of the Feather and Yuba river populations were not assessed by the Central Valley TRT due to insufficient data.

With demonstrably viable populations in only one of at least three diversity groups that historically contained them, Central Valley spring-run Chinook salmon fail the representation and redundancy rule for ESU viability. Historically, the Central Valley spring-run Chinook salmon ESU spanned four ecoregions: the Basalt and Porous Lava Diversity Group, the Northern Sierra Nevada Diversity Group, the Northwestern California Diversity Group and the Southern Sierra Nevada Diversity Group. There are two or three viable populations in the Northern Sierra Nevada Diversity Group (Mill, Deer and Butte creeks), although these populations were once probably relatively small compared to populations such as the Feather River. A few ephemeral or dependent populations are found in the Northwestern California Diversity Group (e.g., Beegum and Clear creeks). With the exception of a small population in Battle Creek, spring-run Chinook salmon have been entirely extirpated from the Basalt and Porous Lava Diversity Group. Spring-run Chinook salmon have been extirpated from the Southern Sierra Nevada Diversity Group – historically the most productive region for these fish.

The present distribution of viable populations of Central Valley spring-run Chinook salmon ESU renders them vulnerable to catastrophic disturbance. All three extant independent populations are in watersheds whose headwaters lie within the debris and pyroclastic flow radii of Mt. Lassen. The historical ESU was of such a large scale that neither Mt. Lassen, Mt. Shasta, or Medicine Lake could have extirpated even an entire diversity group, let alone the entire ESU. In addition, the current ESU structure is vulnerable to the catastrophic disturbances of drought and wildfires. Lindley et al. (2007) notes that the historical Central Valley spring-run Chinook salmon ESU was widespread enough to be invulnerable to all of these catastrophes, except perhaps prolonged drought. It is possible that Central Valley spring-run Chinook salmon were less vulnerable to drought than might be expected because they once occupied diverse types of watersheds, including those with very high influence from springs.

In consideration of the foregoing, the recovery scenarios include the objectives of a minimum of two viable populations of spring-run Chinook salmon within each of the four spring-run Chinook salmon Diversity Groups, with the exception of the Northwestern California Diversity Group which historically did not contain independent spring-run Chinook salmon populations. For the Northwestern California Diversity Group, observed occupancy will suffice rather than viability, as defined.

To meet these objectives, the conceptual recovery scenario for the spring-run Chinook Salmon ESU (**Figure 5-2**) includes: (1) securing extant populations by implementing key habitat restoration actions, particularly in the near term; and (2) establishment of additional viable independent populations in the ESU. In addition to considerations of historical distribution, current population status, and recovery potential (including restoration actions) of the individual watersheds, one of the factors taken into account in the identification of candidate reintroduction watersheds is long-term climate change.

Long-term climate change is an additional consideration regarding the viability of the spring-run Chinook salmon ESU and specific populations in the long-term. Global and localized climate changes, such as El Nino ocean conditions and prolonged drought conditions, may play an important role in the suitability of spring-run Chinook salmon habitat and, hence, viability. The spring-run Chinook salmon ESU is highly vulnerable to drought conditions.

As previously described in the winter-run Chinook salmon ESU conceptual recovery scenario, Lindley et al. (2007) postulated that mean summer air temperatures are expected to rise by at least 2°C, are expected to increase by around 5°C (9°F), and the less likely but still possible scenario of an 8°C (14.4°F) warming by the year 2100. Under the expected warming of around 5°C, substantial spring-run Chinook salmon habitat would be lost, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento and McCloud rivers, Battle and Mill creeks, and the Stanislaus River. Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the North Fork Feather River, Battle Creek and Mill Creek.

Long-term climate change considerations emphasize the importance of a recovery scenario that ultimately results in re-establishing viable populations in the spring-run Chinook salmon ESU. As depicted in Figure 5-2, candidate areas for reintroduction of spring-run Chinook salmon in the conceptual recovery scenario include:

Little Sacramento River
McCloud River
North Fork Feather River
North Fork Yuba River
Middle Fork Yuba River
South Fork Yuba River
North Fork American River
Middle Fork American River
South Fork American River
Mokelumne River
Middle Fork Stanislaus River
Tuolumne River
Merced River
San Joaquin River

In order to secure the extant populations of spring-run Chinook salmon, particularly in the near term, and to recover the spring-run Chinook salmon ESU in the long-term, several key actions associated with habitat restoration and reintroduction have been identified in the section titled Recovery Opportunities by Diversity Group, below. As previously described, numerous recovery actions are specific to the Sacramento River and the Delta, which serve as migratory corridors for populations of spring-run Chinook salmon spawning north of the Delta.

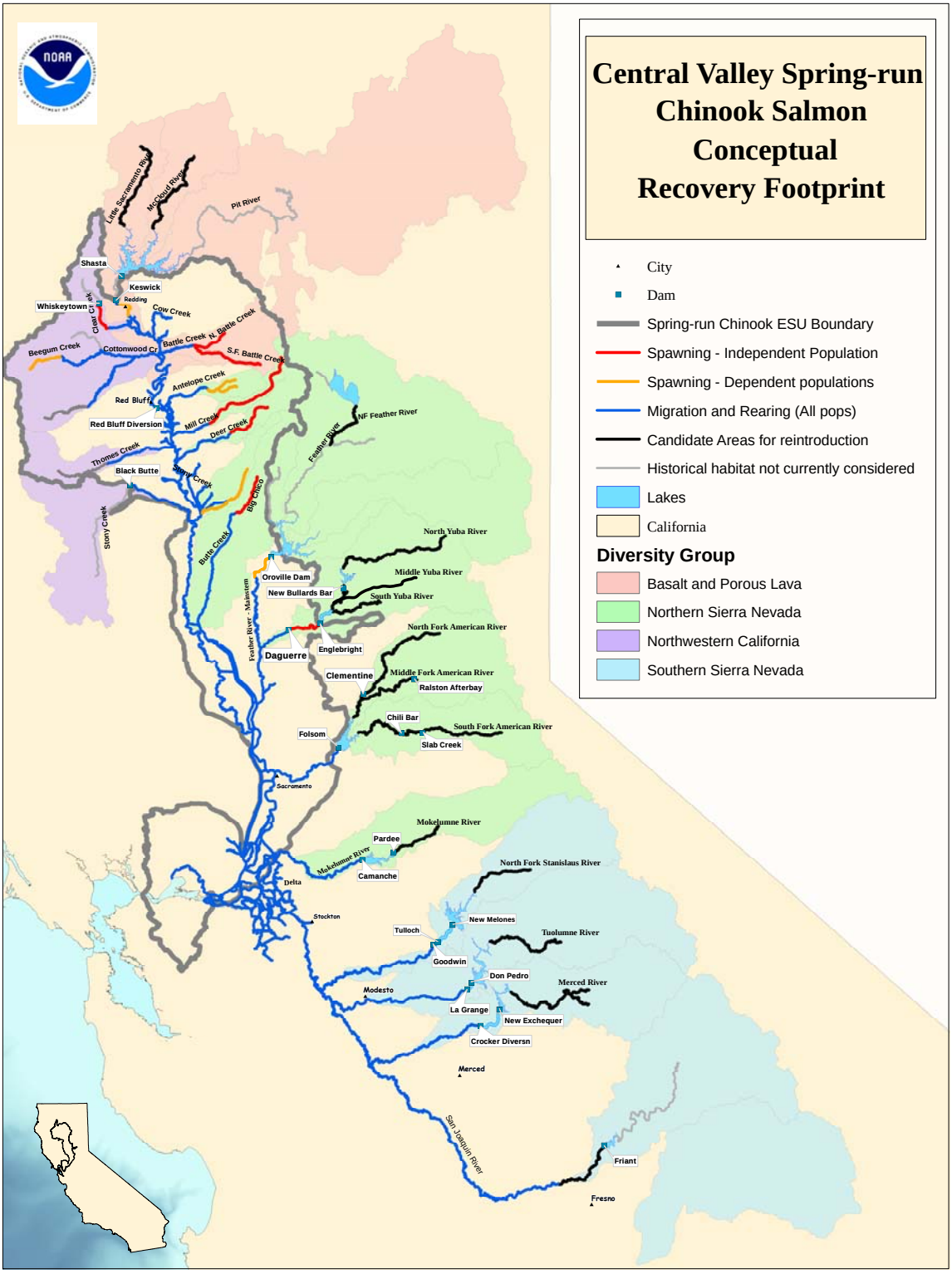


Figure 5-2 Central Valley Spring-run Chinook Salmon ESU Conceptual Recovery Footprint. The candidate areas for reintroduction that are depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning, and rearing still exist or could be restored.

Recovery Opportunities by Diversity Group

Basalt and Porous Lava Diversity Group

The conceptual recovery scenario includes maintaining and enhancing persistent populations in the Basalt and Porous Lava Diversity Group. Persistent populations are primarily limited to dependent populations in the Sacramento River below Keswick Dam and in Battle Creek. The scenario also includes maintaining and enhancing the more ephemeral and dependent populations in the smaller streams tributary to the upper mainstem Sacramento River by implementing actions which are previously described in each of the individual watershed profiles.

The spring-run Chinook salmon conceptual recovery scenario for the Basalt and Porous Lava Diversity Group also includes reintroduction of spring-run Chinook salmon to the candidate areas of the Little Sacramento and McCloud rivers. Reintroductions would be dependent upon successful passage programs above Keswick and Shasta dams.

The following discussion of recovery opportunities for the Basalt and Porous Lava Diversity Group within the conceptual recovery scenario does not explicitly include those watersheds characterized by having more ephemeral and dependent populations, those that would require significant restoration actions, those that generally have relatively low recovery potential (as described in the watershed profiles (Appendix A) and other preceding sections of this Recovery Plan), and/or those that are not considered candidate areas for reintroduction of spring-run Chinook salmon. Consequently, the following conceptual recovery scenario discussion for the Basalt and Porous Lava Diversity Group focuses on Battle Creek, the Sacramento River below Keswick Dam, and the Little Sacramento and McCloud rivers.

Battle Creek

Battle Creek has had persistent spawning populations of spring-run Chinook salmon in the reaches currently accessible on North Fork Battle and South Fork Battle creeks in recent years, although the populations have been relatively small. Currently, the Battle Creek Watershed has five dams blocking upstream migration of salmonids to much of the suitable and historic habitat. However, once complete, the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project) (CALFED 2007) will provide access to 21 miles of currently inaccessible historical habitat, and will restore and enhance a total of nearly 50 miles of habitat.

It is anticipated that the Battle Creek Watershed, once restored, will be a conservation stronghold for spring-run Chinook salmon (Reclamation et al. 2004). Battle Creek has been identified as having high potential for successful fisheries restoration, because of its relatively high and consistent flow of cold water (Newton et al. 2008). It has the highest base flow (i.e., dry-season flow) of any tributary to the Sacramento River between the Feather River and Keswick Dam (Ward and Kier 1999, as cited in Newton et al. 2008).

Battle Creek is characterized as having a high potential to support viable independent populations of spring-run Chinook salmon. In order to secure the extant population of spring-run Chinook salmon, particularly in the near term, several key habitat restoration actions have been identified, including the following:

Install state-of-the-art fish ladders at, or remove small dams on the North Fork Battle Creek to provide fish passage

- ❑ Install state-of-the-art ladders at, or remove small dams on the South Fork Battle Creek to provide fish passage

- Increase streamflows, and flow releases from remaining diversion dams affecting anadromous fish on Battle Creek as per the Restoration Project

- Develop HGMPs and control hatchery release timing, numbers and locations in Battle Creek to minimize adverse effects to wild stock

- Conduct a feasibility study of moving and/or modifying Coleman Hatchery operations to prevent adverse impacts to wild populations of spring-run Chinook salmon in Battle Creek

- The conceptual recovery scenario for Battle Creek includes securing long-term spring-run Chinook salmon populations by continuing the implementation of the near-term actions, as well as the successful reintroduction and establishment of viable independent spawning populations in North Fork Battle Creek and South Fork Battle Creek.

Mainstem Sacramento River Below Keswick Dam

Lindley et al. (2007) did not characterize spring-run Chinook salmon populations in the upper mainstem Sacramento River, although developing information suggests that some spring-run may be present in the river. NMFS considers the spring-run Chinook salmon population in the upper mainstem Sacramento River to be data deficient, and believes that additional information needs to be collected to better understand the potential for the river to support a viable population.

For currently occupied habitats between Keswick Dam and Red Bluff, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a population spring-run Chinook salmon can be improved and sustained with extensive long-term human intervention, including improvements to water temperature management and spawning gravel conditions. The potential to restore ecological processes capable of supporting spring-run Chinook salmon is low to moderate, primarily because the potential for reproductive isolation between spring-run Chinook salmon and fall-run Chinook salmon is complicated by overlapping migration and spawning periods.

Between Keswick Dam and Red Bluff, it is unlikely that currently occupied habitats can be restored to pre-dam conditions, but habitat can be improved and sustained. In order to secure the extant population of spring-run Chinook salmon and promote a viable population, several key near- and long-term actions have been identified, including the following:

- Achieve the daily average water temperature targets described in the Biological Opinion on the Long-Term Central Valley Project Operations Criteria and Plan (NMFS 2009)

- Implement a river flow management plan that balances carryover storage needs with instream flow needs for spring-run Chinook salmon based on runoff and storage conditions, including flow fluctuation and ramping criteria

- Use the best available data regarding spring-run Chinook salmon spawning habitat availability as a key consideration for determining Keswick Dam releases

- Develop a long-term strategy for monitoring and regulating discharges from agricultural lands to protect waters within the Central Valley, including enforcing the regulations

- Conduct periodic (e.g., every 5 years) spawning gravel assessments in the upper Sacramento River (i.e., above RBDD) and implement gravel augmentation projects, as necessary

The spring-run Chinook salmon conceptual recovery scenario also includes reintroduction of spring-run Chinook salmon to the candidate areas of the Little Sacramento and McCloud rivers. They both have a high potential to support spring-run Chinook salmon populations due to the number of connected miles of suitable spawning and rearing habitat. The Pit River has a low potential to support spring-run Chinook salmon populations due to the extensive presence of hydroelectric facilities that inundate or substantially affect historic habitat.

Northwestern California Diversity Group

As previously described, ESU recovery criteria includes a minimum of two viable populations of spring-run Chinook salmon within each of the four spring-run Chinook salmon Diversity Groups, with the exception of the Northwestern California Diversity Group. The Northwestern California Diversity Group historically did not contain independent spring-run Chinook salmon populations. For the Northwestern California Diversity Group, observed occupancy will suffice rather than viability for most of the watersheds included in this Diversity Group. However, the conceptual recovery scenario does include the establishment of an independent spawning population in Clear Creek above the current spawning distribution.

The Central Valley TRT postulated that all of the creeks in the Northwestern California Diversity Group may be dependant upon input of migrants from populations such as Deer, Mill and Butte creeks (Lindley et al. 2004). They further hypothesized that the group of streams in the Northwestern California Diversity Group operate as a metapopulation - i.e., individual populations may not be viable on their own, but migration among members of the group maintains persistence of the whole group. The classification of these populations as dependent does not mean that they have no role to play in the persistence or recovery of the Central Valley spring-run Chinook salmon ESU. If these populations are adapted to their unusual spawning and rearing habitats, they may contain a valuable genetic resource (perhaps being more tolerant of high temperatures than other spring-run Chinook salmon). These habitats and populations may also serve to link other populations in ways that increase ESU viability over longer time scales (Lindley et al. 2004). Thus, the conceptual recovery scenario includes maintaining and enhancing the more ephemeral and dependent populations in the smaller streams in the Northwestern California Diversity Group (e.g., Thomes and Beegum creeks) by implementing actions which are previously described in each of the individual watershed profiles.

Although possibly present historically, existing conditions in Stony Creek preclude the annual production of anadromous salmonids (H.T. Harvey and Associates 2007), including spring-run Chinook salmon. Excessively low flows and warm water temperatures in Stony Creek during all life stages prevents the successful production of spring-run Chinook salmon. Stony Creek is characterized as having a low potential to support viable populations of spring-run Chinook salmon. This characterization is based on the following factors: (1) the system does not currently support populations of spring-run Chinook salmon; (2) water diversions limit instream flows; (3) the watershed is at a relatively low elevation (Lindley et al. 2004) and, thus, instream flow inputs are in the form of rainfall, not snowmelt; and (4) water temperatures under the current climate may already be beyond the thermal requirements of coldwater species such as spring-run Chinook salmon,

and climate change is expected to increase water temperatures in the Central Valley (Lindley et al. 2007).

The conceptual recovery scenario also includes maintaining and enhancing persistent populations in the Northwestern California Diversity Group. Persistent populations are primarily limited to dependent populations in Clear Creek and Cottonwood/Beegum Creek.

The following discussion of recovery opportunities for the Northwestern California Diversity Group within the conceptual recovery scenario does not explicitly include those watersheds characterized by having more ephemeral (i.e., non-persistent) and dependent populations, those that would require significant restoration actions, and those that generally have relatively low recovery potential (as described in the watershed profiles and other preceding sections of this Recovery Plan) for spring-run Chinook salmon. Consequently, the following conceptual recovery scenario discussion for the Northwestern California Diversity Group focuses on Clear and Cottonwood/Beegum creeks.

Clear Creek

Clear Creek historically was not known to support a large Central Valley spring-run population. However, since 1998, spring-run Chinook salmon have shown an increasing trend in abundance. In 2000, a small dam was removed which opened up 12 miles of prime spawning habitat for spring-run Chinook salmon. Increasing abundance is due, in part, to the reliable cool water source diverted from the Trinity River watershed, released at Whiskeytown Reservoir (Reclamation 2008). In addition, the spring-run Chinook salmon population in Clear Creek has apparently responded to extensive restoration efforts by joint agency partnerships through such programs as CVPIA and CALFED.

The Clear Creek spring-run Chinook salmon population is presently considered persistent, although dependent upon input of migrants from populations such as Deer, Mill and Butte creeks. Indications that the Clear Creek population has a high potential to become a viable independent population with a low risk of extinction include low stray rates from hatchery produced salmonids, and a recent increase in the annual number of spring-run Chinook salmon migrating into the creek. A recent review of habitat potential on Clear Creek indicated carrying capacity estimates of 3,122 spring-run Chinook salmon (M. Brown, USFWS, pers. com.).

Clear Creek is characterized as having a high potential to support a viable independent population of spring-run Chinook salmon. Restoration efforts supporting this characterization include implementation of a long-term gravel augmentation plan, managed releases of optimal flows, maintaining water temperatures below 65°F year-round and recent extensive riparian, instream channel and floodplain restoration. In order to secure the extant population of spring-run Chinook salmon, particularly in the near-term, several key habitat restoration actions have been identified, including the following:

- Develop a spawning gravel budget and implement a long-term augmentation plan in Clear Creek, and use flow management to optimize spawning weighted usable area in consideration of hydrologic limitations and lifestage requirements

- Increase stream flows in Clear Creek as needed to reduce water temperatures

- Develop a real-time water temperature model to track the coldwater pool in Whiskeytown Reservoir and budget releases to Clear Creek to meet daily water temperature of 60ºF at the Igo gauge from June 1 to September 15,

and 56ºF from September 15 to October 31

- Develop and implement flow ramping protocols in Clear Creek to protect all lifestages of spring-run Chinook salmon

- Develop and implement optimal pulse flow schedules and increase flow allocation for Clear Creek in years with low water availability

The conceptual recovery scenario for Clear Creek includes securing a long-term spring-run Chinook salmon viable and independent population by continuing the implementation of the near-term actions.

Cottonwood/Beegum Creek

Cottonwood/Beegum Creek historically was not known to support a large Central Valley spring-run population. Cottonwood Creek itself does not contain suitable spawning habitat to support a spring-run Chinook salmon population. However, Beegum Creek, a tributary of Cottonwood Creek, has supported a small persistent population since 1998. Lindley et al. (2004) considers the Beegum Creek population to be dependant upon input of migrants from populations such as Deer, Mill and Butte creeks.

The Cottonwood/Beegum Creek Watershed is characterized as having a low potential to support a viable independent population of spring-run Chinook salmon. Spring-run Chinook salmon in the Cottonwood/Beegum Creek Watershed have a high risk of extinction. Spring-run Chinook salmon in Beegum Creek are limited to low elevation habitat that is thermally marginal now, and will become intolerable within decades if the climate warms as expected (Williams 2006). With the implementation of successful restoration efforts in the watershed to improve habitat, the risk of extinction of spring-run Chinook salmon may be reduced.

In order to secure the extant population of spring-run Chinook salmon, particularly in the near-term, several key habitat restoration actions have been identified, including the following:

- Develop and implement a spawning gravel augmentation plan in Beegum Creek

- Re-establish natural channel morphology in Cottonwood/Beegum Creek by: (1) applying NMFS gravel mining criteria to all gravel mining projects; (2) integrating natural morphological features and functions into bank protection and other stream side development projects; and (3) implementing non-native plant (e.g., Arundo) eradication plan

- Integrate riparian habitat restoration into bank protection and other stream-side development projects in Beegum Creek, and the greater Cottonwood/Beegum Creek Watershed

- Develop cooperative water use agreements (e.g., groundwater exchange agreements) with local water users to provide flows in Cottonwood Creek during the spring-run Chinook salmon adult immigration lifestage

- Enhance watershed resiliency in Beegum Creek by identifying and implementing projects that would: (1) reduce the potential for, and the magnitude of, a catastrophic wildfire; and/or (2) restore forested areas (including riparian areas) in the watershed

The conceptual recovery scenario for Cottonwood/Beegum Creek includes securing

a long-term spring-run Chinook salmon dependent population by continuing the implementation of the near-term actions.

Northern Sierra Nevada Diversity Group

The conceptual recovery scenario includes maintaining and potentially enhancing the presently viable populations (i.e., Deer, Mill, and Butte creeks) in the Northern Sierra Diversity Group. In addition, the scenario includes maintaining and enhancing persistent independent and dependent populations in this Diversity Group.

As previously discussed, the ESU recovery scenario includes the objectives of a minimum of two viable populations of spring-run Chinook salmon within each of the four spring-run Chinook salmon Diversity Groups. The Northern Sierra Nevada Diversity Group presently contains two or three viable populations of spring-run Chinook salmon. However, the present distribution of viable populations of spring-run Chinook salmon in the Northern Sierra Nevada Diversity Group renders them vulnerable to catastrophic disturbance. All viable populations are in watersheds whose headwaters lie within the debris and pyroclastic flow radii of Mt. Lassen. In addition, the viable populations in this Diversity Group are vulnerable to the catastrophic disturbances of drought and wildfires.

The spring-run Chinook salmon conceptual recovery scenario for the Northern Sierra Nevada Diversity Group also includes reintroduction of spring-run Chinook salmon to the candidate areas of the North Fork Feather River, North Fork Yuba River, Middle Fork Yuba River, South Fork Yuba River, North Fork American River, Middle Fork American River, South Fork American River and the Mokelumne River. In addition to considerations of historical distribution, current population status, and recovery potential (including restoration actions) of the individual watersheds, one of the factors taken into account in the identification of candidate reintroduction watersheds is long-term climate change. Reintroductions also would be dependent upon successful passage programs above the dams in these watersheds. For each of these candidate areas for reintroduction, passage feasibility studies, habitat suitability assessments and other related investigations are underway in separate processes (e.g., FERC relicensings), some of which are described in Appendix A (watershed profiles), or they need to be conducted. Hence, the conceptual recovery scenario does not further discuss specific considerations regarding these candidate reintroduction areas.

The following discussion of recovery opportunities for the Northern Sierra Nevada Diversity Group within the conceptual recovery scenario does not explicitly include those watersheds characterized by having more ephemeral and dependent populations, and/or those that are not considered candidate areas for reintroduction of spring-run Chinook salmon. Consequently, the following conceptual recovery scenario discussion for the Northern Sierra Nevada Diversity Group focuses on the presently viable populations, as well as presently occupied habitats that have opportunities to support viable populations of spring-run Chinook salmon with the implementation of specific restoration actions.

Antelope Creek

Antelope Creek historically was not known to support a large spring-run Chinook salmon population. Lindley et al. (2007) did not classify the viability of spring-run Chinook salmon in Antelope Creek, but instead characterized the population as dependant upon other populations for its existence (Lindley et al. 2004). The current extinction risk for this population is high, despite low hatchery influence.

Antelope Creek is believed to support a dependent population of spring-run Chinook salmon, although CDFG (1998) states that the Antelope Creek spring-run population is not persistent. The upper reaches of Antelope Creek are still fairly undeveloped and contain good salmonid habitats. Antelope Creek reportedly has the potential to produce a sustainable population of 2,000 spring-run Chinook salmon, although inadequate flows due to two low head diversion dams prevent runs from realizing this potential (Rectenwald 1998).

Antelope Creek is characterized as having a moderate potential to support a dependent population of spring-run Chinook salmon. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed in good condition.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of spring-run Chinook salmon in Antelope Creek. Those actions that are required are localized in nature and, when fully implemented, have a high likelihood of restoring good fish passage conditions. Antelope Creek is diverted into several channels below the Edward Diversion Dam. A single migration channel and fish passage flows need to be established to ensure that adult spring-run Chinook salmon have unimpeded access to upstream spawning habitat and juveniles have unimpaired downstream migration. Fish screens with suitable bypass flows also need to be installed at the Edward Dam. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy, although private timberland management plans lack a comprehensive anadromous habitat protection strategy.

In Antelope Creek the primary focus for spring-run Chinook salmon restoration is on improving flow conditions and fish passage for upstream migrating adults to access important holding and spawning habitat, and for outmigration of juveniles. In order to realize Antelope Creek's moderate potential to support a dependent population of spring-run Chinook salmon, and to secure the extant population of spring-run Chinook salmon in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- ❑ Restore instream flows during upstream and downstream migration periods
  - Develop water exchange agreements to provide alternative water supplies to Edwards Ranch and Los Molinos Mutual Water Company in exchange for instream fish flows

- ❑ Restore connectivity of the migration corridor during upstream and downstream migration periods
  - Implement Edwards and Penryn fish passage and entrainment improvement projects
  - Identify and define or construct a defined stream channel for upstream and downstream fish migration

- ❑ Restore the lower watershed riparian corridor

Mill Creek

Although Lindley et al. (2004) suggest that Mill Creek spring-run Chinook salmon populations were never very large historically, Mill Creek is recognized as supporting one of three remaining self-sustaining, viable spring-run Chinook salmon populations. Lindley et al. (2007) classified the Mill Creek spring-run Chinook salmon population as having a moderate risk of extinction according to the

PVA, but the population appears to satisfy the other viability criteria for low-risk status. Over the past three years, the abundance of the Mill Creek population has been in steep decline, and the extinction risk may be trending toward moderate to high. The Central Valley TRT did not conclude whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley spring-run Chinook salmon ESU.

Habitat used for holding and spawning is located at high elevations and is considered to be high quality (CDFG 1998). The high elevation habitats in Mill Creek are isolated from fall-run Chinook salmon by low summer and fall flows. High water temperatures prevent geographic co-occurrence, and the thermal gradient maintains genetic and phenotypic diversity of the populations.

Mill Creek is considered a conservation stronghold for the ESU. With the implementation of key recovery actions, the watershed has a high potential for sustaining an independent population of spring-run Chinook salmon at a low risk of extinction because: (1) Mill Creek contains a sufficient amount of holding and spawning habitat to support a population that meets the abundance criteria for viability; (2) hatchery influence is low and expected to decrease over time; and (3) the number and magnitude of recovery actions needed within the Mill Creek watershed are limited and localized.

The aquatic habitats in Mill Creek (along with Deer, Antelope, Battle and Butte Creeks) are among the best remaining habitat above the Central Valley floor for anadromous salmonids. Although diversion structures are present in the valley section of Mill Creek, there are no major water impoundments along the Mill Creek corridor. Fish have been able to maintain passage, and native fish communities have survived in the free-flowing sections.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of spring-run Chinook salmon in Mill Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. Those actions that are required are localized in nature and, when fully implemented, have a high likelihood of restoring or maintaining good fish passage conditions. A water exchange agreement already is in place between the CDFG and water users on Mill Creek. The programs are intended to develop and operate wells to offset bypass flows needed for spring-run Chinook salmon and to implement water use efficiency measures to reduce irrigation water demand. Although the agreement improves fish passage conditions for spring-run Chinook salmon, a comprehensive fish passage evaluation and monitoring plan has not been developed to assess the effectiveness of the agreement. Long-term verification of the flows, and an evaluation of existing dams for fish passage suitability are needed to ensure passage is provided at a wide range of stream flows. In the upper watershed, Federal land management practices are guided by a long-term anadromous fish conservation strategy, although private timberland management plans lack a comprehensive anadromous habitat protection strategy.

In Mill Creek the primary focus for spring-run Chinook salmon restoration is on maintaining flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for outmigration of juveniles. Mill Creek is characterized as having a high potential to support a viable independent population of spring-run Chinook salmon with the implementation of key restoration actions. In

order to secure an independent viable population of spring-run Chinook salmon in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Implement a Mill Creek anadromous fish passage study (AFRP Website 2005) that will evaluate fish passage at all agricultural diversions to determine if they meet NMFS' fish passage criteria. Design and install state-of-the-art fish passage facilities at diversions that currently do not meet the passage criteria

- Conduct a study designed to determine adult fish passage flows at critical riffles and fish ladders in Mill Creek. Develop a water exchange agreement with all Mill Creek water users to allow implementation of those flows

- Enhance watershed resiliency in Mill Creek by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade and reduce sources of chronic road-related erosion of sediment (Mill Creek Conservancy Watershed Report, U.S. Forest Service Long-term Anadromous Fish Conservation Strategy)

- Eliminate sources of chronic sediment delivered to Mill Creek from roads and other near stream development by out-sloping roads, replacing under-sized culverts and applying other storm proofing guidelines

- Work with State and Federal water acquisition programs to develop dedicated instream water; participate in the lower Mill Creek Watershed Restoration Project (AFRP Website 2005)

Deer Creek

Deer Creek is recognized as supporting one of three remaining self-sustaining, viable spring-run Chinook salmon populations, although Lindley et al. (2004) suggest that Deer Creek spring-run Chinook salmon populations were never very abundant historically, relative to spring-run Chinook salmon populations occurring in larger watersheds such as the Feather River. Lindley et al. (2007) classified the Deer Creek spring-run Chinook salmon population as having a low risk of extinction satisfying both the PVA and other viability criteria for low-risk status. The Central Valley TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley spring-run Chinook salmon ESU.

The high quality holding and spawning habitat located at high elevations, and high water temperatures in the lower section prevent geographic co-occurrence with fall-run Chinook salmon, maintaining the genetic and phenotypic diversity of the populations. Deer Creek is considered a conservation stronghold for the ESU. Similar to Mill Creek, with the implementation of key recovery actions, the watershed has a high potential for sustaining a population at a low risk of extinction because: (1) Deer Creek contains a sufficient amount of holding and spawning habitat to support a population that meets the abundance criteria for viability; (2) hatchery influence is low and expected to decrease over time; and (3) the number and magnitude of recovery actions

needed within the Deer Creek watershed are limited and localized.

The aquatic habitats in Deer Creek are among the best remaining habitat above the Central Valley floor for anadromous salmonids. Although diversion structures are present in the valley section of Deer Creek, there are no major water impoundments along the Deer Creek corridor. Fish have been able to maintain passage, and native fish communities have survived in the free-flowing sections.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of spring-run Chinook salmon in Deer Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. Those actions that are required are localized in nature and, when fully implemented, have a high likelihood of restoring or maintaining good fish passage conditions. Water exchange programs are presently underway or in development with cooperation irrigation districts. The programs are intended to develop and operate wells to offset bypass flows needed for spring-run Chinook salmon and to implement water use efficiency measures to reduce irrigation water demand. In the upper watershed, Federal land management practices are guided by a long-term anadromous fish conservation strategy, although private timberland management plans lack a comprehensive anadromous habitat protection strategy.

In Deer Creek the primary focus for spring-run Chinook salmon restoration is on maintaining flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for outmigration of juveniles. In particular, long-term fish passage improvements should be addressed by installing state-of-the-art passage facilities at the Cone-Kimball, Stanford Vina, and Deer Creek Irrigation District dams, and existing dam structures should be replaced with inflatable bladder dams that can be installed during the irrigation season and lowered during periods of high stream flow and bedload transport.

Deer Creek is characterized as having a high potential to support a viable independent population of spring-run Chinook salmon with the implementation of key restoration actions. In order to secure the extant population and support a viable independent population of spring-run Chinook salmon, several key habitat restoration actions have been identified, including the following:

- Develop and implement a water exchange agreement with the Deer Creek Irrigation Company and the Stanford-Vina Irrigation District and dedicate fish passage flows

- Construct state-of-the-art inflatable dams and install fish ladders that meet NMFS' adult fish passage criteria at the Cone-Kimball Diversion, Stanford-Vina Dam, and the Deer Creek Irrigation District Dam

- Implement watershed restoration actions that reduce sedimentation and thermal loading in low gradient headwater habitats of Deer Creek Meadows and Gurnsey Creek

- Enhance watershed resiliency in Deer Creek by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire

- Revise inland fishery management practices to eliminate the stocking of out-of-basin rainbow trout in Deer Creek in all waters upstream of Upper Deer Creek Falls

Big Chico Creek

Big Chico Creek historically was not known to support a large spring-run Chinook salmon population. Lindley et al. (2007) did not classify the viability of spring-run Chinook salmon in Big Chico Creek, but instead characterized the population as dependent upon migrants from other populations for its existence (Lindley et al. 2004). Spring-run Chinook salmon populations persist in Big Chico Creek, albeit at an annual population size in the tens or hundreds of fish, with no returning spawners in some years (NMFS 2009).

Because of the relatively low abundance and sporadic annual escapement of spring-run Chinook salmon, the extinction risk for this dependent population is high. Implementation of key recovery actions could improve conditions to reduce the risk of extinction.

Big Chico Creek is characterized as having a low to moderate potential to support a persistent population of spring-run Chinook salmon. Big Chico Creek is a small watershed with substantial urban impacts in the lower watershed. Big Chico Creek contains marginally suitable habitat for salmon that most likely was opportunistically used in the past by salmon and steelhead (Yoshiyama et al. 1996). However, the middle and upper watershed areas are not urbanized and much effort by local groups and land owners has been made to secure conservation easements along this portion of the river corridor. These easements protect the riparian zone from the impacts of long-term development. In addition, passage to the middle and upper watershed areas, where cooler water is found in the late summer, is provided by a ladder in Iron Canyon. There are plans to improve this fish ladder, which would be an important restoration activity to assist in securing the extant population.

With successful restoration efforts in Big Chico Creek, particularly in the lower sections of the creek and through improvements in the Iron Canyon fish ladder, the dependent population of spring-run Chinook salmon will be able to access upstream areas where cooler pools exist at Higgins Hole, an important summer holding area. In order to secure the dependent population of spring-run Chinook salmon in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Restore the lower watershed riparian corridor through native riparian planting, and improve off-channel refugia
- Improve the Iron Canyon Fish Ladder so that salmonids can pass at low summer flows

Butte Creek

Butte Creek is recognized as supporting one of three remaining self-sustaining, viable spring-run Chinook salmon populations. Lindley et al. (2007) classified the Butte Creek spring-run Chinook salmon population as having a low risk of extinction satisfying both the PVA and other viability criteria for low-risk status. Adult abundance has declined in recent years, but the population still remains strong and should still be considered to be at low risk of extinction.

Because the Butte Creek spring-run fish population is now considered persistent, independent and viable, the watershed is considered a conservation stronghold for spring-run Chinook salmon. Butte Creek is one of the most productive spring-run Chinook salmon streams in the Sacramento Valley (DWR 2005), and is one of only three streams (in addition to Mill and Deer creeks) that support a genetically distinct population of spring-run Chinook salmon (CDFG 1998).

Therefore, the viability of the Central Valley spring-run Chinook salmon ESU is reliant upon sustaining the Butte Creek spring-run Chinook salmon population.

Because of the low elevation of holding and spawning habitat in Butte Creek, historic water temperatures were likely too warm to support over-summering adult spring-run Chinook salmon and, hence, a self-sustaining population of spring-run Chinook salmon. Presently, cold water is imported from the upper West Branch Feather River, which creates habitat conditions that allow spring-run Chinook salmon to over-summer, spawn and successfully occupy Butte Creek.

The success of numerous restoration efforts that have been undertaken on Butte Creek are illustrated by the abundance of spring-run Chinook salmon that have been observed since 1998. Once impaired by numerous dams with poor fish passage facilities, no dedicated fish flows, and unscreened diversions, Butte Creek now provides state-of-the-art fish ladders and screens, and dedicated instream flows. However, elevated water temperature continues to pose a threat to holding adult spring-run Chinook salmon, particularly in consideration of long-term climate change.

Butte Creek is characterized as having a high potential to support a viable independent population of spring-run Chinook salmon with the implementation of key restoration actions. In order to secure the viable independent population of spring-run Chinook salmon in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Enhance watershed resiliency in Butte Creek by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade (U.S. Forest Service Long-term Anadromous Fish Conservation Strategy)
- Install state-of-the-art fish ladders at DWR Weir 2 and Willow Slough Weir
- Maintain state-of-the-art fish passage facilities at diversions in Butte Creek to meet NMFS' passage criteria
- Conduct an instream flow study in Butte Creek to identify a spawning habitat-flow relationship and to identify factors (e.g., substrate size and quality, velocity, water depth) limiting spawning habitat availability

Feather River

Lindley et al. (2007) characterized the spring-run Chinook salmon population in the Feather River as data deficient, and therefore did not characterize its viability. However, the existing spring-run Chinook population in the Feather River, including fish produced by the Feather River Hatchery, may be the only remaining representatives of this important ESU component. The Feather River Hatchery spring-run Chinook salmon stock ultimately may play an important role in the recovery of spring-run Chinook in the Feather River Basin.

The lower Feather River, below Oroville Dam, is characterized as having a moderate potential to support a viable independent population of spring-run Chinook salmon, primarily based on the presence of a hatchery-supported population that is known to reproduce naturally in the Low Flow Channel between River Miles 59 and 67. CWT information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices which have compromised

the genetic integrity of spring-run Chinook salmon.

Nonetheless, the recently signed Settlement Agreement for Licensing of the Oroville Facilities (March 2006) includes measures to improve the short- and long-term genetic management of the Feather River Hatchery, and measures to physically separate and isolate spring-run Chinook salmon from fall-run Chinook salmon.

For currently occupied habitats below Oroville Dam, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a population of spring-run Chinook salmon can be improved and sustained with extensive long-term human intervention, including improvements to water temperature management, habitat availability, spatial distribution and separation of spring- and fall-run Chinook salmon, and modified hatchery management. Implementation of the Settlement Agreement for the Oroville FERC license is expected to address these factors and considerably improve the habitat in the lower Feather River.

The spring-run Chinook salmon conceptual recovery scenario includes reintroduction of spring-run Chinook salmon to the candidate area of the North Fork Feather River. Reintroduction would be dependent upon successful passage programs above Oroville Dam. Regarding the candidate area for reintroduction above Oroville Dam, passage feasibility studies, habitat suitability assessments and other related investigations are underway in separate processes (e.g., FERC relicensing), some of which are described in Appendix A (watershed profile). Hence, the conceptual recovery scenario does not further discuss specific restoration actions associated with reintroduction.

In order to secure the extant population of spring-run Chinook salmon in the lower Feather River, several key near-term and the long-term habitat restoration actions have been identified, including the following:

- Increase lower Feather River stream flows as needed to reduce water temperatures for juvenile rearing
- Identify stream reaches that have been most altered by anthropogenic factors and reconstruct natural channel geometry scaled to current channel forming flows in the lower Feather River
- Implement Facilities Modifications(s) to achieve lower Feather River water temperatures at least as protective as those specified in Table 2 of the Settlement Agreement For Licensing of the Oroville Facilities
- Develop a spawning gravel budget, identify gravel starved areas, and implement an augmentation plan in the lower Feather River
- Implement the use of a temporary weir in the lower Feather River to spatially segregate spring-run Chinook salmon and fall-run Chinook salmon during spawning
- Determine the feasibility of providing access to habitat above the Fish Barrier Dam
- Develop a hatchery management plan for the Feather River Fish Hatchery, including specific criteria for operating as either an integrated or segregated hatchery
- Develop a spring-run Chinook salmon conservation hatchery program at the Feather River Fish Hatchery

Yuba River

Lindley et al. (2007) characterized the spring-run Chinook salmon population in the lower Yuba River as data deficient, and therefore did not characterize its viability. There is limited information on the current population size of spring-run Chinook salmon in the lower Yuba River, although ongoing monitoring is presently providing additional information. In general, the current data indicate that adult escapement of spring-run Chinook salmon is low relative to historical levels (NMFS 2007a). According to NMFS (2007a), infrared and videographic sampling on both ladders at Daguerre Point Dam from 2003 through 2007 has provided estimates of spring-run Chinook salmon numbers migrating into the lower Yuba River ranging from several hundred to over 1,200 fish. However, these numbers should be considered to be preliminary, minimum estimates, as periodic problems with the sampling equipment have resulted in periods when fish ascending the ladders were not counted, so it is likely that the actual numbers are higher than those reported. The detection of adipose fin clips on some of these fish indicates that they were hatchery strays, most likely from the Feather River Hatchery.

The lower Yuba River supports a persistent population of spring-run Chinook salmon that spawn in the lower Yuba River below the U.S. Army Corps of Engineers' (Corps) Englebright Dam. There is no hatchery located on the lower Yuba River - thus the genetic integrity of spring-run Chinook salmon may be largely uncompromised by hatchery influence, although some straying, most likely from the Feather River Hatchery into the lower Yuba River, does occur. The estimated abundance of adult spring-run Chinook salmon indicates that the population is at a moderate risk of extinction.

The lower Yuba River, below Englebright Dam, is characterized as having a high potential to support a viable independent population of spring-run Chinook salmon, primarily because: (1) flow and water temperature conditions are generally suitable to support all life stage requirements; (2) the river does not have a hatchery on it; (3) spawning habitat availability is believed not to be limiting; and (4) high habitat restoration potential (see the watershed profile).

For currently occupied habitats below Englebright Dam, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a viable independent population of spring-run Chinook salmon can be improved with provision of appropriate instream flow regimes, water temperatures, and habitat availability. Continued implementation of the Yuba Accord is expected to address these factors and considerably improve conditions in the lower Yuba River. Additional habitat improvements and restoration actions are anticipated to be addressed in the forthcoming Yuba County Water Agency FERC relicensing process.

The spring-run Chinook salmon conceptual recovery scenario also includes reintroduction of spring-run Chinook salmon to the candidate areas of the North Fork, Middle Fork and South Fork Yuba rivers. Reintroduction of anadromous salmonids above Englebright Dam has been the subject of recent and current investigations. Evaluation of habitat suitability for anadromous salmonids upstream of Englebright Dam was recently undertaken (DWR 2007), but those evaluations have yet to be finalized as part of the Upper Yuba River Watershed Studies Program. Currently, NMFS is evaluating the feasibility of providing passage for anadromous salmonids at Englebright Dam. Hence, the conceptual recovery scenario does not further discuss specific restoration actions associated with reintroduction.

In order to secure a viable independent population of spring-run Chinook salmon in the lower Yuba River, several key near-term and the long-term habitat restoration actions have been identified, including the following:

- Continue implementation of the Yuba Accord flow schedules to provide suitable habitat (flow and water temperature) conditions for all life stages
- Improve adult salmonid upstream passage at Daguerre Point Dam
- Improve juvenile salmonid downstream passage at Daguerre Point Dam
- Implement a spawning gravel augmentation program in the uppermost area (i.e., Englebright Dam to the Narrows) of the lower Yuba River
- Improve riparian habitats for juvenile salmonid rearing
- Create and restore side-channel habitats to increase the quantity and quality of off-channel rearing (and spawning) areas
- Implement projects to increase floodplain habitat availability to improve habitat conditions for juvenile rearing

Southern Sierra Nevada Diversity Group

Although spring-run Chinook salmon were extirpated from the Southern Sierra Nevada Diversity Group and this region is not included in the listed ESU, re-establishing wild populations in the San Joaquin River system would certainly contribute to the viability of spring-run Chinook salmon in the Central Valley.

The spring-run Chinook salmon conceptual recovery scenario for the Southern Sierra Nevada Diversity Group includes reintroduction of spring-run Chinook salmon to the candidate areas of the North Fork Stanislaus River above New Melones Dam, the Tuolumne River above Don Pedro Dam, the Merced River above New Exchequer Dam, and the San Joaquin River into presently unoccupied areas below Friant Dam. For each of these candidate areas for reintroduction, passage feasibility studies, habitat suitability assessments and other related investigations are or will be undertaken in separate processes (e.g., FERC relicensings, San Joaquin River Restoration Program), some of which are described in Appendix A (watershed profiles).

By 1928, the California Department of Fish and Game (CDFG) issued a bulletin reporting that there were "very few" salmon remaining in the San Joaquin River above the Merced River confluence and the "historical" salmon fishery that once existed had been "severely depleted" as a result of seasonal water diversions and the operation of upstream hydropower reservoirs. Since the 1950s, the remaining Chinook salmon in the watershed consist only of fall-run Chinook salmon populations found in major tributaries to the lower San Joaquin River. Because of these developments, which caused the extinction of the San Joaquin spring-run salmon population, several legal actions were taken in the case of *NRDC et al. v. Kirk Rodgers et al.*, and resulted in a 2006 Settlement that was termed the San Joaquin River Restoration Program (SJRRP). The SJRRP Settlement Process 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.

With implementation of these actions, the San Joaquin River Watershed below Friant Dam can be characterized as having a high potential to support a spawning population of reintroduced spring-run Chinook salmon. The high potential to support a viable population of spring-run is based upon successful re-introduction through the SJRRP program. This population will be an experimental population using Sacramento River basin stock while implementing various habitat improvements throughout the restoration area between Friant Dam and the Merced River confluence. The important factor that increases the chances of a successful reintroduction of Central Valley spring-run salmon into the system is the availability of cold water releases from Friant Dam. Habitat objectives for the restoration area along the San Joaquin River were developed to address physical habitat, stream flow, water temperature and water quality impairments (SJRRP 2009).

In order to establish and maintain populations of spring-run Chinook salmon in both the near-term and the long-term, several key habitat restoration actions have been identified in the SJRRP (2009) and include the following:

- ❑ Provide flows sufficient to ensure habitat connectivity and allow for unimpeded upstream passage and outmigration
  - Modify San Joaquin River and Eastside and Mariposa bypasses to create a low-flow channel suitable to support fish passage
  - Modify channels in Reaches 2B and 4B to increase flow capacity (low-flow or migration-flow capacity)
  - Implement Settlement flow schedule
  - Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary
  - Implement trap-and-haul operation to move Chinook salmon into suitable habitat areas when flows and/or habitat conditions are unsuitable

- ❑ Release flows sufficient to provide suitable Chinook salmon spawning depth and velocity
  - Implement Settlement flow schedule (see Action A3 of the 2009 Draft Fisheries Management Plan)
  - Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4 of the 2009 Draft Fisheries Management Plan)
  - Modify existing channel(s) to provide Chinook salmon spawning habitat

- ❑ Provide suitable flow for egg incubation and fry emergence
  - Implement Restoration Flows including hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4 of the 2009 Draft Fisheries Management Plan)

- ❑ Minimize juvenile entrainment losses
  - Screen Arroyo Canal to prevent fish losses
  - Construct Mendota Pool Bypass
  - Modify the Chowchilla Bypass Bifurcation Structure to reduce juvenile Chinook salmon entrainment
  - Fill and isolate the highest priority mining pits
  - Consolidate diversion locations

- ❑ Minimize losses to nonviable pathways and prevent adult migration delays
  - Implement temporary or permanent barriers at Mud and Salt sloughs or any other location deemed necessary
  - Screen Arroyo Canal to prevent fish losses (see Action D1 of the 2009 Draft Fisheries Management Plan)
  - Fill and isolate the highest priority mining pits (see Action D3 of the 2009 Draft Fisheries Management Plan)

- ❑ Eliminate fish passage barriers and minimize migration delays
  - Modify Sand Slough Control Structure
  - Modify Reach 4B headgate
  - Retrofit Sack Dam to ensure fish passage
  - Construct Mendota Pool Bypass (see Action D2 of the 2009 Draft Fisheries Management Plan)
  - Ensure fish passage is sufficient at all other structures and potential barriers
  - Implement a trap-and-haul operation to move Chinook salmon into suitable habitat areas when flows are inadequate (see Action A5 of the 2009 Draft Fisheries Management Plan)

- ❑ Provide suitable water temperatures for upstream passage, spawning, egg incubation, rearing, smoltification, and outmigration to the extent achievable considering hydrologic, climatic, and physical channel characteristics
  - Implement Settlement flow schedule (see Action A3 of the 2009 Draft Fisheries Management Plan)
  - Implement hydrograph flexibility, buffer flows, and use of additional purchased water, as necessary (see Action A4 of the 2009 Draft Fisheries Management Plan)
  - Fill and isolate the highest priority mining pits (see Action D3 of the 2009 Draft Fisheries Management Plan)

- ❑ Provide suitable water temperature releases
  - Modify Friant and Madera canals to provide suitable water temperature releases from Friant Dam

- ❑ Meet or exceed the genetic fitness goals for Chinook salmon
  - Select and manage genetically fit stock sources for Chinook salmon
  - Incorporate conservation practices in artificial propagation of Chinook salmon

- ❑ Provide and/or maintain suitable water quality
  - Implement Settlement flow schedule (see Action A3 of the 2009 Draft Fisheries Management Plan)
  - Support existing public outreach and education programs incorporating education on best management practices

- ❑ Minimize in-river harvest, unlawful take, and disturbance
  - Implement public outreach program to reduce unlawful take of Chinook salmon and disturbance associated with spawning habitat
  - Restrict seasonal access in sensitive river sections (i.e., spring-run Chinook salmon holding and

spawning habitat) and change current fishing regulation
- Increasing law enforcement in the Restoration Area will reduce unlawful harvest of Chinook salmon

- ❑ Minimize Chinook salmon redd superimposition
  - Determine if additional spawning habitat (i.e., augment gravel at existing riffles and other suitable locations) is necessary to sustain Chinook salmon populations
  - Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs (see Action I3 of the 2009 Draft Fisheries Management Plan)

- ❑ Minimize hybridization between spring-run and fall-run Chinook salmon
  - Modify operation of Hills Ferry Barrier or construct other temporary barriers to segregate Chinook salmon runs (see Action I3 of the 2009 Draft Fisheries Management Plan)
  - Increase the amount of Chinook salmon spawning habitat available to minimize overlap of runs and reduce hybridization

- ❑ Ensure sufficient quantity and quality of holding pool habitat to meet Restoration Goal
  - Implement Settlement flow schedule (see Action A3 of the 2009 Draft Fisheries Management Plan)
  - Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4 of the 2009 Draft Fisheries Management Plan)
  - Evaluate the quality and quantity of holding pool habitat

- ❑ Provide sufficient quantity and quality of spawning habitat for Chinook salmon
  - Implement Settlement flow schedule (see Action A3 of the 2009 Draft Fisheries Management Plan)
  - Implement hydrograph flexibility, buffer flows, flushing flows, and use of additional purchased water, as necessary (see Action A4 of the 2009 Draft Fisheries Management Plan)
  - Augment gravel at existing riffles and other suitable locations (see Action L1 of the 2009 Draft Fisheries Management Plan)
  - Modify channels to provide Chinook salmon spawning habitat (see Action B3 of the 2009 Draft Fisheries Management Plan)

- ❑ Minimize fine deposited and suspended sediment
  - Implement measures to clean Chinook salmon spawning gravel
  - Implement public outreach program (see Action J2 of the 2009 Draft Fisheries Management Plan)
  - Construct settling basins

- ❑ Ensure suitable quantity and quality of floodplain and riparian habitat to provide habitat and food resources for Chinook salmon and other fishes
  - Implement Settlement flow schedule (see Action A3 of the 2009 Draft Fisheries Management Plan)
  - Implement hydrograph flexibility, buffer flows, and use of additional

purchased water, as necessary (see Action A4 of the 2009 Draft Fisheries Management Plan)
    - Restore floodplain habitat
    - Create off-channel Chinook salmon rearing areas

- ❑ Ensure favorable conditions for food availability, growth, and development
    - Increase invertebrate production
    - Restore floodplain habitat (see Action Q3 of the 2009 Draft Fisheries Management Plan)

- ❑ Reduce predation of Chinook salmon by nonnative fishes and other aquatic organisms
    - Fill and isolate the highest priority mining pits (see Action D4 of the 2009 Draft Fisheries Management Plan)
    - Construct a low-flow channel (see Action A1 of the 2009 Draft Fisheries Management Plan)
    - Restore floodplain habitat (see Action Q3 of the 2009 Draft Fisheries Management Plan)
    - Reduce the number of nonnative predatory fishes in the Restoration Area
    - Create an increase in turbidity during juvenile downstream migration to reduce detection and therefore predation by piscivore fishes
    - Use pulse flows to displace nonnative predatory fishes in the Restoration Area

Although spring-run Chinook salmon historically were the most abundant in the San Joaquin River basin (Yoshiyama, et al 1996), spring-run were extirpated from San Joaquin Basin and below Friant Dam in the 1950's, and no clear genetic stock remains. A successfully re-introduced population in the mainstem San Joaquin River will require flexible management objectives that allow fish that express the run timing and holding patterns of spring-run Chinook salmon to adapt to the unique and local habitat characteristics that ultimately will select which fish are most suited to inhabit this reach of the river.

The conceptual recovery scenario for the Southern Sierra Nevada Diversity Group, and for the San Joaquin Basin in particular, is likely to be conservation-reliant, particularly in the near-term (five to ten generations). It seems highly unlikely that enough habitat can be restored, particularly in the near-term, such that the spring-run Chinook salmon ESU could be expected to persist without appropriate conservation management. Although spring-run Chinook salmon historically were the most abundant in the San Joaquin River Basin (Yoshiyama, et al), spring-run were extirpated from the San Joaquin Basin and below Friant Dam in the 1950's, and no clear genetic stock remains. Reintroduction of spring-run Chinook salmon in areas of the Southern Sierra Nevada Diversity Group probably most likely will require the use of artificial propagation as a source of fish. In the short term, establishing self sustaining populations that demonstrate the phenotypic life history traits of spring-run Chinook salmon may be the most realistic objective. Unique genetic diversity will likely take many generations to achieve.

Because spring-run Chinook salmon are anadromous, populations in the Southern Sierra Nevada Diversity Group would utilize the lower San Joaquin River downstream of the confluence with the Merced River and the Delta during adult upstream migration, and juvenile rearing and outmigration. The conceptual recovery scenario recognizes that the successful reintroduction of spring-run Chinook salmon populations would, in part, be influenced by conditions in the lower San Joaquin River and the Delta.

The technical memorandum regarding the San Joaquin River Reasonable and Prudent Alternative (RPA) in the 2009 NMFS OCAP BO recognizes the importance of the lower San Joaquin River and the Delta as part of the migratory/rearing corridor for populations originating in East Side tributaries, and contains specific actions. Although many of these actions were specifically listed as pertinent to Central Valley steelhead, similar considerations would apply to habitats used by spring-run Chinook salmon. For example, *Action Suite IV.2: Flow Management* of the Delta Division RPA specifies that adequate flows should be maintained in both the Sacramento River and San Joaquin River basins to increase survival of steelhead emigrating to the estuary from the San Joaquin River, and of spring-run Chinook salmon emigrating from the Sacramento River through the Delta. As another example, *Action IV.2.1: San Joaquin River Inflow to Export Ratio* of the Delta Division RPA is designed to reduce the vulnerability of emigrating steelhead within the lower San Joaquin River to diversion into the channels of the south Delta, and thereby increasing their risk of eventual entrainment at the export pumps due to the diversion of water by the export facilities in the south Delta (NMFS 2009).

Actions in the RPA, including management of river flows on the San Joaquin River, are intended to avoid jeopardy to the Central Valley steelhead population currently residing in the San Joaquin Basin and its tributaries. The RPA identifies actions that shall be implemented in consideration of maintaining appropriate river flows in the mainstem San Joaquin River at Vernalis that are beneficial to steelhead based on the life history requirements. Management of exports as part of the implementation of the OCAP RPA will enhance the benefits derived from increasing flows on the San Joaquin River (NMFS 2009). Other issues relevant to listed anadromous fish species in the San Joaquin River Basin and the Delta that are addressed by the RPA in the 2009 NMFS OCAP BO include, but are not limited to:

- Increasing survival of emigrating smolts from the tributaries into the main stem of the San Joaquin River
- Increasing survival of emigrating smolts through the main stem of the San Joaquin River downstream into the Delta
- Increasing survival of emigrating smolts through the Delta
- The role and influence of flow and exports on survival in these migratory reaches
- Selection of routes under the influence of flows and exports
- Identifying reach-specific mortality and or loss
- The effectiveness of experimental technologies, if any, *e.g.*, non-physical barrier ("bubble curtain")

5.4.6 Steelhead

Lindley et al. (2006) identify 81 historical independent populations of Central Valley steelhead in 48 watersheds, listed below.

<u>Watersheds with Historical Independent Populations</u>

American River
Antelope Creek
Battle Creek
Bear River (Sacramento R. tributary)
Bear River (Feather R. tributary)
Big Chico Creek
Coon Creek
Cosumnes River

Cottonwood Creek
Deer Creek (Kaweah R. tributary)
Del Puerto Creek
Elder Creek
Feather River
Kaweah River
Kern River
Kings River
Little Cow Creek
Lone Tree Creek
Los Banos Creek
Los Gatos Creek
Marsh Creek
McCloud River
Merced River
Mill Creek
Mokelumne River
Panoche Creek
Paynes Creek

The posited historical existence of 81 independent populations is likely to be an underestimate because large watersheds that span a variety of hydrological and environmental conditions, such as the Pit River, probably contained multiple populations (Lindley et al. 2006). Regardless, the distribution of many discrete populations across a wide variety of environmental conditions implies that the Central Valley steelhead DPS contained biologically significant amounts of spatially structured genetic diversity (Lindley et al. 2006). However, it appears that much of the historical diversity within Central Valley *O. mykiss* has been lost or is threatened by dams, which have heavily altered the distribution and population structure of steelhead in the Central Valley (Lindley et al. 2006).

Although there were once two different runs of steelhead (summer-run and winter-run) in the Central Valley (McEwan and Jackson 1996), the summer run has been all but extirpated due to a lack of suitable holding and staging habitat, such as coldwater pools in the headwaters of Central Valley streams, presently located above impassible dams (Lindley et al. 2006). Throughout the Central Valley (and in particular the Merced River, Tuolumne River, and upper Sacramento River) it is difficult to discriminate between adult anadromous and resident forms of *O. mykiss*, as well as their progeny (McEwan 2001), further complicating resource management agencies' understanding of steelhead distribution in the Central Valley (CDFG 2008).

Presently, steelhead populations in the Central Valley are critically depressed in most if not all rivers and streams (CDFG 2008). In many cases, particularly in the San Joaquin Basin, anadromy in *O. mykiss* populations may be nonexistent or too low to detect while resident *O. mykiss* populations in the same rivers have remained strong (CDFG 2008). Remnant steelhead populations are presently distributed through the mainstem of the Sacramento and San Joaquin rivers, as well as many of the major tributaries of these rivers. Steelhead presence in highly variable "flashy" streams and creeks in the Central Valley depend primarily on flow and water temperature, which can change drastically from year to year (McEwan and Jackson 1996). Recent spawner surveys of small Sacramento River tributaries (Mill, Deer, Antelope, Clear, and Beegum creeks; Moore 2001) and incidental captures of juvenile steelhead during Chinook salmon monitoring (Calaveras, Cosumnes, Stanislaus, Tuolumne, and Merced rivers) confirmed that steelhead are widespread, if not abundant, throughout accessible streams and rivers (Good et al. 2005).

For the Recovery Plan and this conceptual recovery scenario, 26 individual rivers/watersheds[5] in the Sacramento and San Joaquin river systems that historically and

[5] It is recognized that more than 26 individual rivers/watersheds exist that historically supported, and can currently support steelhead in the Central Valley. However, it is assumed that recovery of the Central Valley steelhead DPS is primarily dependent on the 26 populations included in the threats assessment (Appendix A).

currently support populations of steelhead were identified using literature describing the historical population structure of steelhead in the Central Valley (Lindley et al. 2006) and by using the best available professional knowledge of Central Valley salmonid biologists regarding the current distribution of steelhead. These 26 steelhead populations were categorized into four Diversity Groups based on the geographic structure described in Lindley et al. (2007), which are listed below.

- Basalt and Porous Lava Diversity Group
  - Battle Creek
  - Cow Creek
  - Small tributaries to the upper Sacramento River
  - Upper Sacramento River Mainstem
- Northwestern California Diversity Group
  - Cottonwood/Beegum Creek
  - Thomes Creek
  - Clear Creek
  - Stony Creek
  - Putah Creek
- Northern Sierra Nevada Diversity Group
  - Antelope Creek
  - Mill Creek
  - Deer Creek
  - Big Chico Creek
  - Butte Creek
  - Feather River
  - Bear River
  - Yuba River
  - Auburn Ravine/Coon Creek
  - Dry Creek
  - American River
- Southern Sierra Nevada Diversity Group
  - Mokelumne River
  - Calaveras River
  - Stanislaus River
  - Tuolumne River
  - Merced River
  - San Joaquin River Mainstem

Without demonstrably viable populations in any of the diversity groups that historically contained them, Central Valley steelhead fail the representation and redundancy rule for DPS viability. Extant populations in the Central Valley steelhead DPS span four ecoregions, including: (1) the Basalt and Porous Lava Diversity Group; (2) the Northwestern California Diversity Group; (3) the Northern Sierra Nevada Diversity Group; and (4) the Southern Sierra Nevada Diversity Group.

The conceptual recovery scenarios require that each Diversity Group within the Central Valley steelhead DPS must be represented, and population redundancy within the groups must be met to achieve Diversity Group recovery. Therefore, the recovery scenarios include the objectives of a minimum of two viable populations of steelhead within each of the four extant steelhead Diversity Groups (i.e., the Basalt and Porous Lava Diversity Group, the Northwestern California Diversity Group, the Northern Sierra Nevada Diversity Group and the Southern Sierra Nevada Diversity Group).

To meet the aforementioned objectives, the conceptual recovery scenario for the steelhead DPS (**Figure 5-3**) includes: (1) securing extant populations by implementing key habitat restoration actions, particularly in the near-term; and (2) establishment of viable independent populations in the DPS. The recovery scenario includes the identification of candidate reintroduction watersheds. In addition to considerations of historical distribution, current population status, and recovery potential (including restoration actions) of the individual watersheds, one of

the factors taken into account in the identification of candidate reintroduction watersheds is long-term climate change.

Long-term climate change is an additional consideration regarding the viability of the steelhead DPS and specific populations in the long-term. Global and localized climate changes, such as El Nino ocean conditions and prolonged drought conditions, may play an important role in the suitability of steelhead habitat and, hence, viability. As previously described in the spring-run Chinook salmon ESU conceptual recovery scenario, Lindley et al. (2007) postulated that mean summer air temperatures are expected to rise by at least 2°C, are expected to increase by around 5°C (9°F), and the less likely but still possible scenario of an 8°C (14.4°F) warming by the year 2100. Because spring-run Chinook salmon and steelhead both exhibit juvenile over-summer rearing as part of their lifehistory strategies, long-term climate change considerations are similar for both species. Therefore, under the expected warming of around 5°C, substantial steelhead habitat would be lost, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento and McCloud rivers, Battle and Mill creeks, and the Stanislaus River. Under the less likely but still possible scenario of an 8°C warming, steelhead habitat would be found only in the upper-most reaches of Battle Creek and Mill Creek.

Long-term climate change considerations emphasize the importance of a recovery scenario that ultimately results in re-establishing viable, independent populations in the steelhead DPS. Reestablishment of viable steelhead populations could be in watersheds currently occupied, or in candidate areas for reintroduction. As depicted in Figure5-3, candidate areas for reintroduction of steelhead in the conceptual recovery scenario include:

Little Sacramento River
McCloud River
North Fork Yuba River
Middle Fork Yuba River
South Fork Yuba River
North Fork American River
Middle Fork American River
South Fork American River
Mokelumne River
Middle Fork Stanislaus River
Tuolumne River
Merced River

In order to secure the extant populations of steelhead, particularly in the near-term, and to recover the steelhead DPS in the long-term, several key actions associated with habitat restoration and reintroduction have been identified in the section titled Recovery Opportunities by Diversity Group, below. As previously described, numerous recovery actions are specific to the Sacramento River, the lower San Joaquin River and the Delta, which serve as a migratory corridor for populations of steelhead spawning in rivers and streams in the Central Valley Domain. These key actions are previously described in the spring-run recovery scenario and therefore are not repeated here, nor are they reiterated in the conceptual recovery scenario discussions of steelhead Diversity Groups or individual populations.

Figure 5-3. Central Valley Steelhead DPS Conceptual Recovery Footprint. The candidate areas for reintroduction that are depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning, and rearing still exist or could be restored.

Recovery Opportunities by Diversity Group

The conceptual recovery scenario requires that each Diversity Group within the Central Valley steelhead DPS must be represented, and population redundancy within the groups must be met to achieve Diversity Group recovery. Therefore, the recovery scenario includes the objective of a minimum of two viable populations of steelhead within each of the four extant steelhead Diversity Groups (i.e., the Basalt and Porous Lava Diversity Group, the Northwestern California Diversity Group, the Northern Sierra Nevada Diversity Group and the Southern Sierra Nevada Diversity Group).

Presently, no viable independent steelhead populations have been identified in any of the Diversity Groups in the steelhead DPS, and for those populations that could be classified by the Central Valley TRT (Lindley et al. 2007) all are at high risk of extinction. Therefore, the conceptual recovery scenario includes securing extant populations in the near-term, and establishing spawning populations in numerous streams and rivers within individual Diversity Groups throughout the Central Valley Domain (see Figure 3). However, the proximity of many of these rivers and streams in the individual Diversity Groups may not result in the establishment of independent populations. Rather, most of these spawning populations may be dependant upon input of migrants from other independent populations, and may operate as a metapopulation. However, if these populations are adapted to spawning and rearing habitats unique to their specific stream or river, they may contribute a valuable genetic resource to their respective Diversity Groups, and may also serve to link other populations in ways that increase DPS viability over longer time scales (Lindley et al. 2004).

The recovery potential of the Central Valley steelhead DPS overall is considered to be low to moderate due to a lack of suitable habitat (e.g., cool water temperatures particularly during the over-summer juvenile rearing period) and restriction to areas below presently impassable barriers, inadequate status and trends data to assess Diversity Group and individual population viability, and the widespread stocking of hatchery fish (which could negatively impact wild steelhead populations). For Central Valley steelhead, improved distribution and abundance data are needed to refine specific recovery strategies for the DPS and its Diversity Groups. It also is important to better understand the role that resident *O. mykiss* play in population maintenance and persistence, and the relationship between resident and anadromous life-history forms. Considering that approximately 80 percent of the habitat that was historically available to anadromous steelhead is now behind impassable dams (Lindley et al. 2006), restoring access to historic habitat is needed to recover the DPS.

The following discussion of recovery opportunities within each Diversity Group does not explicitly include those watersheds characterized by having more ephemeral and dependent steelhead populations, those that would require significant restoration actions, those that generally have relatively low recovery potential (as described in the watershed profiles and other preceding sections of this Recovery Plan), and/or those that are not considered candidate areas for reintroduction of steelhead. Consequently, the following conceptual recovery scenario discussion for each Diversity Group focuses on the presently anticipated potential to establish future spawning populations, including all extant 26 populations, and candidate areas for reintroduction.

In consideration of the foregoing discussions regarding steelhead population data deficiencies, the following scenario represents some of the many possible combinations of populations, restoration actions, risk minimization and threat abatement. Different scenarios may fulfill the biological requirements

for recovery. It is expected that information brought forth in the 5- and 10-year status reviews of the steelhead DPS will lead to adjustments in recovery expectations and restoration actions and, thus, the following conceptual recovery scenario for each Diversity Group.

BASALT AND POROUS LAVA DIVERSITY GROUP

Extant populations of steelhead in the Basalt and Porous Lava Diversity Group are known or believed to occur in Battle Creek, Cow Creek, small tributaries to the upper Sacramento River (e.g., Stillwater, Churn, Sulphur, Salt, Olney and Paynes creeks) and the Upper Sacramento River (mainstem).

As previously discussed, no viable independent steelhead populations have been identified in the Basalt and Porous Lava Diversity Group, and all of them are at high risk of extinction. Nonetheless, one of the recovery goals is to secure and/or improve all extant populations. Lindley et al. (2007) state with the exception of Battle Creek, which has a long-running hatchery program, all of these populations are data deficient. However, local efforts to investigate steelhead presence, habitat utilization and restoration opportunities have been conducted or are ongoing in many watersheds including Olney, Salt, Sulphur, Stillwater, Churn, Bear, and Paynes creeks. All of these watersheds are believed to have habitat conditions of limited suitability for steelhead, would require significant restoration actions, generally have relatively low recovery potential (as described in the watershed profiles) or are data deficient. Consequently, the following conceptual recovery scenario discussion for the Basalt and Porous Lava Diversity Group focuses on Battle Creek, Cow Creek and the Sacramento River below Keswick Dam, as well as candidate areas for reintroduction including the Little Sacramento and McCloud rivers.

BATTLE CREEK

Battle Creek has had persistent spawning populations of steelhead in the reaches currently accessible on North Fork Battle and South Fork Battle creeks in recent years, although the populations have been relatively small. Currently, the Battle Creek Watershed has five dams blocking upstream migration of salmonids to much of the suitable and historic habitat. However, once complete, the Battle Creek Salmon and Steelhead Restoration Project (CALFED 2007) will provide access to 21 miles of currently inaccessible historical habitat, and will restore and enhance a total of nearly 50 miles of habitat.

It is anticipated that the Battle Creek Watershed, once restored, will be a conservation stronghold for steelhead (Reclamation et al. 2004). Battle Creek has been identified as having high potential for successful fisheries restoration, because of its relatively high and consistent flow of cold water (Newton et al. 2008). Battle Creek has been identified as offering the best opportunity for wild steelhead populations in the upper Sacramento River (McEwan and Jackson 1996). It has the highest base flow (i.e., dry-season flow) of any tributary to the Sacramento River between the Feather River and Keswick Dam (Ward and Kier 1999, as cited in Newton et al. 2008).

The Battle Creek Watershed is characterized as having a high potential to support a viable independent population of steelhead. In order to secure the extant population of steelhead, particularly in the near-term, several key habitat restoration actions have been identified, and are previously described in the spring-run Chinook salmon conceptual recovery scenario.

The conceptual recovery scenario for Battle Creek includes securing long-term steelhead populations by continuing the implementation of the near-term actions and the successful establishment of spawning populations in the Battle Creek Watershed including North Fork

Battle Creek, South Fork Battle Creek, Soap Creek and Panther Creek.

Cow Creek

As reported in the Cow Creek Watershed Assessment (SHN 2001), steelhead populations have not been estimated in Cow Creek. No specific studies have been conducted on Cow Creek to estimate the size of the steelhead spawning run, although CDFG estimated that Cow Creek historically supported annual spawning runs of up to 500 steelhead (SHN 2001). Adult steelhead have been observed in North Cow, Old Cow and South Cow creeks; however, it is unknown what percentage of the steelhead run utilizes the other tributaries (SHN 2001). During February to April of 2002 snorkel surveys were conducted in South Cow Creek, but no steelhead adults, carcasses or redds were identified (Moore 2003). During February to April of 2003, snorkel surveys and one walking survey in South Cow Creek, and one snorkel survey in Old Cow Creek were conducted to identify steelhead adults, carcasses and redds. Seven adult steelhead and two possible redds were identified in South Cow Creek (Moore 2003).

The Cow Creek Watershed is considered to have a moderate potential to support a viable population of steelhead. Most steelhead spawning in South Cow Creek probably occurs above South Cow Creek diversion. The best spawning habitat occurs in the 5-mile reach of stream extending from about 1.5 miles below South Cow Creek Diversion Dam to 3.5 miles above the diversion dam (Healy 1997, as cited in SHN 2001). Additional spawning habitat occurs upstream of this reach, but it is much less abundant. Sightings of adult steelhead have been made at the South Cow Creek Campground (approximately 8.5 miles upstream of the South Cow Creek Diversion Dam) and in Atkins Creek, located just upstream from the campground (SHN 2001).

Cow Creek has been identified by CDFG and USFWS as a candidate for restoration of anadromous fisheries (SHN 2001). Cow Creek and its tributaries have been characterized as in "relatively good condition" regarding salmon and steelhead spawning habitat (SHN 2001). As previously discussed in the watershed profile, there are sections throughout the watershed that appear to have suitable water temperatures year-round (primarily in the upper reaches of Old Cow and South Cow creeks), and that overall the habitat appeared to be suitable for spawning adult and rearing juvenile steelhead, with no definite barriers to anadromy. Yet, many Cow Creek Watershed areas do not have suitable habitat, sufficient flows (with over 20 unscreened diversions in the watershed), or suitable juvenile steelhead rearing water temperatures. Restoration actions in the watershed have addressed fish passage and entrainment issues. In addition, a hydropower project has filed decommission plans, which will return flows to their natural state, and remove specific passage impediment and entrainment concerns. Nonetheless, extensive restoration is needed in the Cow Creek Watershed for a steelhead population to persist.

The conceptual recovery scenario includes maintaining a spawning population in the Cow Creek Watershed. Implementation of key recovery actions could improve the population viability of steelhead in the Cow Creek Watershed by reducing the risk of extinction to moderate. These actions include:

- Investigate measures to increase flows in Cow Creek and tributaries, such as: (1) investigating opportunities to increase irrigation efficiency; (2) managing vegetation to improve water supply and timing of supply; (3) purchasing water or water rights from willing sellers; (4) removing or laddering diversions; (5) providing alternate water sources during important periods; and (6)

implementing a conjunctive use program

- Conduct feasibility analyses and prioritize screening and laddering five agricultural diversions in Cow Creek
- Install water temperature recorders at select locations in Cow Creek; develop recommendations for minimum instream flow based on temperature needs
- Implement projects to increase floodplain habitat availability to improve juvenile rearing habitat, and restore instream and riparian habitat in Cow Creek
- Implement actions (e.g., spawning gravel augmentation) designed to increase spawning habitat availability and complement flows in Cow Creek
- Enhance watershed resiliency in Cow Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas

Mainstem Sacramento River Below Keswick Dam

Lindley et al. (2007) did not characterize steelhead populations in the upper mainstem Sacramento River. Although large numbers of resident O. mykiss are present, little is known about potential anadromy in this population. NMFS considers the steelhead population in the upper mainstem Sacramento River to be data deficient, and believes that additional information needs to be collected to better understand the potential for the river to support a viable population.

For currently occupied habitats between Keswick Dam and Red Bluff, it is unlikely that habitats can be restored to pre-dam conditions. The potential to restore ecological processes capable of supporting steelhead is low to moderate, primarily because water temperatures and flow regimes to support the summer spawning of winter-run Chinook salmon may discourage anadromy for steelhead.

The conceptual recovery scenario includes reintroduction of steelhead into candidate areas of the Little Sacramento and McCloud rivers. They have a high potential to support steelhead populations due to the number of connected miles of suitable spawning and rearing habitat. The Pit River has a low potential to support steelhead populations due to the extensive presence of hydroelectric facilities that inundate or substantially affect historic habitat.

In order to secure the extant population of steelhead, particularly in the near-term, several key habitat restoration actions have been identified, and the previously described actions in the spring-run Chinook salmon conceptual recovery scenario also pertain to steelhead.

Northwestern California Diversity Group

Extant populations of steelhead in the Northwestern California Diversity Group are known or believed to occur in Clear Creek, Cottonwood/Beegum Creek, Thomes Creek and Putah Creek. As previously discussed, no viable independent steelhead populations have been identified in the Northwestern California Diversity Group and all of them are at high risk of extinction, but one of the recovery goals is to secure and/or improve all extant populations.

Lindley et al. (2007) state that all of these populations are data deficient. However, local efforts to investigate steelhead presence, habitat utilization and restoration opportunities have been conducted or are ongoing in many watersheds including Clear, Cottonwood/Beegum, and Thomes creeks. Each

of these creeks supports extant populations of steelhead, and are characterized as having moderate to high potential to support steelhead recovery.

By contrast, although possibly present historically, existing conditions in Stony Creek preclude the annual production of steelhead (H.T. Harvey and Associates 2007). Excessively low flows and warm water temperatures in Stony Creek during all life stages prevents the successful production of steelhead (H.T. Harvey and Associates 2007). Stony Creek is characterized as having a low potential to support viable populations of steelhead. This characterization is based on the following factors: (1) the system does not currently support populations of steelhead; (2) water diversions limit instream flows; (3) the watershed is at a relatively low elevation (Lindley et al. 2004) and, thus, instream flow inputs are in the form of rainfall, not snowmelt; and (4) water temperatures under the current climate may already be beyond the thermal requirements of coldwater species such as steelhead, and climate change is expected to increase water temperatures in the Central Valley (Lindley et al. 2007).

Consequently, the following conceptual recovery scenario discussion for the Northwestern California Diversity Group focuses on Clear, Cottonwood/Beegum, Thomes and Putah creeks.

Clear Creek

Clear Creek historically was not known to support a large Central Valley steelhead population. However, removal of the McCormick-Saeltzer Dam in 2000 has provided steelhead access to an additional 12 miles of habitat (NMFS 2009). In recent years, a multi-phase restoration project (i.e., The Lower Clear Creek Floodway Rehabilitation Project) has been implemented on lower Clear Creek. One of the actions has included spawning gravel augmentation, which has improved suitable habitat for steelhead (NMFS 2009). Spawning distribution has recently expanded from the upper 4 miles to throughout the 18 miles of Clear Creek, although it appears to be concentrated in areas of newly added spawning gravels (NMFS 2009). Steelhead redd surveys conducted since 2001 indicate a small but increasing population resides in Clear Creek, with the highest density in the first mile below Whiskeytown Dam (USFWS 2007a, as cited in NMFS 2009).

During the summer months, flows in Clear Creek are maintained to provide adequate water temperatures for rearing steelhead. Water temperatures in Clear Creek at the USGS Igo gaging station (RM 10.85) are maintained below 65°F year-round due to releases of cool Whiskeytown Reservoir water diverted from the Trinity River (Reclamation 2008).

The Clear Creek steelhead population is presently considered persistent, although dependent upon input of migrants from populations such as Deer, Mill and Butte creeks. No hatchery steelhead (i.e., presence of adipose fin-clip) were observed during the 2003-2007 kayak and snorkel surveys, suggesting that straying of hatchery steelhead into Clear Creek is probably low (USFWS 2008a). Indications that the Clear Creek steelhead population has a high potential to become a viable independent population with a low risk of extinction include low stray rates from hatchery produced salmonids, provision of suitable water temperatures year-round, a recent increase in the annual number of steelhead migrating into the creek and spawning, and a recently implemented and ongoing habitat restoration program. A recent review of habitat potential on Clear Creek indicated a carrying capacity estimate of 7,292 steelhead (M. Brown, USFWS, pers. com., 2009).

Clear Creek is characterized as having a high potential to support a viable independent population of steelhead. Restoration efforts supporting this characterization include

implementation of a long-term gravel augmentation plan, managed releases of optimal flows, maintaining water temperatures below 65°F year-round and recent extensive riparian, instream channel and floodplain restoration. In order to secure the extant population of steelhead, particularly in the near-term, and to promote a viable independent population of steelhead in the long-term, several key habitat restoration actions have been identified, and the previously described actions in the spring-run Chinook salmon conceptual recovery scenario also pertain to steelhead.

Cottonwood/Beegum Creek

Cottonwood Creek is one of the major tributaries to the Sacramento River system that supports steelhead spawning (CH2MHILL 2002). Because they migrate during high flows, and it is difficult to distinguish juvenile steelhead from resident rainbow trout, few steelhead population estimates have been recorded in Cottonwood Creek (CH2MHILL 2002). The USFS and CDFG have observed populations of juvenile steelhead in the upper South Fork Cottonwood Creek Yolla Bolly Middle Eel Wilderness Area in the summer of 1976 (CH2MHILL 2002). Small runs of adult steelhead have been observed to migrate in the mainstem and lower reaches of the North, Middle, and South Fork Cottonwood Creek.

The Cottonwood Creek Watershed remains relatively undeveloped and is essentially unregulated. The Beegum Creek watershed is generally forest-covered and has not been significantly modified (D. Killam, CDFG, pers. comm. 2009).

The Cottonwood Creek Watershed, including Beegum Creek has a moderate potential to support a viable population of steelhead. It is likely, however, that steelhead populations in the watershed will remain dependent upon input of migrants from populations such as Deer, Mill and Butte creeks. Although comprehensive population abundance data are not available, there is a widespread presence of O. mykiss throughout the watershed, and it is currently designated as critical habitat for steelhead.

Sections of the Cottonwood Creek watershed, such as the middle fork, south fork, and Beegum Creek contain more suitable habitat than other areas within the watershed, and have the potential to support steelhead populations. However, thermal conditions in the Cottonwood/Beegum Creek Watershed may become unsuitable for steelhead within decades if the climate warms as expected. Nonetheless, with the implementation of successful restoration efforts in the watershed to improve habitat, the risk of extinction of steelhead may be reduced, particularly in the near-term.

The conceptual recovery scenario for Cottonwood/Beegum Creek includes establishing spawning populations of steelhead in the North, Middle, and South Fork Cottonwood Creek, and Beegum Creek. In order to secure the extant population and to establish spawning populations of steelhead in the Cottonwood/Beegum Creek Watershed, particularly in the near-term, several key habitat restoration actions have been identified, and the previously described actions in the spring-run Chinook salmon conceptual recovery scenario also pertain to steelhead.

Thomes Creek

Consistent monitoring of the fish populations in Thomes Creek has not occurred and, therefore, little information is available regarding utilization of Thomes Creek by steelhead. As reported by TCRCD (2006), in 1982, 22 species of fish were recorded within various portions of Thomes Creek (Brown et. al. 1983 as cited in CALFED 2000a). Steelhead were reported to be the most abundant fish species above the "Gorge". However, these fish were likely rainbow trout, as there is an andromous fish barrier a short distance above the "Gorge" (TCRCD 2006).

The Thomes Creek watershed has limited habitat availability for fishery resources. Flows in Thomes Creek tend to rise quickly following storm events, drop equally promptly following storms, and carry very large quantities of sediment (TCRCD 2006). The snowpack in this watershed results in relatively light warm-season runoff, resulting in perennial upper stream reaches, mid-reach sections that may be dry in mid-summer, and lower reaches near the Sacramento River that may contain small amounts of water from irrigation run-off (TCRCD 2006). Thomes Creek is usually dry or intermittent below the USGS stream gage near Paskenta until the first heavy fall rains occur (DWR Website 2007).

There are no significant dams on Thomes Creek other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream (DWR Website 2007). Combined, seasonal diversions reduce instream flows and presumably result in undocumented levels of entrainment. Additionally, gravel mining downstream of the Tehama-Colusa Canal siphon crossing has reportedly resulted in a partial barrier to salmonids returning to Thomes Creek to spawn (Vestra Resources, Inc. 2006).

In May 2004 CDFG determined that an impassible barrier to Chinook salmon and steelhead exists at the point immediately above the confluence of the stream with Horse Trough Creek (Barron, pers. comm., 2005, as cited in TCRCD 2006). This location is approximately 9 miles upstream from Paskenta and at an elevation of approximately 1,500 feet (TCRCD 2006).

During most years, water temperatures during the summer months likely limit the suitability of juvenile steelhead over-summer rearing. In addition, the lower reach of Thomes Creek has been significantly altered by the construction of flood control levees and bank protection measures (i.e., riprapping) (CALFED 2000b), resulting in reduced habitat availability for juvenile salmonids.

Headwaters of the streams in the Tehama West Watershed, including Thomes Creek, have relatively little, if any, drainage area with significant snowpack (TCRCD 2006). However, the upper-most elevation of Thomes Creek exceeds 5,000 feet and during some years may have significant snowpack.

Thomes Creek is characterized as having a low to moderate potential to support a steelhead population because: (1) it is uncertain whether Thomes Creek currently supports an extant population of steelhead; (2) the watershed has limited area at higher elevation and is highly dependent on rainfall, rather than having a large snowpack to provide inputs of cool snowmelt during the spring (Lindley et al. 2004); (3) an impassible barrier to steelhead exists at an elevation of approximately 1,500 feet, located approximately 9 miles upstream from Paskenta; (4) water diversions limit instream flows and also affect fish passage; and (5) with the possible exceptions of the highest elevation reach of Thomes Creek and upstream tributaries, water temperatures under current conditions may already be beyond the thermal requirements of steelhead, particularly during the over-summer rearing life stage, and climate change is expected to increase water temperatures in the Central Valley (Lindley et al. 2007).

The conceptual recovery scenario for Thomes Creek includes establishing spawning populations of steelhead in the perennial reaches of upper Thomes Creek and the upstream tributaries of Fish Creek and Willow Creek. It is likely, however, that steelhead populations in the watershed will be dependent upon input of migrants from populations such as Deer, Mill and Butte creeks.

In order to establish and support spawning populations of steelhead in the Thomes Creek Watershed, several key habitat restoration

actions have been identified, including the following.

- Conduct a feasibility study on potential channel modifications that would improve upstream migration conditions in Thomes Creek
- Enhance watershed resiliency in Thomes Creek by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade
- Develop and implement a spawning gravel augmentation plan in Thomes Creek
- Implement projects to increase floodplain habitat availability in Thomes Creek to improve juvenile rearing habitat
- Re-establish natural channel morphology in Thomes Creek by: (1) applying NMFS gravel mining criteria to all gravel mining projects; (2) integrating natural morphological features and functions into bank protection and other stream side development projects; and (3) implementing non-native plant (e.g. Arundo) eradication plan

PUTAH CREEK

Anadromous steelhead are considered to have historically spawned in the upper tributaries flowing into Putah Creek above the Berryessa Valley (now Lake Berryessa) but there have been no recently confirmed reports of anadromous steelhead in the creek. Two structures, the Putah Diversion Dam and Monticello Dam, completely block migration into historic spawning and rearing areas in the interdam reach and as far upstream as the Berryessa Valley. Migratory rainbow trout with a steelhead-like life history continue to spawn in the upper tributaries.

Putah Creek is characterized as having a low potential to support a steelhead population. On May 23, 2000, following 10 years of litigation related to stream flows for supporting fish and other natural resources, Putah Creek Council, City of Davis, and UC Davis signed onto an historic water accord with the Solano County Water Agency, Solano Irrigation District, and other Solano water interests to establish permanent surface water flows for the 23 miles of Putah Creek below the Putah Diversion Dam. One element of the Accord is to provide permanent seasonal instream flows for anadromous steelhead.

The supplemental flow regime, although designed primarily to benefit salmon, may be adequate for rearing juvenile steelhead as well. Adult steelhead may make it up the stream under high winter flows, but it is likely that in most years flows from December to February are too low to attract steelhead, unless water is spilling from Lake Berryessa.

The conceptual recovery scenario for steelhead in the Northwestern California Diversity Group includes a spawning population of steelhead in a small reach located proximate to the Putah Diversion Dam. It is likely, however, that steelhead populations in Putah Creek will be dependent upon input of migrants from populations originating from upstream areas in the Sacramento Valley. In order to secure a spawning population of steelhead in Putah Creek, several key restoration actions have been identified, including the following.

- Develop and implement fish passage improvements at Solano and Montecello dams
- Develop and implement measures to improve flow conditions and reduce flow fluctuations

- Develop and implement spawning gravel augmentation plans
- Develop and implement habitat restoration measures to improve floodplain habitat, natural river morphology, and riparian habitat and instream cover
- Implement measures to improve water quality

NORTHERN SIERRA NEVADA DIVERSITY GROUP

Extant populations of steelhead in the Northern Sierra Diversity Group are known or believed to occur in Antelope Creek, Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, Feather River, Yuba River, Bear River, Auburn Ravine/Coon Creek, Dry Creek, and the American River. As previously discussed, no viable steelhead populations have been identified in the Northern Sierra Diversity Group and all of them are either data deficient or at high risk of extinction. However, one of the recovery goals is to secure and/or improve all extant populations.

Local efforts to investigate steelhead presence, habitat utilization and restoration opportunities have been conducted or are ongoing in most of these watersheds, which are generally characterized as having moderate to high potential to support steelhead recovery. The exceptions are Big Chico Creek with a low to moderate recovery potential, and the Bear River with a low recovery potential for steelhead. Lindley et al. (2006) identified those few streams where historical habitat may still be accessible as likely candidates for conservation actions. In the Northern Sierra Nevada Diversity Group, this includes Mill, Deer, and Butte creeks.

The conceptual recovery scenario also includes establishing a spawning population of steelhead in the upper reaches of the Cosumnes River. However, the Cosumnes River does not currently support an extant population of steelhead, and previous efforts to promote the establishment of populations in the Cosumnes River have not been successful. Therefore, the Cosumnes River should be characterized as having a low recovery potential for steelhead, is a lower priority relative to other rivers and creeks within this diversity group, and is not discussed further in the recovery scenario.

The steelhead conceptual recovery scenario for the Northern Sierra Nevada Diversity Group also includes the reintroduction of steelhead to the candidate areas of the North Fork Yuba River, Middle Fork Yuba River, South Fork Yuba River, North Fork American River, Middle Fork American River, and the South Fork American River. In addition to considerations of historical distribution, current population status, and recovery potential (including restoration actions) of the individual watersheds, one of the factors taken into account in the identification of candidate reintroduction watersheds is long-term climate change. Reintroductions also would be dependent upon successful passage programs above the dams in these watersheds. For each of these candidate areas for reintroduction, passage feasibility studies, habitat suitability assessments and other related investigations are underway in separate processes (e.g., FERC relicensings), some of which are previously described in the watershed profiles, or they need to be conducted. Hence, the conceptual recovery scenario does not further discuss specific considerations regarding these candidate reintroduction areas.

ANTELOPE CREEK

Although comprehensive population abundance data are not available, Antelope Creek is believed to support a population of steelhead. *O. mykiss* are widely distributed throughout the Antelope Creek watershed, with up to several thousand fish per mile in some reaches (M. Berry, pers. com. 2005).

Antelope Creek has a high potential to support a viable population of steelhead. The upper reaches of Antelope Creek are still fairly undeveloped. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. The characterization of having a high recovery potential for steelhead is based on: (1) the existing wide distribution of steelhead throughout the watershed; (2) the quality of existing spawning and rearing habitat; (3) Federal land management strategies that protect, maintain, and restore anadromous habitat within important parts of the upper watershed; (4) the small channel characteristics with up to 20 miles of suitable steelhead spawning habitat; and (5) water temperatures that support spawning and rearing.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of steelhead in Antelope Creek. Those actions that are required are localized in nature and, when fully implemented, have a high likelihood of restoring good fish passage conditions. Antelope Creek is diverted into several channels below the Edward Diversion Dam. A single migration channel and fish passage flows need to be established to ensure that adult steelhead have unimpeded access to upstream spawning habitat and juveniles have unimpaired downstream migration. Fish screens with suitable bypass flows also need to be installed at the Edward Dam. In the upper watershed, Federal land management practices are guided by a long-term anadromous fish conservation strategy, although private timberland management plans lack a comprehensive anadromous habitat protection strategy.

The conceptual recovery scenario for Antelope Creek includes the establishment of spawning populations in the upper reaches of the creek as well as the North and South Forks of Antelope Creek. Approximately 2 and 3 miles of steelhead habitat are available on the North and South Forks of Antelope Creek, respectively, above their confluence (Armentrout et al. 1998). Steelhead habitat is relatively unaltered in these areas, but lack of adequate migratory attraction flows into the Sacramento River to this habitat prevents optimum use by anadromous fish (DWR 2009).

In Antelope Creek the primary focus for steelhead restoration is on improving flow conditions and fish passage for upstream migrating adults to access important holding and spawning habitat, and for outmigration of juveniles. In order to realize Antelope Creek's high potential to support a viable population of steelhead, and to secure the extant population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead.

Mill Creek

With the exception of some limited data on run size and timing, information regarding the status of the steelhead population in Mill Creek is generally lacking. CDFG has not systematically monitored steelhead escapement into Mill Creek since the spring of 1963, when reported escapement was 2,269 (Killam and Johnson 2008). More recently, observations using a video weir in Mill Creek from early March through mid-June 2007 indicated that peak upstream and downstream steelhead passage occurred from May 8-10, 2007 (Killam and Johnson 2008). This may represent the presence of two runs of steelhead in Mill Creek, with one run exiting the system while another run is entering the system during May (Killam and Johnson 2008). During the 2007-2008 juvenile steelhead outmigration monitoring period, 297 steelhead were captured in the Mill Creek RST from mid-October 2007 through early June 2008 (Harvey-Arrison 2008).

Mill Creek is considered a conservation stronghold for the Central Valley steelhead DPS. With the implementation of key recovery actions, the watershed has a high potential for sustaining a viable steelhead population because: (1) Mill Creek contains an extensive amount of suitable spawning and rearing habitat; (2) hatchery influence is believed to be low; and (3) the number and magnitude of recovery actions needed within the Mill Creek watershed are limited and localized. In addition, under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with remnant amounts of habitat remaining in Mill Creek, among a few others. Under the less likely but still possible scenario of an 8°C warming, salmonid habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley et al. 2007).

The aquatic habitats in Mill Creek (along with Deer, Antelope, Battle and Butte Creeks) are among the best remaining habitat above the Central Valley floor for anadromous salmonids. Although diversion structures are present in the valley section of Mill Creek, there are no major water impoundments along the Mill Creek corridor. Fish have been able to maintain passage, and native fish communities have survived in the free-flowing sections.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of steelhead in Mill Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. Those actions that are required are localized in nature and, when fully implemented, have a high likelihood of restoring or maintaining good fish passage conditions. A water exchange agreement already is in place between the CDFG and water users on Mill Creek. The programs are intended to develop and operate wells to offset bypass flows needed for steelhead and to implement water use efficiency measures to reduce irrigation water demand. Although the agreement improves fish passage conditions for steelhead, a comprehensive fish passage evaluation and monitoring plan has not been developed to assess the effectiveness of the agreement. Long-term verification of the flows, and an evaluation of existing dams for fish passage suitability are needed to ensure passage is provided at a wide range of stream flows. In the upper watershed, Federal land management practices are guided by a long-term anadromous fish conservation strategy, although private timberland management plans lack a comprehensive anadromous habitat protection strategy.

The conceptual recovery scenario for Mill Creek includes the establishment and maintenance of a steelhead spawning population in the upper reaches of Mill Creek including areas within the Lassen National Forest, starting just upstream of Rancheria Trail and extending upstream.

In order to secure the extant population and promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead.

Deer Creek

Although comprehensive population abundance data are not available, Deer Creek is believed to support a population of steelhead. With the exception of some limited data on juvenile outmigration, steelhead population monitoring data in Deer Creek is lacking.

Deer Creek is considered a conservation stronghold for the Central Valley steelhead DPS. Similar to Mill Creek, with the implementation of key recovery actions, the watershed has a high potential for sustaining a viable steelhead population because: (1) Deer Creek contains an extensive amount of suitable spawning and rearing habitat; (2) steelhead habitat in the

upper watershed is considered to be excellent with an abundance of spawning gravel (DWR 2005; USFWS 1999); (3) hatchery influence is believed to be low; (4) water temperatures throughout the Deer Creek watershed are suitable for juvenile steelhead rearing except for the summer months, although cold water refugia are likely available in the upper watershed; and (5) the number and magnitude of recovery actions needed within the Deer Creek watershed are limited and localized.

The aquatic habitats in Deer Creek are among the best remaining habitat above the Central Valley floor for anadromous salmonids. Although diversion structures are present in the valley section of Deer Creek, there are no major water impoundments along the Deer Creek corridor. Fish have been able to maintain passage, and native fish communities have survived in the free-flowing sections. Deer Creek is also considered essential to the recovery and perpetuation of the wild stocks of winter-run steelhead in the Central Valley (Reynolds et. al. 1993; McEwan and Jackson 1996) in part because of its current habitat conditions.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of steelhead in Deer Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. Those actions that are required are localized in nature and, when fully implemented, have a high likelihood of restoring or maintaining good fish passage conditions. In particular, long-term fish passage improvements should be addressed by installing state-of-the-art passage facilities at the Cone-Kimball, Stanford Vina, and Deer Creek Irrigation District dams, and existing dam structures should be replaced with inflatable bladder dams that can be installed during the irrigation season and lowered during periods of high stream flow and bedload transport. In addition, water exchange programs are presently underway or in development with cooperation irrigation districts. The programs are intended to develop and operate wells to offset bypass flows needed for steelhead and to implement water use efficiency measures to reduce irrigation water demand. In the upper watershed, Federal land management practices are guided by a long-term anadromous fish conservation strategy, although private timberland management plans lack a comprehensive anadromous habitat protection strategy.

The conceptual recovery scenario for Deer Creek includes the establishment and maintenance of a steelhead spawning population in the upper reaches of Deer Creek including areas within the Lassen National Forest, starting at approximately 4 miles above Upper Dam and extending upstream. Steelhead habitat in this area is considered to be excellent with an abundance of spawning gravel.

In order to secure the extant population and promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead.

Big Chico Creek

Although population abundance data are not available, Big Chico Creek is believed to support a population of steelhead. Steelhead reportedly occur in Big Chico Creek along with resident trout. Steelhead are believed to use the foothill zone to spawn except in low water years, when they spawn lower in the creek.

Big Chico Creek is characterized as having a low to moderate potential to support a viable population of steelhead. Big Chico Creek is a small watershed with substantial urban impacts in the lower watershed. Big Chico Creek contains marginally suitable habitat that most likely was opportunistically used in the past by

salmon and steelhead (Yoshiyama et al. 1996). However, the middle and upper watershed areas are not urbanized and much effort by local groups and land owners has been made to secure conservation easements along this portion of the river corridor. These easements protect the riparian zone from the impacts of long-term development. In addition, passage to the middle and upper watershed areas, where cooler water is found in the late summer, is provided by a ladder in Iron Canyon. There are plans to improve this fish ladder, which would be an important restoration activity to assist in securing the extant population.

The conceptual recovery scenario for Big Chico Creek includes the establishment and maintenance of a steelhead spawning population in the upper reaches of Big Chico Creek. With successful restoration efforts in Big Chico Creek, particularly in the lower sections of the creek and through improvements in the Iron Canyon fish ladder, steelhead will be able to access upstream areas where cooler water temperatures exist.

In order to secure the extant population and promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead.

Butte Creek

As reported by the Butte Creek Watershed Conservancy (1999), steelhead have been reported in Butte Creek principally through reports by CDFG wardens of angler catches. However, no estimate of steelhead abundance in Butte Creek is known to be available (Butte Creek Watershed Conservancy 1999; FERC 2008). Because of the low elevation of available habitat in Butte Creek, historic water temperatures were likely too warm to support a population of steelhead. Presently, cold water is imported from the upper West Branch Feather River, which improves habitat conditions for steelhead.

Steelhead spawning occurs in tributaries such as Dry Creek and in the mainstem of Butte Creek above Parrott-Phelan diversion during winter and spring (generally December through April). The spawning area for steelhead in Butte Creek extends from the Centerville Head Dam downstream to the vicinity of the Western Canal Siphon crossing (Butte Creek Watershed Conservancy 1999). Steelhead generally spawn upstream of the Parrott-Phelan diversion. Spawning gravel in the reach of the creek from the Centerville Head Dam downstream to the vicinity of Helltown is extremely limited, with the major gravel beds existing below the Centerville Powerhouse (Butte Creek Watershed Conservancy 1999). The Sutter Bypass is reportedly used by juvenile steelhead as rearing habitat (Butte Creek Watershed Conservancy 1999).

Butte Creek is characterized as having a moderate potential to support a viable population of steelhead. Numerous restoration efforts have been undertaken on Butte Creek. Once impaired by numerous dams with poor fish passage facilities, no dedicated fish flows, and unscreened diversions, Butte Creek now provides state-of-the-art fish ladders and screens, and dedicated instream flows. However, elevated water temperature continues to pose a threat to steelhead, particularly in consideration of long-term climate change.

The conceptual recovery scenario for Butte Creek includes the maintenance of a steelhead spawning population in reaches of Butte Creek extending from Centerville Diversion Dam upstream approximately equidistant in the West Branch Butte Creek and Butte Creek, and in the upper reaches of Little Dry Creek.

In order to secure the extant population and promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously

identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead.

Feather River

Lindley et al. (2007) characterized the spring-run Chinook salmon population in the Feather River as data deficient, and therefore did not characterize its viability. However, Lindley et al. (2007) characterized the existing steelhead population in the Feather River, including fish produced by the Feather River Hatchery, at a high level of extinction risk. NMFS (2007b) is concerned that the proportion of naturally produced fish is declining. The artificial propagation program for steelhead in the Feather River Hatchery may decrease risk to the DPS to some degree by contributing increased abundance to the DPS. However, hatchery-origin fish likely comprise the majority of the natural spawning run, placing the natural populations at high risk of extinction.

The lower Feather River, below Oroville Dam, is characterized as having a moderate potential to support a viable population of steelhead, primarily based on the presence of a hatchery-supported population that is known to reproduce naturally in the Low Flow Channel between River Miles 59 and 67. Nonetheless, the recently signed Settlement Agreement for Licensing of the Oroville Facilities (March 2006) includes the Lower Feather River Habitat Improvement Plan, which requires the development and implementation of numerous programs and projects that will improve the ecological condition of the Lower Feather River, in a manner that is expected to improve the quality and quantity of steelhead habitat for the next 50 years. The Settlement Agreement includes measures to improve the short- and long-term genetic management of the Feather River Hatchery, and measures that will increase the spatial availability of spawning habitat for steelhead.

The conceptual recovery scenario for the Feather River includes the maintenance of a steelhead spawning population in the reach extending from approximately the confluence with Honcut Creek upstream through the Low Flow Channel. In order to secure the extant population and promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead. One additional habitat restoration action specifically for steelhead in the Feather River includes increasing stream flows as needed to reduce water temperatures for steelhead juvenile rearing.

Yuba River

As with spring-run Chinook salmon, there has been little information published on population trends and abundance of steelhead in the Yuba River (NMFS 2007a). Lindley et al. (2007) characterized the steelhead population in the lower Yuba River as data deficient, and therefore did not characterize its viability. The available information on the current population size of steelhead in the lower Yuba River indicates that adult escapement of steelhead is relatively low compared to historical levels (NMFS 2007a). Prior to construction of Englebright Dam, CDFG fisheries biologists stated that they observed large numbers of steelhead spawning in the uppermost reaches of the Yuba River and its tributaries (CDFG 1998; Yoshiyama et al. 1996).

Infrared and videographic sampling on both ladders at Daguerre Point Dam since 2003 has provided estimates of steelhead numbers migrating up the Yuba River, annually ranging from about 150 to over 750 adults (CDFG unpublished data, as cited in NMFS 2007a). However, these estimates should be considered preliminary, minimum numbers, as periodic problems with the sampling equipment have caused periods when fish ascending the ladders were not counted. Additionally, because steelhead can be similar in size to many other species of fish in the Yuba River, only those

infrared images that were backed up by photographic images clearly showing that the fish was a steelhead were included in the counts. Therefore, it is likely that the actual numbers of steelhead passing Daguerre Point Dam are higher than those reported, and does not take into account steelhead that may have remained in the lower Yuba River below Daguerre Point Dam.

Clearly, the lower Yuba River supports a persistent population of steelhead. There is no hatchery located on the lower Yuba River - thus the genetic integrity of steelhead may be largely uncompromised by hatchery influence. CDFG stopped stocking steelhead from the Coleman National Fish Hatchery into the lower Yuba River in 1979, and currently manages the river to protect natural steelhead through strict "catch-and release" fishing regulations (NMFS 2007a).

The lower Yuba River, below Englebright Dam, is characterized as having a high potential to support a viable population of steelhead, primarily because: (1) the river supports a persistent population of steelhead and historically supported the largest, naturally-reproducing population of steelhead in the Central Valley (McEwan and Jackson 1996); (2) flow and water temperature conditions are generally suitable to support all life stage requirements; (3) the river does not have a hatchery on it; (4) spawning habitat availability does not appear to be limited; and (5) high habitat restoration potential (see the watershed profile).

The conceptual recovery scenario for the lower Yuba River includes the maintenance of a steelhead spawning population in the reach extending from Englebright Dam downstream to the confluence with the Feather River. For currently occupied habitats between below Englebright Dam, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a population of steelhead can be improved with improvements to instream flow regimes, water temperatures, and habitat availability. Continued implementation of the Yuba Accord is expected to address these factors and considerably improve conditions in the lower Yuba River. Additional habitat improvements and restoration actions are anticipated to be addressed in the forthcoming Yuba County Water Agency FERC relicensing process.

The steelhead conceptual recovery scenario includes reintroduction of steelhead to the candidate areas of the North Fork, Middle Fork and South Fork Yuba rivers. Reintroduction of anadromous salmonids above Englebright Dam has been the subject of recent and current investigations. Evaluation of habitat suitability for anadromous salmonids upstream of Englebright Dam was recently undertaken (DWR 2007), but those evaluations have yet to be finalized as part of the Upper Yuba River Watershed Studies Program. Currently, NMFS is evaluating the feasibility of providing passage for anadromous salmonids at Englebright Dam. Hence, the conceptual recovery scenario does not further discuss specific restoration actions associated with reintroduction of steelhead above Englebright Dam.

In order to secure the extant population and promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been previously identified in the spring-run Chinook salmon recovery scenario, and also pertain to steelhead.

Bear River

The Bear River is considered to support an extant population of steelhead, although utilization of the river most likely is opportunistic under certain hydrologic conditions. Although present historically, existing conditions in the Bear River preclude the establishment of a self-sustaining population of steelhead. Minimum releases below Rollins Lake (10 cfs) and Lake Combie (5 cfs) from approximately June to November result in warm

water temperatures that are suitable only for bass and other warm water species (Bear River Watershed Group Website 2009). However, during periods of high flows, steelhead are known to utilize the river for limited spawning (JSA 2004). Because environmental conditions do not support a self-sustaining population of steelhead in the Bear River, those steelhead that do spawn during high flow years have likely originated from the Feather River Fish Hatchery. The present system of diversions results in abnormal flow fluctuations, in contrast to historical natural seasonal flow variations (Bear River Watershed Group Website 2009).

The Bear River is characterized as having a low potential to support viable populations of steelhead. This characterization is based on the following factors: (1) the system does not currently support populations of steelhead, particularly due to inadequate instream flows; (2) the lower reach has become narrow and incised; (3) downstream gravel recruitment has been limited for many years and would have to be actively supplemented to provide suitable habitat conditions for steelhead (Bear River Watershed Group Website 2009); and (4) New Camp Far West Reservoir is both shallow and warm and may not be able to provide releases or through-flows during late summer and early fall at water temperatures that are suitable to juvenile salmonids downstream (Bear River Watershed Group Website 2009).

The conceptual recovery scenario includes the goal of securing extant populations, albeit opportunistic and dependent in the Bear River. Habitat improvements and restoration actions to accomplish this goal are anticipated to be addressed in the ongoing FERC relicensing process. Presently, key restoration actions include the following.

- Develop and implement measures to improve flow conditions (i.e., low flows and flow fluctuations)
- Develop and implement measures to improve water temperature conditions
- Develop and implement spawning gravel augmentation programs
- Implement measures to improve water quality
- Develop and implement habitat restoration actions to improve natural river morphology, riparian habitat, floodplain habitat and instream cover

Auburn Ravine/Coon Creek

Information regarding steelhead presence and habitat utilization in Auburn Ravine is generally lacking. However, CDFG (2005a, unpublished data) electrofishing survey results indicate that Auburn Ravine may constitute a probable steelhead spawning area given the presence of very small juveniles during spring. Auburn Ravine, both upstream and downstream of the Auburn Tunnel Outlet, may represent a year-round rearing area for juvenile steelhead, given the presence of both YOY and larger juveniles during November, December, and April (County of Placer 2009).

Compared to the historical flow regime, current management practices produce higher flows year-round and more consistent flows during the spring and summer months in Auburn Ravine. Most of the instream flow in Auburn Ravine is water imported from the Yuba River, Bear River, and American River watersheds to meet domestic and agricultural needs in western Placer County and southeastern Sutter County (Sierra Business Council 2003). Current water management practices in Auburn Ravine likely provide cold water habitat for salmonids during time periods which historically lacked cold water habitat (Sierra Business Council 2003).

The Auburn Ravine/Coon Creek Watershed is characterized as having a moderate to high potential to support viable populations of

steelhead, primarily based on the present abundance of O. mykiss, generally suitable habitat conditions particularly in upstream areas, and habitat restoration potential. Auburn Ravine, Coon Creek, and Doty Ravine all support steelhead and have the potential to support higher levels of production after an ecosystem restoration program is implemented (County of Placer 2002).

Auburn Ravine provides a diversity of aquatic habitats, including shallow, fast-water riffles, glides, runs and pools. Similar to the lower reach of Auburn Ravine, the middle reaches of Coon Creek and portions of Doty Ravine also contain sandy substrate (County of Placer 2002). Summer water temperatures are adequate to support salmonids throughout the summer in about half of the channel lengths in Auburn Ravine, Coon Creek and Doty Ravine (County of Placer 2002). In Auburn Ravine, the lack of riparian buffers along the downstream reaches likely contributes to elevated water temperatures.

Installation of seasonal dams during the spring and removal during the fall reportedly can affect the upstream migration of steelhead (JSA 1999). As reported by SARSAS (2009), Placer Legacy and NID are currently in the process of retrofitting the Lincoln Gaging Station and Hemphill Dam for fish passage. These dams will reportedly be retrofitted in 2009. Fish will then be able to reach the base of NID's Gold Hill Diversion Dam. NID has identified retrofitting Gold Hill Dam to facilitate fish passage as a focus for NID after fish are able to reach the Gold Hill Dam (SARSAS 2009).

The conceptual recovery scenario for the Auburn Ravine/Coon Creek watershed includes the maintenance steelhead spawning populations in the upper reaches of Auburn Ravine and Coon Creek, and in Doty Ravine. In order to secure the extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Conduct an anadromous fish passage assessment in the Auburn Ravine/Coon Creek Watershed to develop recommendations for improving passage conditions
- Conduct a hydrologic analysis of the Auburn Ravine/Coon Creek watershed that explores conjunctive use opportunities to reduce water allocations that are dependent on surface water
- Increase habitat complexity and enhance riparian vegetation to improve juvenile rearing and emigration conditions
- Enhance watershed resiliency by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade
- Assess feasibility of providing enhanced steelhead habitat
- Consolidate diversions
- Reduce flow fluctuations
- Reduce non-point application of pesticides (timing, amount and dilution)

Dry Creek

General information on the historical presence of anadromous salmonids, including steelhead, in Dry Creek is available through many small-scale inventory surveys and anecdotal information, and suggests that the watershed supports a persistent population of steelhead. CDFG conducted a reconnaissance-level assessment of steelhead distribution and

abundance, relative to stream habitat conditions, in 1998 and 1999. At that time, steelhead escapement to the upper Dry Creek watershed was estimated at a few hundred fish. Monitoring of juvenile salmonid emigration also was conducted by CDFG during 1999 and 2000. During both years, juvenile steelhead were collected in rotary screw traps located immediately downstream of the confluence of Secret and Miners ravines (ECORP Consulting 2003). During the fall/winter of 2004 and the spring of 2005, CDFG conducted two-pass electrofishing surveys on a total of seven reaches in Dry Creek, as well as in several reaches in Miners and Secret ravines. No steelhead/rainbow trout were captured in Dry Creek or Miners Ravine. However, 41 steelhead/rainbow trout were captured in Secret Ravine in 2004, and 95 were captured during 2005 (CDFG 2005b, unpublished data).

These surveys, as well as previous studies and anecdotal information suggest that Dry Creek is utilized as a migratory corridor for anadromous salmonid passage upstream to spawning and rearing habitat in the upstream tributaries (Secret Ravine and Miners Ravine). The Dry Creek Watershed Coordinated Resource Management Plan (ECORP Consulting 2003) states that the mainstem of Dry Creek is not suitable anadromous salmonid habitat and is considered only as a migratory corridor to upstream areas containing suitable spawning and rearing habitat.

The Dry Creek Watershed is characterized as having a moderate potential to support viable populations of steelhead, primarily based on the present abundance of O. mykiss, generally suitable habitat conditions particularly in upstream areas, and habitat restoration potential. Miners Ravine still supports salmonids, although many reaches are heavily degraded. Secret Ravine also still supports salmonids and has the highest quality fisheries habitat in the Dry Creek watershed (ECORP Consulting 2003).

Land use impacts have affected the form and function of stream channels throughout the Dry Creek Watershed, which in turn have impacted riparian and aquatic communities. Throughout the watershed, reaches have been straightened, floodplain area reduced, reaches dredged, and riparian vegetation removed, resulting in eroding banks, sediment deposition, lack of cover, lack of pools and riffles, lack of riparian vegetation, and barriers to fish passage. However, Dry Creek does support a relatively healthy riparian corridor upstream of Folsom Road to the confluence with Miners and Secret ravines (ECORP Consulting 2003), and water temperatures in the upstream portions of the watershed may remain somewhat suitable for over-summer juvenile steelhead rearing.

Several studies and projects have been implemented to improve fish passage and restore aquatic habitat in Miners Ravine, Secret Ravine, and small tributaries. For example, riparian trees have been planted along Dry Creek by the City of Roseville in association with the Dry Creek Reforestation Project.

The conceptual recovery scenario for the Dry Creek Watershed includes the maintenance of steelhead spawning populations in Miner's Ravine and Secret Ravine. In order to secure the extant population and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Improve passage conditions in the Dry Creek watershed
- Improve flow conditions (i.e., low flows) associated with attraction and migratory cues affecting adult immigration, as well as juvenile rearing and outmigration
- Develop a spawning gravel augmentation plan

- Develop a program to restore natural morphology, riparian habitat and instream cover

American River

The American River provides habitat for a persistent, dependent population of steelhead. The Central Valley steelhead DPS includes naturally-spawned steelhead in the American River (and other Central Valley stocks) and excludes steelhead spawned and reared at Nimbus Fish Hatchery. The abundance of naturally-spawning steelhead in the lower American River has been low for several years. From 2002 through 2007, annual population abundance estimates for American River steelhead spawning in the river have ranged from about 160 to about 240 individuals (Hannon and Deason 2008).

Lindley et al. (2007) classify the listed (i.e., naturally-spawning) population of American River steelhead at a high risk of extinction because this population is reportedly mostly composed of steelhead originating from Nimbus Fish Hatchery. The relatively small population size, complete loss of historic spawning habitat, and reduced genetic diversity further support this classification (NMFS 2009).

The American River watershed can be characterized as having a moderate potential to support a viable population of steelhead. There is a general consensus in the available literature suggesting that habitat for steelhead in the American River is impaired (Reclamation 2008; Water Forum 2005a; SWRI 2001; CDFG 2001). Of particular concern are warm water temperatures from spring through early fall, especially during the summer (NMFS 2009).

In addition to elevated water temperatures during the steelhead embryo incubation, juvenile rearing, and juvenile migration periods, past habitat alterations primarily associated with bank protection have reduced natural river function and morphology and, consequently, have degraded steelhead habitat suitability. Flow fluctuations are another major stressor, and have been documented to result in steelhead redd dewatering (Hannon et al. 2003; Water Forum 2005b; Hannon and Deason 2008), and juvenile stranding and isolation in the lower American River (NMFS 2009).

However, the reasonable and prudent alternative (RPA) for the lower American River in the 2009 NMFS OCAP BO (NMFS 2009) includes implementing a new Flow Management Standard and water temperature management plan, minimization of flows exceeding 4,000 cfs to reduce potential flow fluctuation effects, technological modifications to improve water temperature management of Folsom Reservoir's coldwater pool and resultant downstream water temperatures, and development of a Genetics Management Plan for the Nimbus Hatchery. These actions are anticipated to improve near-term habitat conditions and accomplish the previously stated goal of securing the extant population and increasing the viability of the American River steelhead population.

The conceptual recovery scenario includes the reintroduction of steelhead above Folsom Dam into the North Fork American River, Middle Fork American River and South Fork American River. Indeed, reintroduction of steelhead into the American River Watershed above Folsom Dam is included in the 2009 OCAP NMFS BO (NMFS 2009). The BO states that by January 2011, Reclamation, with assistance from a Steering Committee, shall complete a 3-year plan for a Fish Passage Pilot program, including the American River Basin.

- The conceptual recovery scenario for the American River includes the maintenance of a steelhead spawning population in the reach extending from approximately the Nimbus Fish Hatchery Weir downstream to approximately Watt Avenue. In order to secure the extant population and

promote a viable population of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Conduct a passage feasibility study, including an assessment of potential salmonid habitat above Nimbus and Folsom dams
- Implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management
- Evaluate the potential to replace the Nimbus Fish Hatchery broodstock with genetically more appropriate sources (e.g., the O.mykiss in the watershed above Folsom Dam which retain ancestral American River steelhead genetics)
- Develop a Nimbus Fish Hatchery Genetic Management Plan for steelhead
- Evaluate Nimbus Fish Hatchery steelhead production and stocking practices to identify and implement measures that would promote restoration of wild steelhead in the lower American River
- Develop State and national levee vegetation policies to maintain and restore riparian corridors in the American River (Corps vegetation management policy and FloodSAFE)
- Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the American River
- Inventory locations for creating shallow inundated floodplain habitat in the American River for multi-species benefits and implement where suitable opportunities are available
- Continue to implement spawning habitat improvement and gravel augmentation measures
- Develop and implement side channel habitat improvement and creation, and riparian habitat restoration measures
- Develop and implement a woody debris maintenance program

SOUTHERN SIERRA NEVADA DIVERSITY GROUP

Extant populations of steelhead in the Southern Sierra Diversity Group are known or believed to occur in the Calaveras, Stanislaus, Tuolumne, and Merced rivers (NMFS 2009). In addition, a hatchery-dependent steelhead population is present on the Mokelumne River (Marsh 2007). As previously discussed, no viable independent steelhead populations have been identified in the Southern Sierra Diversity Group, and all of them are either data deficient or at high risk of extinction. However, one of the recovery goals is to secure and/or improve all extant populations. Specifically, the Southern Sierra Diversity Group is critical to preserving the spatial structure of the Central Valley steelhead DPS (NMFS 2009).

Local efforts to investigate steelhead presence, habitat utilization and restoration opportunities targeting steelhead have been minimal in most of these watersheds. Watersheds in this diversity group are generally characterized as having low to moderate potential to support steelhead recovery. However, the steelhead conceptual recovery scenario for the Southern Sierra Diversity Group includes the maintenance and/or establishment of spawning steelhead populations in the Mokelumne River, Dry Creek, and the Calaveras, Stanislaus, Tuolumne and Merced rivers.

The steelhead conceptual recovery scenario for the Southern Sierra Nevada Diversity Group also includes the reintroduction of steelhead to the candidate areas of the North Fork Mokelumne River, the Middle Fork Stanislaus River, the upper Tuolumne River, the upper Merced River and the South Fork Merced River. In addition to considerations of historical distribution, current population status, and recovery potential (including restoration actions) of the individual watersheds, one of the factors taken into account in the identification of candidate reintroduction watersheds is long-term climate change. Reintroductions also would be dependent upon successful passage programs above the dams in these watersheds.

It is clear that the long-term viability of this diversity group will depend not only on implementation of actions related to flow, water temperature, and habitat specified in the RPA of the 2009 NMFS OCAP BO, but also additional actions, particularly increasing flows in the Tuolumne and Merced rivers (NMFS 2009). The State Water Resources Control Board has made establishing additional flows in these rivers a priority and intends to take action within the near-term. A CVP/SWP operations consultation with NMFS that will be triggered by implementation of San Joaquin Restoration Program flows also will provide further opportunities to update and refine actions critical to this diversity group (NMFS 2009).

Mokelumne River

Steelhead historically were abundant in the Mokelumne River. Recent monitoring has detected small, self-sustaining populations of steelhead (although influenced by the Mokelumne River Hatchery steelhead program) in the Mokelumne River (NMFS 2009). The Central Valley steelhead DPS includes naturally-spawned steelhead in the Mokelumne River (and other Central Valley stocks) and excludes steelhead spawned and reared at Mokelumne River Hatchery.

Since implementation of the Joint Settlement Agreement, East Bay Municipal Utilities District has conducted recent monitoring of O. mykiss populations in the lower Mokelumne River using video monitoring as the Woodbridge Irrigation District Dam (WIDD) fish ladder, rotary screw traps in the lower Mokelumne River downstream of the WIDD, and conducted seasonal fish surveys from Camanche Dam downstream to WIDD (EBMUD et al. 2008). Steelhead redd surveys in the lower Mokelumne River are conducted between Camanche Dam and the Elliott Road Bridge (EBMUD et al. 2008). Monitoring results regarding steelhead populations in the lower Mokelumne River are presently becoming available.

The Mokelumne River Watershed can be characterized as having a low potential to support a viable population of steelhead. Mokelumne River natural-origin steelhead are reportedly extinct (USFWS 1998), and the steelhead population is believed to be maintained by hatchery supplementation (Marsh 2007). Elevated water temperatures, low flow conditions, flow fluctuations, and limited supplies of instream gravel diminish the potential for a viable population of steelhead in the Mokelumne River.

The conceptual recovery scenario for the Mokelumne River Watershed includes the maintenance of steelhead spawning populations in the upper reach of the Mokelumne River below Camanche Reservoir, and in the upper reaches of Dry Creek. Over the past few years, Mokelumne River studies have used an extensive acoustic receiver array system deployed in the river to track the movement, survival, and habitat use of hatchery origin steelhead smolts, hatchery steelhead kelts and multiple life stages (>160mm) of the wild river population of O. mykiss (Workman et al. 2008). EBMUD, CDFG and USFWS continue to collaboratively work to improve conditions for the lower Mokelumne River. Restoration objectives have focused on providing additional salmonid spawning gravel, improving

intergravel water quality, and increasing floodplain connectivity in the first 1 mile below Camanche Dam (EBMUD 2009). Side channel and riparian habitat restoration projects also have been conducted. Woodbridge Irrigation District has completed the rebuilding of the dam at Woodbridge with improved fish passage facilities and improved screening at the diversion (USFWS 2008b).

The conceptual recovery scenario also includes the reintroduction of steelhead above Pardee Reservoir into the North Fork Mokelumne River. Habitat conditions in the North Fork Mokelumne River are likely suitable for steelhead spawning and juvenile rearing.

In order to secure the extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Evaluate and, if feasible, develop and implement a fish passage program for Camanche and Pardee dams
- Evaluate pulse flow benefits for steelhead attraction and passage in the Mokelumne River; if pulse flows are determined to be effective for attracting steelhead, implement the most beneficial pulse flow regime
- Develop and implement a spawning gravel augmentation plan for the Mokelumne River
- Develop a Mokelumne River Steelhead Hatchery Genetic Management Plan to minimize adverse effects to the wild stock
- Manage cold water pools in Camanche and Pardee Reservoirs to provide suitable water temperatures for all steelhead life stages
- Develop and implement an instream flow management plan that fully considers all steelhead life history stages

Calaveras River

A small, apparently self-sustaining population of steelhead reportedly exists in the Calaveras River (NMFS 2008). Current annual escapements of steelhead in the Calaveras River are limited due to the long-term scarcity of steelhead in the basin (Reclamation 2001). Data regarding hatchery influence on the Calaveras River steelhead population is lacking (USFWS 2003).

The Calaveras River is characterized as having a moderate potential to support a viable population of steelhead. Historically, steelhead production in the Calaveras River was limited by low, intermittent flows during summer and fall. Mormon Slough, the primary salmonid migration channel, still experiences dry periods during summer and early fall as it did under the pre-1964 unregulated hydrologic regime (Marsh 2006). Instream flow is reported to be a principal factor currently limiting salmonids in the Calaveras River (CALFED 2000b, as cited in Marsh 2006). Below the Bellota Weir, the spawning gravels are limited and have poor permeability. Several steelhead redds were present in this area in 2002, but water temperatures reached lethal levels for steelhead eggs during the spring (USFWS 2003).

However, the Calaveras River does have the potential to support anadromous fish based on habitat qualities such as geomorphology (i.e., 22 feet per mile gradient, numerous riffles and pools), adequate spawning gravels, and a dense riparian canopy (USFWS 1993, CALFED 2000b, as cited in Marsh 2006), particularly upstream of the Bellota Weir. Along the 18 miles between the Bellota Weir and New Hogan Dam there is a dense riparian corridor bordering the river (USFWS 1998, as cited in Marsh 2006). Spawning gravels in the first mile below New Hogan Dam do exhibit low permeability, but are reportedly

adequate to support several hundred pairs of salmon (USFWS 2003).

The conceptual recovery scenario for the Calaveras River includes the maintenance of a steelhead spawning population in the upper reach of the Calaveras River extending from the Bellota Weir upstream to New Hogan Dam. Restoration actions in the Calaveras River have focused on passage and instream flow improvements. Opportunities to improve fish passage and aquatic habitat for anadromous salmonids have been identified at several locations, including the Mormon Slough flood control channel, the Old Calaveras River channel, and at the SEWD and the CCWD facilities (Fishbio 2008). SEWD and CCWD are working cooperatively with NMFS to improve conditions for salmonids in the Calaveras River by including appropriate conservation measures and an adaptive management plan as part of this Calaveras River Habitat Conservation Plan. SEWD also is continuing to implement interim fish passage improvements until long-term fish passage and screening solutions are identified and implemented (Fishbio 2008).

In order to secure the extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Improve fish passage conditions in Mormon Slough, the Old Calaveras River channel, at Bellota Weir, and other locations
- Improve flow conditions (i.e., low flows) and reduce flow fluctuations
- Improve water quality conditions (i.e., urban and agricultural runoff)
- Develop and implement spawning gravel augmentation programs
- Develop and implement restoration actions to reduce water temperatures

Stanislaus River

Steelhead were previously thought to be extirpated from the Stanislaus River, however, monitoring has detected a small self-sustaining (i.e., non-hatchery origin) population of steelhead in the Stanislaus River (McEwan 2001, as cited in NMFS 2009). A fish counting weir operated in the river near the town of Riverbank has documented the passage of large O. mykiss moving upstream. Although the abundance of steelhead in the Stanislaus River is unknown, the catch of adult steelhead using hook-and-line began to increase in 1997 and again in 1999 (SRFG et al. 2003).

The Stanislaus River Watershed below Goodwin Dam can be characterized as having a low to moderate potential to support a viable population of steelhead. A series of dams in the Stanislaus River has blocked access to spawning habitat in the upper watershed, and has blocked the transport of gravel to downstream reaches (KDH Environmental Services 2008). Gravel recruitment was reduced by 92 percent following construction of Goodwin Dam in 1912 (KDH Environmental Services 2008). Kondolf et al. (2001) and references therein identify a reduction of more than 60 percent of the spawning area in the Stanislaus River since 1966. Along most of the lower Stanislaus River, agricultural and urban encroachment has separated the river from its floodplain. As a result, the channel is incised, which prevents the river from developing and maintaining shallow spawning and rearing habitats necessary for salmonids. The lack of suitable spawning and rearing habitat may reduce the likelihood of establishing a viable steelhead population in the Stanislaus River.

However, the reasonable and prudent alternative (RPA) for the Stanislaus River in the 2009 NMFS OCAP BO (NMFS 2009) includes implementation of a year-round flow regime to

support juvenile steelhead rearing habitat formation and inundation, and to create pulse flows to cue juvenile steelhead outmigration, in addition to implementation of water temperature requirements downstream of Goodwin Dam (NMFS 2009). The RPA also includes spawning gravel augmentation of 50,000 tons of gravel by 2014 (NMFS 2009).

The conceptual recovery scenario for the Stanislaus River includes the maintenance of a steelhead spawning population in the upper reach of the Stanislaus River extending from approximately Orange Blossom Bridge (RM 47) upstream to Goodwin Dam. Although steelhead redd surveys have not been conducted, it is presumed that a majority of the spawning occurs between Goodwin Dam and the Orange Blossom Bridge (SRFG et al. 2003). Moreover, steelhead rearing in the Stanislaus River occurs upstream of Orange Blossom Bridge, where gradients are highest (NMFS 2009).

Despite the future implementation of actions to improve water temperature management in the Stanislaus River, NMFS (2009) concluded that steelhead will continue to be vulnerable to adverse effects of elevated water temperatures during dry and critically dry years. Water temperatures are expected to increase with climate change and increased water demands. Therefore, the conceptual recovery scenario also includes the reintroduction of steelhead above New Melones Reservoir into the Middle Fork Stanislaus River. Moreover, an evaluation of reintroducing steelhead into the Stanislaus River Watershed above New Melones Reservoir is included in the 2009 NMFS OCAP BO (NMFS 2009). The BO states that by March 31, 2011, Reclamation shall develop a plan to obtain information needed to evaluate options for fish passage on the Stanislaus River above Goodwin, Tulloch and New Melones Dams. By December 31, 2018, Reclamation shall develop recommendations regarding fish passage into the upper Stanislaus River (NMFS 2009).

Restoration actions conducted to date in the Stanislaus River have been limited to spawning gravel augmentation and providing additional water to supplement flows in accordance with Section 3406(b)(2) and 3406(b)(3) provisions of the Central Valley Project Improvement Act (CVPIA)6. Additional restoration work is needed to replace gravel lost to mining and dams, and to provide additional floodplain habitat (USFWS 2008c). In order to secure the extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Manage releases from New Melones Reservoir in consideration of all steelhead life stages

- Implement the Spawning Gravel Augmentation Program (Reclamation); augment spawning gravel in suitable locations upstream of Oakdale

- Conduct feasibility studies for allowing steelhead access to habitat above New Melones Dam, including assessing habitat suitability and passage logistics. If the feasibility studies suggest that fish passage can be successful, then design and conduct an experimental fish passage program evaluating adult distribution, survival, spawning, and production in habitats above New Melones Dam

- Evaluate pulse flow benefits for steelhead attraction and passage in the Stanislaus River; if pulse flows are determined to be effective for attracting

[6] Section 3406(b)(2) of the CVPIA directs the Secretary of the Interior to dedicate and manage annually eight hundred thousand acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by the CVPIA. The 800,000 acre-feet of water dedicated by the CVPIA is referred to as "(b)(2) water."

steelhead, implement the most beneficial pulse flow regime

- Work with State and Federal water acquisition programs to dedicate instream water in the Stanislaus River

- Develop and implement floodplain habitat restoration measures

TUOLUMNE RIVER

Steelhead historically occurred throughout the Tuolumne River Watershed. Recent fisheries monitoring for the Don Pedro Project (FERC Project No. 2299) by the Turlock Irrigation District (TID) and the Modesto Irrigation District (MID) has documented the presence of O. mykiss in the lower Tuolumne River (TID/MID 2005). During 2008, a total of 135 YOY/juvenile (< 150 mm FL) and 45 adult (> 150 mm FL) O. mykiss were observed from RM 51.8 to RM 41.1 within the study reach extending down to RM 39.6 (TID/MID 2009). Approximately 3,096 O. mykiss were estimated within the survey reach, with 95% confidence bounds of 1,905–3,047 and 325–914 for the YOY/juvenile and adult size classes, respectively (TID/MID 2009).

The lower Tuolumne River is characterized as having a low to moderate potential to support a viable population of steelhead. Extensive habitat restoration has already occurred in the lower watershed through AFRP programs and other agreements. However, steelhead production in the lower Tuolumne River is limited by low flows. It is reported that the remaining accessible prime spawning reach of the lower Tuolumne River lacks native riparian vegetation and floodplain habitat, and has a high fine sediment load (Tuolumne River Preservation Trust 2002). In addition, despite previous restoration actions, the lower Tolumne River lacks channel complexity and off-channel juvenile rearing habitats.

However, over the past several years, the AFRP has been working with the Tuolumne River Technical Advisory Committee (TRTAC) and the FERC Settlement Agreement framework to develop restoration and monitoring strategies in the Tuolumne River (USFWS 2008d). Initial priorities include: (1) continue to develop and fund the remaining two segments within the 6-mile Mining Reach; (2) complete restoration of two large in-channel pits; (3) develop a sediment management plan that will protect and restore critical spawning and rearing areas in the upper Tuolumne River; (4) work with agriculture and municipal interests in the lower river to establish and restore a riparian corridor; and (5) continue to work with local interests and the Corps on a flood protection strategy (USFWS 2008d). The AFRP also is working with the TRTAC to finalize river-wide and project-specific monitoring strategies that will guide adaptive management and allow the TRTAC to evaluate efficacy of FERC Settlement Agreement actions (USFWS 2008d).

The conceptual recovery scenario for the Tuolumne River includes the maintenance of a steelhead spawning population in the upper reach of the Tuolumne River extending from approximately RM 46.6 to RM 52.1 (i.e. the critical spawning reach).

The conceptual recovery scenario also includes the reintroduction of steelhead above Don Pedro Reservoir. Aquatic habitat above the Don Pedro and La Grange reservoir system historically was likely suitable for steelhead spawning and juvenile rearing. In addition, the upper Tuolumne River downstream of Yosemite National Park is designated a National Wild and Scenic River.

In order to secure the extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following:

- Continue with research to determine the distribution of steelhead and assess the

relationship between resident and anadromous forms of O. mykiss

- Improve production of native steelhead by improving adequate water temperature and flow regimes, particularly for juvenile rearing

- Improve project operations, outlet modifications, and establishment of minimum pools for reservoirs so that cool water temperatures could be provided in late-summer and fall

- Install fishways on presently impassable dams to allow access to tail water habitat

MERCED RIVER

Steelhead historically occurred throughout the upper Merced River drainage, occupying habitat as far upstream as Yosemite Valley on the mainstem, and potentially upstream of Wawona on the South Fork, in addition to most of its lower elevation tributaries. Incidental catches and observations of steelhead juveniles have occurred on the Merced River recently (Good et al. 2005), but population abundance data is lacking. During juvenile outmigration surveys in 2007, no O. mykiss were captured (USFWS 2007b).

The lower Merced River is characterized as having a low to moderate potential to support a viable population of steelhead. As reported in the Geomorphic and Riparian Vegetation Investigations Report for the Merced River Corridor Restoration Plan (Stillwater Sciences 2001), the major constraints to restoring geomorphic and riparian processes in the Merced River include: (1) drastic reduction in the flood magnitude, frequency, and duration and the resulting reduction in bedload transport; (2) elimination of floods exceeding 6,000 cfs; (3) the presence of vulnerable structures and land uses in the floodplain; (4) lack of coarse sediment supply; (5) limits to channel migration caused by reduced flows, bank revetment, and development in the floodplain; (6) the extent of bedload impedance reaches throughout the Gravel Mining 1 and Gravel Mining 2 reaches; and (7) chronic fragmentation and clearing of riparian vegetation for floodplain development. To date, numerous projects to restore and protect floodplain function, as well as channel and riparian habitat have been initiated or completed on the Merced River as a result of the CVPIA and the Merced River Corridor Restoration Plan; however, consistent monitoring of juvenile Chinook salmon and steelhead emigration has been lacking (Stillwater Sciences 2001; USFWS 2007b).

The conceptual recovery scenario for the Merced River includes the maintenance of a steelhead spawning population in the upper reach of the lower Merced River extending from approximately the Highway 59 bridge (RM 42) upstream to the Crocker Huffman Dam (RM 52). Suitable O. mykiss spawning and juvenile rearing habitat is restricted to this reach.

The conceptual recovery scenario also includes the reintroduction of steelhead above New Exchequer Reservoir on the mainstem Merced River and on the South Fork Merced River. Aquatic habitat above the New Exchequer and Crocker Huffman dams historically was likely suitable for steelhead spawning and juvenile rearing. In addition, the upper Merced River and South Fork Merced River are designated as National Wild and Scenic Rivers (National Park Service 2005).

In order to secure the extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following.

- Improve production of steelhead by improving adequate water temperature and flow regimes, particularly for juvenile rearing

- Improve project operations, outlet modifications, and establishment of minimum pools for reservoirs so that cool water temperatures could be provided in late-summer and fall

- Install fishways on presently impassable dams to allow access to tail water habitat

- Maintain, recover, and restore stream flow regimes sufficient to sustain desired conditions for populations of steelhead

MAINSTEM SAN JOAQUIN RIVER

There is reportedly an existing population of resident O. mykiss below Friant Dam on the San Joaquin River, although this population is substantially supplemented from hatchery releases (SJRRP 2009). Flows released from Friant Dam are reportedly insufficient to provide year-round fisheries habitat except during high flow events (USACE and Reclamation Board 1999).

The San Joaquin River is characterized as having a low potential to support a viable population of steelhead. As a result of litigation over the past two decades related to instream flows on the San Joaquin River, a settlement was reached between the Natural Resources Defense Council, Friant Water Users Authority and the U.S. Departments of the Interior and Commerce in 2006. The area of the San Joaquin River to be addressed by the Settlement extends from Friant Dam downstream to the confluence with the Merced River (SJRRP 2009). The Settlement provides a framework for accomplishing restoration and water management goals, including establishment of the San Joaquin River Restoration Program (SJRRP). The SJRRP 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. The SJRRP also identifies population abundance targets for Chinook salmon. However, the SJRRP did not determine numeric objectives for steelhead for two reasons: (1) difficulties associated with a viability assessment; and (2) steelhead were not specifically identified as a target species in the Settlement (SJRRP 2009). Subsequent to restoration efforts on the San Joaquin River reach above the Merced River confluence, steelhead may potentially utilize the habitat, although the lack of side channel and small tributary habitat will diminish the potential for establishing a viable steelhead population in this reach. In the event that steelhead reestablish in the San Joaquin River above the Merced River confluence as a result of the SJRRP, NMFS may develop additional steelhead recovery goals.

The conceptual recovery scenario for the San Joaquin River does not include the maintenance of a steelhead spawning population, although the San Joaquin River does serve as a critical migration corridor for Stanislaus, Tuolumne and Merced river steelhead populations below the Merced River confluence. Therefore, in order to secure these extant populations and promote viable populations of steelhead in both the near-term and the long-term, several key habitat restoration actions have been identified, including the following.

- Improve flow conditions (i.e., low flows) associated with adult steelhead attraction and migratory cues, and juvenile outmigration

- Develop and implement measures to improve water temperature and water quality conditions (i.e., urban and agricultural runoff, dissolved oxygen)

- Develop and implement measures to restore floodplain habitat, riparian habitat and instream cover

6.0 Recovery Actions

"Once there is a firm commitment and a strategy alternative has been decided upon, the third and final pillar of an effective salmon recovery effort is that a number of specific actions will be required to achieve effective implementation."

- Jeffrey J. Dose. Commitment, Strategy, Action: The Three Pillars of Wild Salmon Recovery *in* Salmon 2100: the future of wild Pacific salmon

This Recovery Plan establishes a strategic approach to recovery, which identifies critical recovery actions for the Central Valley, as well as watershed- and site-specific recovery actions. Watershed-specific recovery actions address threats occurring in each of the rivers or creeks that currently support spawning populations included in the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, or the Central Valley steelhead DPS. Site-specific recovery actions address threats to these species occurring within a migration corridor (e.g., San Francisco Bay or the Delta).

This Recovery Plan maintains a consistent strategic framework for the establishment of recovery goals and criteria, the identification and prioritization of threats, and the identification of recovery actions. As described in the Recovery Strategy chapter, the framework for ESU or DPS recovery includes goals and criteria directed at the diversity group and population levels. Similarly, the threats assessment framework for each ESU or DPS also was organized by diversity groups and populations. For winter-run Chinook salmon, threats were prioritized within the Sacramento River population, whereas for spring-run Chinook salmon and steelhead, threats were prioritized within each diversity group as well as within each population.

Three steps were used to prioritize recovery actions as they are presented in this plan. First, results from the threats assessment and prioritization process (described in Appendix B) were used to guide the identification of watershed- and site-specific recovery actions for each diversity group and population. This step prioritized recovery actions separately for each species. The second step to prioritize recovery actions was undertaken through consideration of specific actions that benefit multiple species and populations. Results from the second step included tables of recovery actions listed in descending order of priority by geographic region (e.g., Delta, mainstem Sacramento River, Diversity Group) based on multiple species benefits (see Appendix C). These first two steps were the only steps taken to prioritize recovery actions that were presented in the Co-Manager Review Draft Recovery Plan. Based on feedback from co-managers, it was apparent that the priority with which recovery actions should be undertaken was not clear. To address this, we implemented a third step and prioritized each of the region-specific recovery actions according to two categories. Priority 1 actions are those critical actions that must be taken to prevent extinction or to prevent the species from declining irreversibly. Priority 2 actions must be taken to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction. Priority 1 actions are presented in narrative form in this chapter and an implementation schedule for these actions is described in Chapter 8. Priority 2 actions are presented in Appendix C. All priority 1 actions have been assigned a specific number beginning with the number 1 (e.g., 1.1, 1.2, etc.) , while all priority 2 actions are identified by a numbering system starting with 2.

A number of ecosystem and/or anadromous fish enhancement plans for the Central Valley, as well as input received from two recovery planning public workshops, held May 22nd and 24th, 2007 in Sacramento and Redding, respectively, have been used to identify recovery actions. These documents include:

- Final Restoration Plan for the Anadromous Fish Restoration Program (USFWS 2001)
- AFRP Planning Documents (AFRP Website 2005; AFRP Website 2006a; AFRP Website 2006b)
- Ecosystem Restoration Plan Planning Documents (CALFED 2006; CALFED 2007)
- Summary of Threats and Recovery Actions for Spring-run Chinook salmon and Winter-run Chinook Salmon Recovery Actions. Sacramento Salmon and Steelhead Recovery Workshop (NMFS 2007c)
- Summary of Threats and Recovery Actions for Steelhead. Sacramento Salmon and Steelhead Recovery Workshop (NMFS 2007a)
- Steelhead Restoration and Management Plan for California (CDFG 1996)
- Lower Yuba River Revised Implementation Plan and Appendices (CALFED and YCWA 2005)
- Ecosystem Restoration Program Plan (ERPP) (CALFED 1999a)
- Restoring Central Valley Streams: A Plan for Action (CDFG 1993)
- Lower Yuba River Fisheries Management Plan (CDFG 1991a)
- Initial Fisheries and In-Stream Habitat Management and Restoration Plan for the Lower American River (Water Forum 2001)
- CALFED Bay/Delta Program Multi-Species Conservation Strategy. Final Programmatic EIS/EIR Technical Appendix (CALFED 2000a)
- Potential for Re-establishing a Spring-Run Chinook Salmon Population in the Lower Feather River (MWD 2005)
- Central Valley Salmon – A perspective on Chinook and Steelhead in the Central Valley of California (Williams 2006)
- What caused the Sacramento River fall Chinook stock collapse? (Lindley et al. 2009)

6.1 Priority 1 Recovery Actions for the Central Valley

The recovery actions in this recovery strategy target core 1 populations in the Sacramento River Basin, Core 1 and Core 2 populations in the San Joaquin River Basin, and highly ranked threats in the mainstem Sacramento and San Joaquin Rivers, the Bay-Delta region and the Pacific Ocean , and primary reintroduction areas. These actions represent the critical elements for alleviating major threats to populations in core watersheds. Actions are also specified to address limited knowledge regarding the biology and ecology of the species, as well as its changing status within individual core watersheds.

Priority 1 recovery actions have the highest priority across the ESU/DPS and within core watersheds to achieve recovery objectives and criteria. Opportunistically, priority 2 recovery actions or other actions benefiting winter-run, spring-run, and/or steelhead may be implemented prior to these actions, but NMFS considers priority

1 actions to be the keystones for population recovery or measurement of recovery; such actions are also widely recognized in the scientific literature as addressing threats which have caused the wide-spread decline of these species throughout their natural range.

6.1.1 Recovery Action Narrative

Recovery actions have been categorized into eleven geographic scales or regions:
1.1 Throughout California
1.2 Throughout the Central Valley
1.3 Pacific Ocean
1.4 San Francisco Bay
1.5 Delta
1.6 Mainstem Sacramento River
1.7 Northwestern California Diversity Group
1.8 Basalt and Porous Lava Diversity Group
1.9 Northern Sierra Nevada Diversity Group
1.10 Mainstem San Joaquin River
1.11 Southern Sierra Nevada Diversity Group

The actions for each scale or region are described below.

1.1 THROUGHOUT CALIFORNIA

1.1.1 Implement Federal, State, and local initiatives and programs to improve water conservation in order to reduce state-wide water use by 20 percent per capita by 2020.

This effort should take into account regional differences and find ways to improve agricultural efficiency as well as urban water use efficiency.

1.2 THROUGHOUT THE CENTRAL VALLEY

1.2.1 Promote Central Valley resource managers to cooperatively develop and implement an ecosystem based management approach that integrates harvest, hatchery, habitat, and water management, in consideration of ocean conditions and climate change. An ecosystem-based management and ecological risk assessment framework could improve management of Central Valley Chinook stocks by placing harvest management in the broader context of the Central Valley salmon ecosystem, which is strongly influenced by hatchery operations and management of different ecosystem components, including water, habitat and other species (Lindley et al. 2009).

1.2.2 Support programs to provide educational outreach and local involvement in restoration, including programs like Salmonids in the Classroom, Aquatic Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land use on anadromous fish survival.

1.2.3 Develop a monitoring program to determine the level of entrainment at individual diversions. Prioritize diversions based on this monitoring and screen those that are determined to have the greatest impacts on juvenile survival.

1.2.4 Provide additional funding for increased law enforcement to reduce illegal take of anadromous fish, stream alteration, and water pollution and to ensure adequate protection for juvenile fish at pumps and diversions.

1.2.5 Control or relocate the discharge of irrigation return flows and sewage effluent, and restore riparian forests to help provide suitable water temperatures for anadromous salmonids.

1.2.6 Implement and evaluate actions to minimize and/or eliminate the effects of exotic (non-native invasive) species (plants and animals) on production of anadromous fish.

1.2.7 Restore tributaries by evaluating the feasibility of screening or relocating diversions, switching to alternative sources of water for upstream diversions, restoring and maintaining a protected riparian strip, limiting excessive erosion, enforcing dumping ordinances, removing toxic materials or controlling their source, replacing bridge and ford combinations with bridges or larger culverts and installing siphons to prevent truncation of small streams at irrigation canals, and implement actions to address harmful effects.

1.2.8 Conduct Central Valley-wide assessment of keystone dams and passage opportunities and implement programs to restore access to properly functioning habitat that was historically available.

1.2.9 Evaluate passage at small dams or other anthropogenic obstructions and implement fish passage per NMFS criteria.

1.2.10 Increase integration of the State and Federal water projects through shared storage and conveyance agreements.

1.2.11 Secure agreements with or purchase water rights from landowners and Federal and State agencies to provide additional instream flows.

1.2.12 Form a hatchery science review panel to review Central Valley hatchery practices.
The panel should address the issues contained within actions 1.2.13 – 1.2.18.

1.2.13 Evaluate impacts of outplanting and broodstock transfers among hatcheries on straying and population structure and evaluate alternative release strategies.

1.2.14 Evaluate whether production levels are appropriate and if they could be adjusted according to expected ocean conditions.

1.2.15 Evaluate the potential to modify hatchery procedures to benefit native stocks of salmonids and implement beneficial modifications.

1.2.16 Evaluate and avoid potential competitive displacement of naturally produced juvenile salmonids with hatchery-produced juveniles by implementing release strategies for hatchery-produced fish designed to minimize detrimental interactions.

1.2.17 Evaluate and implement specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and natural stocks.

1.2.18 Evaluate a program to tag and fin-clip all or a significant portion of hatchery-produced fish as a means of collecting better information regarding harvest rates on hatchery and naturally produced fish and effects of hatchery-produced fish on naturally produced fish.

1.2.19 Implementation of a comprehensive life history monitoring plan for Central Valley steelhead that will result in basin-wide (Sacramento and San Joaquin) estimates of hatchery and wild steelhead population abundance, production, diversity and distribution.

1.3 OCEAN

1.3.1 Work with the PFMC and NMFS to re-evaluate and modify management measures, annual conservation objectives, harvest forecasting techniques, NMFS consultation standards for ESA listed salmon stocks, and consider implementing an ecosystem-based salmon fishery management plan that considers multi-trophic interactions, ocean currents, upwelling patterns, ocean temperatures, and other relevant factors. Development of the fishery management plan will include the following actions:

- Consult with PFMC to identify sources of, and solutions to reduce bycatch.
- Use of genetic stock identification to determine to what extent listed salmonids are being intercepted in ocean fisheries.

1.3.2 Work with the PFMC and NMFS to implement restrictions that limit harvest of listed anadromous salmonids in commercial and recreational fisheries considering mechanisms such as:

- Genetic Stock Identificaiton (GSI) – Develop a research, testing and monitoring plan to test this technology and establish optimal bycatch levels based on GSI data.
- Review, assess and modify seasonal and area harvest restrictions and closures

- NMFS, CDFG and USFWS coordinate with the Southwest Fisheries Science Center to convene a science panel to review potential measures such as mass marking and mark selective fisheries and make recommendations to improve the identification of listed stocks in the Ocean.
- Consider using hot spot closures in commercial and recreational fisheries when large numbers of listed fish become congregated in certain areas.

1.4 SAN FRANCISCO BAY

1.4.1 Implement projects that improve wastewater and stormwater treatment throughout the Bay and surrounding residential and commercial areas.

1.4.2 Increase monitoring and enforcement to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.

1.4.3 Cities, counties, districts, joint powers authority or other political subdivisions of the State involved with water management should implement agricultural drainage management projects to treat, store, convey, and/or dispose of agricultural drainage.

1.5 DELTA

1.5.1 Develop alternative water operations and conveyance systems that ensure multiple and suitable salmonid rearing and migratory habitats for all Central Valley salmonids and that restore the ecological flow characteristics of the Delta ecosystem.

1.5.2 Large-Scale Habitat Restoration – Identify funding and direct restoration of 80,000 acres of tidal marsh, 130,000 acres of terrestrial grasslands, and 60,000 acres of floodplain habitat. Floodplain habitats should be restored to appropriate elevations using Frequently Activated Floodplain principles and modeling. The habitats should be along primary migration and rearing corridors, and connected in ecologically beneficial ways. This will require separating levee systems from active river and estuary channels, restoring dendritic channel systems in areas where this habitat feature existed historically, and allowing for natural developmental processes to maintain habitats.

1.5.3 Integrate the Ecosystem Restoration Program and the Calfed Science program into an effort to restore the Delta ecosystem.

1.5.4 Implement programs and measures designed to control non-native predatory fish (e.g., striped bass, largemouth bass, and smallmouth bass), including harvest management techniques, non-native vegetation management, and minimizing structural barriers in the Delta, which attract non-native predators and/or that delay or inhibit migration.

1.5.5 Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: (1) all for fish passage through Fremont Weir for multiple species; (2) enhance lower Putah Creek floodplain habitat; (3) improve fish passage along the toe drain/Lisbon weir; (4) enhance floodplain habitat along the toe drain; and (5) eliminate stranding events; and (6) create annual spring inundation of at least 8,000 cfs to fully activate the Yolo Bypass floodplain.

1.5.6 Implement Actions IV.1 through IV.6 of the Reasonable and Prudent Alternative described in the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009):

- Action IV.1: Modify DCC gate operations and evaluate methods to control access to Georgiana Slough and the Interior Delta to reduce diversion of listed fish from the Sacramento River into the southern or central Delta.

- Action IV.2: Control the net negative flows toward the export pumps in Old and Middle rivers to reduce the

likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta.

- Action IV.3: Curtail exports when protected fish are observed near the export facilities to reduce mortality from entrainment and salvage.

- Action IV.4: Improve fish screening and salvage operations to reduce mortality from entrainment and salvage.

- Action IV.5: Establish a technical group to assist in determining real-time operational measures, evaluating the effectiveness of the actions, and modifying them if necessary.

- Action IV.6: Do not implement the South Delta Barriers Improvement Program.

1.5.7 Develop a comprehensive governance system that has reliable funding, takes advantage of established and effective ecosystem restoration and science programs, and has clear authority to determine priorities and strong performance measures to ensure accountability to the new governing doctrine of the Delta: operation for coequal goals of Delta ecosystem restoration and protection and reliable water supply.

1.5.8 Following the first autumn flows exceeding 15,000 cfs at Wilkins Slough, maintain suitable rearing and migratory habitats for emigrating winter-run salmon throughout the Sacramento River and distributaries in the Delta through the end of April.

1.5.9 Provide pulse flows of at least 20,000 cfs measured at Freeport periodically during the winter-run emigration season to facilitate outmigration past Chipps Island (i.e., December-April).

1.6 MAINSTEM SACRAMENTO RIVER

1.6.1 Restore and maintain a continuous meanderbelt along the Sacramento River from Keswick downstream to Colusa.

- Pursue these opportunities, consistent with efforts conducted pursuant to Senate Bill 1086 (SB 1086), to create a meander belt from Keswick Dam to Colusa to recruit gravel and large woody debris, to moderate temperatures and to enhance nutrient input. Also pursue actions under the Sacramento River Flood Control Project and the Central Valley Plan for Flood Control.

1.6.2 Restore and maintain a continuous 60-mile stretch of riparian habitat and functioning floodplains of an appropriate, science-based width to maintain ecologically viable flood-prone lands along both banks of the Sacramento River between Colusa and Verona.

- Separate levee systems from active river channels, restore dendritic channel systems in areas where this habitat feature existed historically, and allow for the natural development of floodplain habitats. Pursue actions under the Sacramento River Flood Control Project and the Central Valley Plan for Flood Control.

1.6.3 Restore and maintain a continuous 70-mile stretch of riparian habitat and maintain existing floodplain terraces along both banks of the Sacramento River between Verona and Collinsville. Restore floodplain areas as necessary to achieve the restoration targets described in action 1.5.2

- Seek opportunities through the Army Corps of Engineers Sacramento River Bank Protection Project, the Central Valley

Plan for Flood Control, and other flood management programs and agencies, such as the Sacramento Area Flood Control Agency, to protect existing riparian habitat, restore riparian, protect remaining floodplain terraces, and integrate flood plain bench designs into levee repair projects.

1.6.4 Relocate the M&T Ranch fish screen and water diversion from its current location to a downstream, geomorphically stable, river reach and relocate the 300,000 cubic yards of dredged gravel to upstream reaches of the Sacramento River for spawning habitat enhancement.

1.6.5 Develop an ecological flow tool for the Sacramento River below Keswick and Shasta Dams and use in conjunction with Frequently Activated Floodplain (FAF) tools and hydrodynamic river models to create and implement a floodplain inundation program that allows for existing functional floodplains to be activated in two out of three years for at least seven days between mid-March to mid-May.

1.6.6 Implement a river flow management plan that balances carryover storage needs with instream flow and water temperature needs for winter-run, spring-run, and steelhead based on runoff and storage conditions, including flow fluctuation and ramping criteria.

1.6.7 Implement Action I.3.1 and I.3.2 (Long-term and interim operations of RBDD) of the Reasonable and Prudent Alternative described in the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009) and install NMFS-approved, state-of-the-art fish screens at the Tehama Colusa Canal diversion point.

1.6.8 Develop a long-term gravel augmentation plan to enhance spawning habitat downstream of Keswick and Shasta Dams.

1.7 NORTHWESTERN CALIFORNIA DIVERSITY GROUP

1.7.1 CLEAR CREEK

1.7.1.1 Operate the Clear Creek weir to separate spring-run and fall-run Chinook salmon.

1.7.1.2 Develop a spawning gravel budget and implement a long-term augmentation plan in Clear Creek.

1.7.1.3 Develop and implement optimal flow schedules to mimic the natural hydrograph (including spring pulse flows and winter spillway releases to restore a proper functioning system) and use instream flow study results to guide flow schedule development.

1.7.1.4 Develop a real time water temperature model to track the coldwater pool in Whiskeytown Reservoir and budget releases to Clear Creek to meet daily water temperature of 60°F at the Igo gauge from June 1 to September 15 and 56°F from September 15 to October 31.

1.8 BASALT AND POROUS LAVA DIVERSITY GROUP

1.8.1 LITTLE SACRAMENTO RIVER

1.8.1.1 Develop and implement a phased approach to salmon reintroduction planning to re-colonize historic habitats above Keswick and Shasta Dams in the Little Sacramento River.

- Conduct feasibility studies
- Conduct habitat evaluations
- Conduct 3-5 year pilot testing program
- Implement long-term fish passage program

1.8.2 McCLOUD RIVER

1.8.2.1 Develop and implement a phased approach to salmon reintroduction planning to re-

colonize historic habitats above Keswick and Shasta Dams in the McCloud River.

- Conduct feasibility studies
- Conduct habitat evaluations
- Conduct 3-5 year pilot testing program
- Implement long-term fish passage program

1.8.3 BATTLE CREEK

1.8.3.1 Develop and implement a salmon reintroduction plan to re-colonize historic habitats after implementation of the Battle Creek Restoration Project.

1.8.3.2 Fully fund and implement the Battle Creek Restoration Project through Phase 2.

1.9 NORTHERN SIERRA NEVADA DIVERSITY GROUP

1.9.1 ANTELOPE CREEK

1.9.1.1 Restore instream flows during upstream and downstream migration periods through water exchange agreements and provide alternative water supplies to Edwards Ranch and Los Molinos Mutual Water Company in exchange for instream fish flows.

1.9.1.2 Restore connectivity of the migration corridor during upstream and downstream migration periods by implementing Edwards and Penryn fish passage and entrainment improvement projects and identify and construct a defined stream channel for upstream and downstream fish migration

1.9.2 MILL CREEK

1.9.2.1 Implement a Mill Creek anadromous fish passage study (AFRP Website 2005) that will evaluate fish passage at all agricultural diversions to determine if they meet NMFS' fish passage criteria. Design and install state-of-the-art fish passage facilities at diversions that currently do not meet the passage criteria.

1.9.2.2 Conduct a study designed to determine adult fish passage flows at critical riffles and fish ladders in Mill Creek. Develop a water exchange agreement with all Mill Creek water users to allow implementation of those flows.

1.9.2.3 Eliminate sources of chronic sediment delivered to Mill Creek from roads and other near stream development by out-sloping roads, constructing diversion prevention dips, replacing under-sized culverts and applying other storm proofing guidelines.

1.9.3 DEER CREEK

1.9.3.1 Develop and implement a water exchange agreement with the Deer Creek Irrigation Company and the Stanford-Vina Irrigation District and dedicate fish passage flows.

1.9.3.2 Construct state-of-the-art inflatable dams and install fish ladders that meet NMFS' adult fish passage criteria at the Cone-Kimball Diversion, Stanford-Vina Dam, and the Deer Creek Irrigation District Dam.

1.9.3.3 Implement the Deer Creek Flood Improvement Project.

1.9.3.4 Implement watershed restoration actions that reduce sedimentation and thermal loading in low gradient headwater habitats of Deer Creek Meadows, and Gurnsey Creek.

1.9.4 BUTTE CREEK

1.9.4.1 Develop, implement and evaluate a Butte Creek flow test for the PG&E DeSabla-Centerville Hydroelectric Project to determine the flow conditions that optimize coldwater holding habitat and spawning distribution.

1.9.4.2 Install state-of-the-art fish ladders at DWR weir 2 and Willow Slough weir.

1.9.4.3 Maintain state-of-the-art fish passage facilities at diversions in Butte Creek to meet NMFS' passage criteria.

1.9.5 FEATHER RIVER

1.9.5.1 Implement the use of a weir in the Feather River to spatially segregate spring-run Chinook salmon and fall-run Chinook salmon during their spawning migrations.

1.9.5.2 Develop a hatchery genetic management plan for the Feather River Fish Hatchery, including specific criteria for operating as either an integrated or segregated hatchery.

1.9.5.3 Develop and implement a spring-run pulse flow schedule that is coordinated with Yuba River operations for dry and critically dry years.

1.9.5.4 Develop a spawning gravel budget, identify gravel depleted areas, and implement an augmentation plan in the Feather River.

1.9.5.5 Construct steelhead side channel habitats using carrying capacity models sufficient to support a viable naturally spawning population of steelhead in the lower Feather River.

1.9.5.6 Implement facilities modifications(s) to achieve Feather River water temperatures at least as protective as those specified in Table 2 of the Settlement Agreement For Licensing of the Oroville Facilities (March 2006)

1.9.6 YUBA RIVER

1.9.6.1 Develop and implement a phased approach to salmon reintroduction planning to re-colonize historic habitats above Englebright Dam. Implement actions to: (1) enhance habitat conditions including providing flows and suitable water temperatures for successful upstream and downstream passage, holding, spawning and rearing; and (2) improve access within the area above Englebright Dam, including increasing minimum flows, providing passage at Our House, New Bullards Bar, and Log Cabin dams, and assessing feasibility of passage improvement at natural barriers. The phased approach should include:

- Conduct feasibility studies
- Conduct habitat evaluations
- Conduct 3-5 year pilot testing program
- Implement long-term fish passage program

1.9.6.2 Improve spawning habitat in the lower river by gravel restoration program below Englebright Dam and improve rearing habitat by increasing floodplain habitat availability.

1.9.7 AMERICAN RIVER

1.9.7.1 Develop and implement a phased approach to steelhead reintroduction planning to re-colonize historic habitats above Folsom Dam.

- Conduct feasibility studies
- Conduct habitat evaluations
- Conduct 3-5 year pilot testing program
- Implement long-term fish passage program

1.9.7.2 Implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management

1.9.8 MOKELUMNE RIVER

1.9.8.1 Evaluate and, if feasible, develop and implement a fish passage program for Camanche and Pardee dams. Any actions should be phased and consider the following elements:

- Conduct feasibility studies
- Conduct habitat evaluations
- Conduct 3-5 year pilot testing program

- Implement long-term fish passage program

1.9.8.2 Manage cold water pools in Camanche and Pardee Reservoirs to provide suitable water temperatures for all downstream life stages.

1.10 MAINSTEM SAN JOAQUIN RIVER

1.10.1 Develop and implement a suite of actions to improve salmon and steelhead outmigration survival through the lower San Joaquin River by:

- ❑ Restoring floodplain habitat, and implementing ecological flow schedules to create frequently activated floodplain;
- ❑ Reducing contaminants;
- ❑ Implementing remedies for the biological oxygen demand and low dissolved oxygen levels in the Stockton Deep Water Ship channel that delay of impede fish migration.

1.10.2 Implement Action IV.2.1 (San Joaquin River Inflow to Export Ratio) of the Reasonable and Prudent Alternative described in the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009) to improve juvenile outmigration for steelhead and future spring-run Chinook salmon.

1.11 SOUTHERN SIERRA NEVADA DIVERSITY GROUP

1.11.1 STANISLAUS RIVER

1.11.1.1 Evaluate and, if feasible, develop and implement a fish passage program for Goodwin, New Melones and Tulloch dams as generally described in Appendix C.

1.11.1.2 Manage cold water pools behind Goodwin, New Melones and Tulloch dams to provide suitable water temperatures for all downstream life stages.

1.11.2 CALAVERAS RIVER

1.11.2.1 Develop long-term instream flow schedules and requirements based on physical habitat modeling and critical riffle analysis.

1.11.2.2 Establish a minimum carryover storage level at New Hogan Reservoir that meets the instream flow and water temperature requirements in the lower Calaveras River.

1.11.2.3 Remove or modify all fish passage impediments in the lower Calaveras River to meet NMFS fish passage criteria.

1.11.3 TUOLUMNE RIVER

1.11.3.1 Evaluate and, if feasible, develop and implement a fish passage program for La Grange and Don Pedro dams. Any reintroduction actions should be a phased approach and consider the following elements:

- Conduct feasibility studies
- Conduct habitat evaluations
- Conduct 3-5 year pilot testing program
- Implement long-term fish passage program

1.11.3.2 Manage cold water pools behind La Grange and Don Pedro dams to provide suitable water temperatures for all downstream life stages.

1.11.4 SAN JOAQUIN RIVER (Friant Dam to Merced River confluence)

1.11.4.1 Implement the San Joaquin River Restoration Program (SJRRP). The SJRRP is a comprehensive long-term effort to restore flows to the San Joaquin River from Friant Dam to the confluence of Merced River and re-establish spring-run Chinook salmon in the river while reducing or avoiding adverse water supply impacts from restoration flows. SJRRP actions include:

- ❑ Implement interim and long-term settlement flows

- Develop and implement a spring-run Chinook salmon reintroduction strategy
- Construct channel modifications to increase the channel capacity from 475 cfs to 4,500 cfs.
- Minimize entrainment and fish losses to non-viable migration pathways
  - Screen Arroyo Canal
  - Retrofit Sack Dam to ensure unimpeded fish passage
  - Construct Mendota Pool Bypass
  - Fill and isolate high priority gravel pits
  - Implement temporary barriers at Mud and Salt Sloughs

7.0 Climate Change and Recovery of Salmon and Steelhead

"Climate variability plays a large role in driving fluctuations in salmon abundance by influencing their physical environment, the availability of food, the competitors for that food, and the predators that prey on small salmon. The complexity of influences on salmon, both climate and otherwise, combined with the scarcity of observations of factors important to salmon in estuaries and the ocean, make it challenging to identify the links between salmon and climate."

- Climate Impacts Group (2004)

7.1 Overview

The scientific basis for understanding the processes and sources of climate variability has grown significantly in recent years, and our ability to forecast human and natural contributions to climate change has improved dramatically. With consensus on the reality of climate change now established (Oreskes 2004; IPCC 2007), the scientific, political, and public priorities are evolving toward determining its ecosystem impacts, and developing strategies for adapting to those impacts. Climate forces directly influence regional temperature, wind, precipitation, snowpack and streamflow patterns, which may impact the habitat suitability for marine and anadramous species directly or indirectly (Schwing 2009).

Salmon populations throughout the West Coast are at historically low levels due to stresses imposed by a variety of human activities including dam construction, logging, pollution, and over-fishing. Climate change affects salmon throughout their life cycle and poses an additional stress. As more winter precipitation falls as rain rather than snow, higher winter flows scour streambeds, damaging spawning redds and washing away eggs incubating in the streambed. Earlier peak flows flush young salmon from rivers to estuaries before they are physically mature enough for the transition, increasing a variety of stresses including the risk of being eaten by predators. Earlier snowmelt leaves rivers and streams warmer and shallower during the summer and fall (Thomas et al. 2009).

Increasing air temperatures, particularly during the summer, lead to rising water temperatures, which increase stress on coldwater fish such as salmon and steelhead. Projected temperatures for the 2020s and 2040s under a higher emissions scenario suggest that the habitat for these fish is likely to decrease dramatically (Mote et al. 2008; Salathé et al. 2005; Keleher et al. 1996; McCullough et al. 2001). Reduced summer flows and warmer water temperatures will create less favorable instream habitat conditions for salmon and other coldwater fish species. Warmer water causes eggs to hatch earlier in the year, resulting in young that are smaller and more vulnerable to predators. Warmer conditions also increase the fish's

metabolism, taking energy away from growth and forcing the fish to find more food, but earlier hatching of eggs could put them out of sync with the insects they consume (Thomas et al. 2009). In addition, diseases and parasites that infect salmon tend to flourish in warmer water. Climate change also impacts the ocean environment, where salmon spend years of their lives. Historically, warm periods in the coastal ocean have coincided with relatively low abundances of salmon, while cooler ocean periods have coincided with relatively high salmon numbers (Janetos et al. 2008; Crozier et al. 2008).

Studies suggest that up to 40 percent of Pacific Northwest salmon populations may be lost by 2050 (Battin et al. 2007). In California and the Pacific Northwest, most wild salmon populations are extinct or imperiled in 56 percent of their historical range (Francis and Mantua 2003). Studies also suggest that about one-third of the current habitat for salmon and other coldwater fish will no longer be suitable for them by the end of this century as key temperature thresholds are exceeded (Thomas et al. 2009). Because climate change impacts on salmon and steelhead habitat is projected to be negative, climate change is expected to hinder efforts to recover depleted populations of Chinook salmon and steelhead (Thomas et al. 2009).

7.2 Climate Change and Environmental Variability

For ecosystem concerns (e.g., warming, wildfire, sea level rise, anthropogenic influences, El Niño) related to long-term climate changes, all regions under the management jurisdiction of NMFS are expected to experience environmental conditions that have not been experienced before (NMFS 2007). Warming over this century is projected to be considerably greater than over the last century (Thomas et al. 2009). Since 1900, the global average temperature has risen by about 1.5°F. By about 2100, it is projected to rise between 2°F and 10.5°F (**Figure 7-1**), but could increase up to 11.5°F (Thomas et al. 2009; California Climate Change Center 2006). In the United States, the average temperature has risen by a comparable amount and is very likely to rise more than the global average over this century, with some variation according to location. Several factors will determine future temperature increases. Increases at the lower end of this range are more likely if global heat-trapping gas emissions are substantially reduced.

If emissions continue to rise at or near current rates, temperature increases are more likely to be near the upper end of the range. Volcanic eruptions or other natural variations could temporarily counteract some of the human-induced warming, slowing the rise in global temperature, but these effects would only last a few years (Thomas et al. 2009).

Climate-related fire dynamics also will be affected by changes in the distribution of ecosystems across the landscape. Torn et al. (1998) project that there will be a doubling of catastrophic wildfires in some regions due to faster and more intense burning associated with warming, drying vegetation, and elevated wind speed. Increasing temperatures and shifting precipitation patterns also will drive declines in high elevation ecosystems such as alpine forests. As an example, under higher emissions scenarios (Figure 7-1), high-elevation forests in California are projected to decline by 60 to 90 percent before the end of the century. At the same time, grasslands are projected to expand, another factor likely to increase fire risk. Climate changes also could create subtle shifts in fire behavior, allowing more "runaway fires" – fires that are thought to have been brought under control, but then rekindle (Thomas et al. 2009).

Current climate trends predict a future of warmer oceans and melting glaciers and icecaps, all of which are expected to raise mean sea levels, leading to the inundation and displacement of many estuaries. A rise in sea level will most dramatically affect those estuaries that are confined by surrounding development, which

prohibits their boundaries from naturally shifting in response to inundation. Projections for sea level rise by 2100 vary from 0.18 to 0.58 meters (m), to 0.5 to. 1.4 m (Edgerton 1991 in NMFS 2009; IPCC 2007a; Rahmstorf 2007; Raper and Braithwaite 2006). Paleoclimatic data suggest that the rate of future melting of Greenland and Antarctic ice sheets and related sea-level rise could be faster than currently projected (NMFS 2009). A projected 1 m rise in sea level could potentially inundate 65 percent of the coastal marshlands and estuaries in the United States. In addition, there could be shifts in the quality of the habitats in affected coastal regions. Prior to being inundated, coastal watersheds would become saline due to saltwater intrusion into the surface and groundwater. Regarding California's water supply, the largest effect of sea level rise would likely be in the Delta (DWR 2005). Increased intrusion of salt water from the ocean into the Delta could lead to increased releases of water from upstream reservoirs or reduced pumping from the Delta to maintain compliance with Delta water quality standards (Anderson et al. 2008).

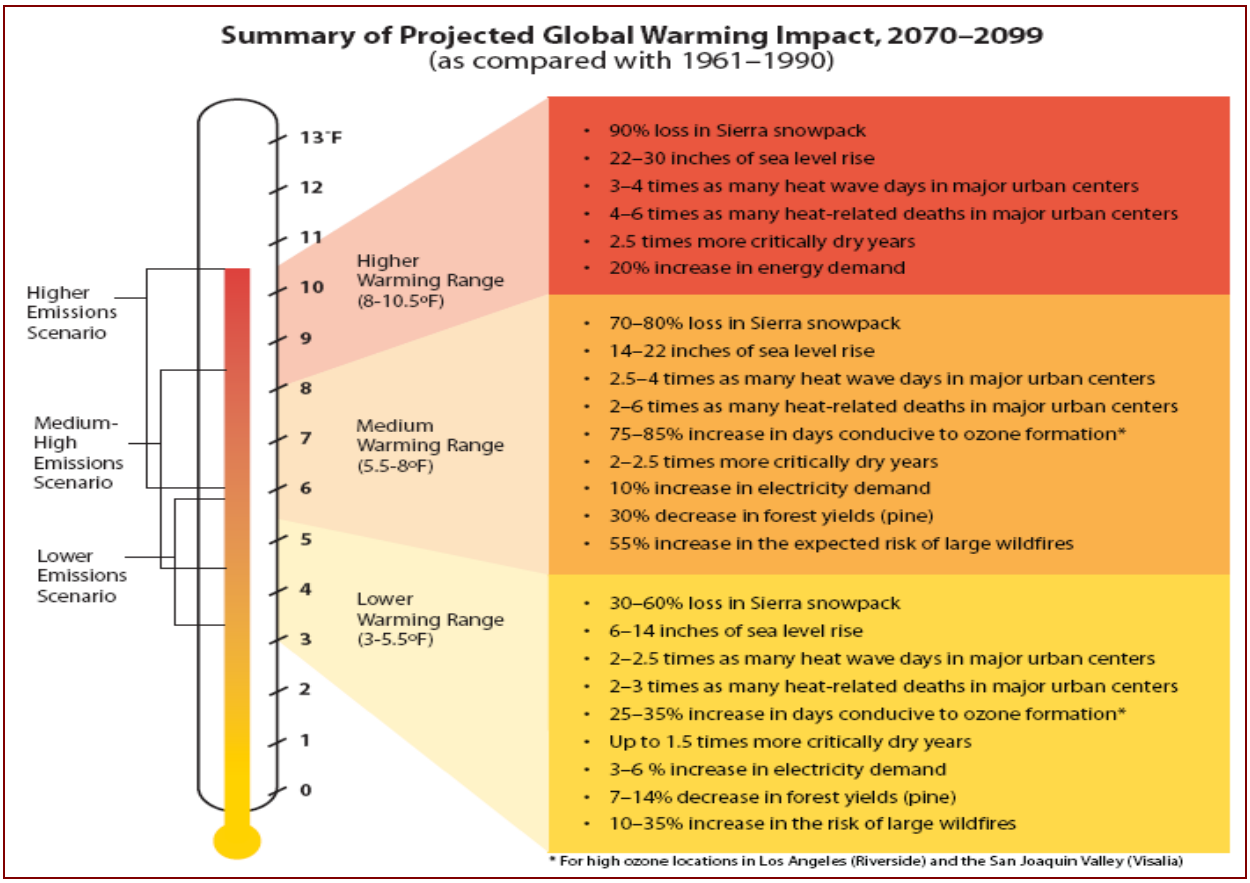


Figure 7-1. Summary of Projected Global Warming Impacts (2070 to 2099 compared to 1961 to 1990).

(Source: California Climate Change Center 2006)

Anthropogenic influences on salmon and steelhead habitat play a primary role in climate influences on extinctions (Francis and Mantua 2003). Over the past 150 years, human activities have degraded, and in some cases completely eliminated, much of the historic stream and estuarine habitats for anadromous salmonids. In many ways, human actions have forced semi-permanent changes to the salmonid landscape that parallel those typically associated with climate change (Karr 1994). For example, stream temperatures, flow regimes, sediment transports, and pool-to-riffle ratios are all subject to anthropogenic and climate changes. Karr (1994) indicates that one major difference between perturbations due to natural climate events versus one caused by human activities is the time scale of the resulting impacts. A warm phase of the El Niño-Southern Oscillation generally impacts precipitation and flow over a single year, while hydropower dam construction alters flow for decades to centuries (Francis and Mantua 2003).

Figure 7-2. Schematic of Coastal Upwelling Near the California Coast. Winds from the northwest during spring and summer drive surface water offshore, and it is replaced by cool water high in nutrients that is "upwelled" onto the continental shelf. (Source: NMFS 2009 - image from NOAA Cordell Bank National Marine Sanctuary).

Because it affects the distribution of heat in the atmosphere and the oceans, climate change will affect winds and currents that move along the nation's coasts, such as the California Current that bathes the West Coast from British Columbia to Baja California (Thomas et al. 2009). Wind-driven upwelling of deeper ocean water along the coast in this area is vital to moderation of temperatures and the high productivity of Pacific Coast ecosystems (**Figure 7-2**). Warmer temperatures are likely to increase ocean stratification, yet possible increases in winds may counter that in ways that mitigate or even increase the wind-driven upwelling of nutrients that fuel a productive food web (CIG 2004).

Coastal currents are subject to periodic variations caused by the El Niño-Southern Oscillation and the Pacific Decadal Oscillation, which have substantial effects on the success of salmon and other fishery resources. Climate change is expected to affect such coastal currents, and possibly the larger scale natural oscillations as well, although these effects are not yet well understood (Thomas et al. 2009).

In addition to carbon dioxide's heat-trapping effect, the increase in its concentration in the atmosphere is gradually acidifying the ocean (Thomas et al. 2009). About one-third of the carbon dioxide emitted by human activities has been absorbed by the ocean, resulting in a decrease in the ocean's pH. Since the beginning of the industrial era, ocean pH has declined demonstrably and is projected to decline much more by 2100 if current emissions trends continue (Thomas et al. 2009). Because less dissolved carbon is available as carbonate ions at a lower pH (Feely et al. 2008; Janetos et al. 2008), further declines in pH are very likely to continue to affect the ability of living organisms to create and maintain shells or skeletons of calcium carbonate. Ocean acidification also is anticipated to affect important plankton species in the open ocean,

mollusks and other shellfish, and corals (Feely et al. 2008; Janetos et al. 2008; Royal Society 2005; Orr et al. 2005). Reductions in pH also affect photosynthesis, growth, and reproduction. The upwelling of deeper ocean water, deficient in carbonate and thus potentially detrimental to the food chains supporting juvenile salmon, has recently been observed along the West Coast (Feely et al. 2008).

It is unclear how coastal ocean conditions will respond to long-term climate change and, in turn, affect Chinook salmon and steelhead populations during their marine lifestages. Results of studies by Pearcy (1992) and Francis and Hare (1994) indicate that many climate-related biophysical linkages to salmonid populations occur very early in the salmon's marine life history - likely just months after juvenile fish enter the ocean. Climate-related investigations conducted by Francis and Mantua (2003) address the superposition of natural climate variability on anthropogenically stressed salmon ecosystems, believed to be an issue of serious concern for the future sustainability of salmon populations. Those authors focused on two particular elements: (1) linear relationships between climate and salmon meta-population variability along the Pacific Coast, from Alaska to California, which yielded a robust large-scale pattern of salmon meta-population responses to climate variability; and (2) selection of case studies to illustrate complex, nonlinear relationships between climate influences and salmon population variability. Of particular interest regarding climatic influences on salmon survival, interdecadal environmental fluctuations associated with the Pacific Decadal Oscillation appear to have significantly reduced ecosystem carrying capacity for West Coast coho salmon since a regime shift occurred during 1977 (Francis and Mantua 2003). While Francis and Mantua's (2003) studies focused on West Coast coho salmon, their results agree with those of previous studies that identify the first few months of the salmon's ocean life as the period of critical climatic influences on survival which, in turn, suggests that coastal and estuarine environments are key areas of biophysical interaction. It seems likely that the polarity of the Pacific Decadal Oscillation climate pattern will continue to change at interdecadal time scales as it has over (at least) the past century.

7.3 Climate Change Effects on Ocean Conditions

Most climate factors affect the entire West Coast complex of salmonids. This is particularly true in their marine phase, because the California populations are believed to range fairly broadly along the coast and intermingle, and climate impacts in the ocean occur over large spatial scales (Schwing 2009). Because ocean warming will be widespread, populations at the southern extreme of their ranges will be most susceptible to future warming. Salmon and steelhead residing in coastal areas where upwelling is the dominant process are more sensitive to climate-driven changes in the strength and timing of upwelling. Coastal sea level is generally not a major issue along the West Coast, but future sea level rise will be important to juvenile fish in the San Francisco Bay and Delta, as well as in lagoons and estuaries where the annual cycle of bar development and breaching are important to salmonid life history strategies. Perhaps the greatest uncertainty is how ocean acidification will affect salmonids and their marine ecosystem (Schwing 2009). The following is a general discussion of anticipated future changes in ocean conditions, as they may affect off-shore areas used by winter- and spring-run Chinook salmon, and steelhead during their marine life stages.

7.3.1 California Current Ecosystem

The California Current Ecosystem (CCE) is designated by NMFS as one of eight large marine ecosystems within the United States Exclusive Economic Zone. The California Current begins at the northern tip of Vancouver Island, Canada and ends somewhere between Punta Eugenia and the tip of Baja California Mexico (NMFS 2009). The

northern end of the current is dominated by strong seasonal variability in winds, temperature, upwelling, plankton production and the spawning times of many fishes, whereas the southern end of the current has much less seasonal variability. For some groups of organisms, the northern end of the CCE is dominated by sub-arctic boreal fauna whereas the southern end is dominated by tropical and sub-tropical species. Faunal boundaries (i.e., regions where rapid changes in species composition are observed) are known for the waters between Cape Blanco Oregon/Cape Mendocino California, and in the vicinity of Point Conception California (**Figure 7-3**). Higher trophic level organisms often take advantage of the strong seasonal cycles of production in the north by migrating to the region during the summer to feed. Climate signals in this region are quite strong. During the past 10 years, the North Pacific has seen two El Niño events (1997/98, 2002/03), one La Niña event (1999), a four-year climate regime shift to a cold phase from 1999 until late 2002, followed by a four-year shift to warm phase from 2002 until 2006. The response of ocean conditions, plankton and fish to these events is well documented in the scientific literature. The biological responses are often so strong that the animals give early warning of events before such shifts are noticed in the physical oceanographic records (Osgood 2008). Numerous climate stressors (e.g., warming, sea level rise, freshwater flow) impact productivity and structure throughout the CCE. It is difficult to isolate the effect of individual stressors on most individual species, and most of these stressors impact many species at multiple trophic levels.

Five climate-related issues are of greatest concern in the CCE (Osgood 2008). The following provides a summary of these issues, based upon the analysis developed as part of NMFS' framework for a long-term plan to address climate impacts on living marine resources (Osgood 2008).

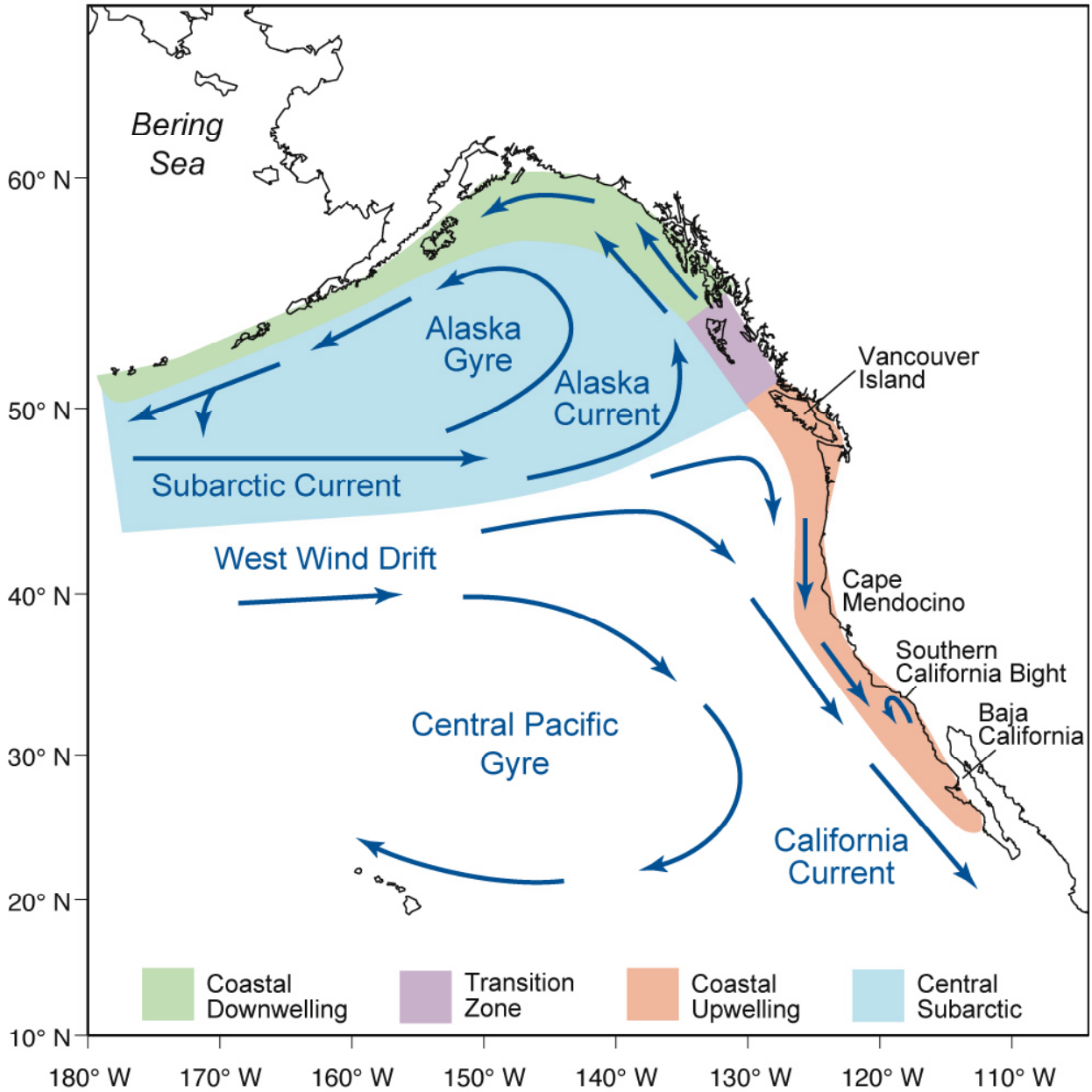


Figure7- 3. The Principal Ocean Currents Affecting the Coastal Waters off of California. Eastward flow (West Wind Drift) bifurcates as it nears the west coast. The southward arm (the California Current) transports, cool, low salinity, nutrient-rich water along the U.S. west coast. (Source: Image from J.A. Barth, Oregon State University)

Increased Future Climate Variability

One of the likely consequences of global climate change will be a more volatile climate with greater extreme events on the intra-seasonal to inter-annual scales. For the CCE, more frequent and severe winter storms are expected to occur, with greater wind mixing, higher waves and coastal erosion, and more extreme precipitation events and years, which would impact coastal circulation and stratification. Some global climate models predict a higher frequency of El Niño events; others predict that the intensity of these events will be stronger. If true, primary and secondary production will be greatly

reduced in the CCE, with negative effects transmitted up the food chain.

The Pacific Decadal Oscillation is a pattern of Pacific climate variability that shifts phases approximately every 20 to 30 years. During a "warm", or "positive" phase, the west Pacific becomes cool and part of the eastern ocean warms; during a "cool" or "negative" phase, the opposite pattern occurs. Most models project roughly the same timing and frequency of decadal variability in the North Pacific under the impacts of global warming. However, combined with the global warming trend, the CCE is expected to experience a greater frequency of years consistent with historical periods of lower productivity (e.g., positive Pacific Decadal Oscillation values). Based on ongoing observations, a positive Pacific Decadal Oscillation and a warmer ocean result in dominance of small warm-water zooplankton (which are lipid-depleted), which may result in food chains with lower bioenergetic content. By about 2030, it is expected that the minima in decadal regimes will be above the historical mean of the 20th Century (i.e., the greenhouse gas warming trend will be as large as natural variability).

The Extent and Timing of Freshwater Input

While variability in ocean conditions has substantial impacts on salmon survival and growth, future changes in freshwater and river conditions also will have a great effect on production of anadromous fish. Warmer air temperatures will result in more precipitation earlier in the year, and less snowpack. Changes in the seasonal and inter-annual timing and intensity of rainfall and snowpack, for example, are expected to increase winter and spring runoff and decrease summer runoff. These hydrologic changes may alter the way that water supplies from the Sacramento River are managed for hydropower generation and water storage, which may affect the manner in which Chinook salmon, steelhead and other estuarine-dependent species are managed.

Climate models project the 21st Century will feature greater annual precipitation in the Pacific Northwest, extreme winter precipitation events in California, and a more rapid spring snowmelt leading to a shorter, more intense spring period of river flow and freshwater discharge (Thomas et al. 2009). These changes are projected to considerably alter coastal stratification and mixing, riverine plume formation and evolution, and the timing of transport of anadromous fish populations to and from the ocean. A warmer and drier future also means that extra care will be needed in planning the allocation of water for the coming decades (Thomas et al. 2009). The current allocation of water resources between salmon and human requirements in the western United States has been a critical factor in the success of many salmon populations, and will be more so if future water availability is altered (Osgood 2008).

Changes in the Timing and Strength of the Spring Transition, and Their Resultant Effects on Marine Populations

The primary issue for the CCE is the onset and length of the upwelling season - when upwelling begins and ends (i.e., the "spring" and "fall" transitions). The biological transition date provides an estimate of when seasonal cycles of significant plankton and euphausiid production are initiated. At present, there is some evidence that coastal upwelling has become stronger over the past several decades due to greater contrasts between warming of the land (resulting in lower atmospheric pressure over the continent), relative to ocean warming. The greater cross-shelf pressure gradient will result in higher along-shore wind speeds and the potential for more upwelling (Bakun 1990). Regional climate models project that not only will upwelling-favorable winds will be stronger in summer, but that the peak in seasonal

upwelling will occur later in the summer (Snyder et al. 2003).

Even though southward winds that cause coastal upwelling are likely to increase in magnitude, these winds may be less effective in driving vertical transport of nutrient-rich water because it is not known if these winds will be able to over-ride increased water column stratification (Osgood 2008; NMFS 2009). That is, the winds may not be able to mix this light buoyant water or transport it offshore resulting in the inability of the cold nutrient-rich water to be brought to the ocean surface. Thus, phytoplankton blooms may not be as intense, which may impact organisms up the food chain (Roemmich and McGowan 1995).

Given that the future climate will be warmer, the upper ocean at the watershed scale will almost certainly be, on average, more stratified (Osgood 2008). This will make it more difficult for winds and upwelling to mix the upper layers of the coastal ocean, and will make offshore Ekman pumping less effective at bringing nutrients into the photic zone. The result will be lower primary productivity throughout the salmon marine habitat (with the possible exception of the nearshore coastal upwelling zones) (Osgood 2008).

Should global warming result in shorter winters in the Pacific Northwest, areas where production is light limited (e.g., the northern California Current) may see higher productivity (Osgood 2008). During most years since 2002, phytoplankton blooms are initiated as early as February off northern California in years when storm intensity is low. These early blooms result in bursts in egg production by both copepods and euphausiids, initiating a cohort of animals that reach adulthood one to two months earlier than a cohort that is initiated with the onset of upwelling during March or April. The result would be a longer plankton production season. Alternatively, regional climate projections are for a later shift in the start time, peak times and end of the upwelling season, which could counter the idea of a longer upwelling season (Osgood 2008).

Ocean Warming and Increased Stratification, and Their Resultant Effects on Pelagic Habitat

This issue focuses on the central and southern California Current, and on the organisms that utilize the upper ocean habitat in this region. Generally warmer ocean conditions will cause a northward shift in the distribution of most species, and possibly the creation of reproductive populations in new regions. Existing faunal boundaries are likely to remain as strong boundaries, but their resiliency to shifts in ocean conditions due to global climate change is not known (Osgood 2008). Warmer water temperatures also will affect freshwater salmon and steelhead habitats by reducing habitat opportunity on both spatial and seasonal time scales. In coastal and oceanic regions, the southern boundaries of pelagic habitats used by many populations are expected to shift northward.

Warmer air temperatures may lead to increased stratification of the coastal CCE. The warmer temperatures will increase the heat flux into the ocean. Mixing and diffusion are not likely to redistribute this heat rapidly enough to prevent an increase in thermal stability and stratification of the upper ocean (Osgood 2008). The vertical gradient in ocean water temperature off of the California coast has intensified over the past several decades (Palacios et al. 2004). Areas with enhanced riverine input into the coastal ocean will also see greater vertical stratification. Moreover, increased melting of glaciers in the Gulf of Alaska coupled with warmer sea surface temperatures will result in increased stratification. Because some of the source waters that supply the northern California Current originate in the Gulf of Alaska, more stratified source waters will contribute to increased stratification of coastal waters of the northern California Current (Osgood 2008).

Changes to Ocean Circulation and Their Resultant Effects on Species Distribution and Community Structure

NMFS (2008) states that this is a climate-induced ecosystem concern primarily for the northern California Current, although changes in transport are known to have subtle effects on the entire Current. A particular biological concern is related to the variability in the transport of organisms, which impacts zooplankton species composition and regional recruitment patterns for demersal fish stocks.

As previously discussed, the California Current extends from the northern tip of Vancouver Island, Canada to southern Baja California, Mexico. As the current flows from north to south, the waters warm and mix with offshore waters such that both temperature and salinity increase gradually in a southward direction (Osgood 2008). Observations of the biota of the California Current show that there are pronounced latitudinal differences in the species composition of plankton, fish, and benthic communities, ranging from cold water boreal sub-arctic species in the north to warm water subtropical species in the south. Changes in abundance and species composition can be gradual in some cases, but it is widely accepted that faunal boundaries (zones of rapid change in species composition) are present in the waters in the vicinity of Capes Blanco and Mendocino, and at Point Conception. The strongest contrasts are observed during summer (Osgood 2008).

The strong contrast in species composition between shelf and offshore waters during summer is due to the upwelling process. A combination of upwelling itself, along with the sub-arctic water which feeds the inshore arm of the northern end of the CCE, create conditions favorable for development of a huge biomass of sub-arctic zooplankton. This pattern is slightly modified as a function of the phase of the Pacific Decadal Oscillation. During a cool phase, all of the northern CCE becomes more sub-Arctic in character (both shelf-slope-oceanic regions); during a warm phase of the Pacific Decadal Oscillation, the water masses and associated copepod community become far more similar to a sub-tropical community. Copepod biodiversity increases in coastal waters, due to shoreward movement of offshore waters onto the continental shelf, due to either weakening of southward wind stress in summer or strengthening of northward wind stress in winter. Thus, when Pacific Decadal Oscillation is in a positive phase, a greater proportion of the water entering the northern end of the current is sub-tropical in character rather than sub-Arctic.

Regardless of the season, the source waters that feed into the California Current from the north and from offshore can exert some control the over the phytoplankton and zooplankton species that dominate the current (**Figure 7-4**).

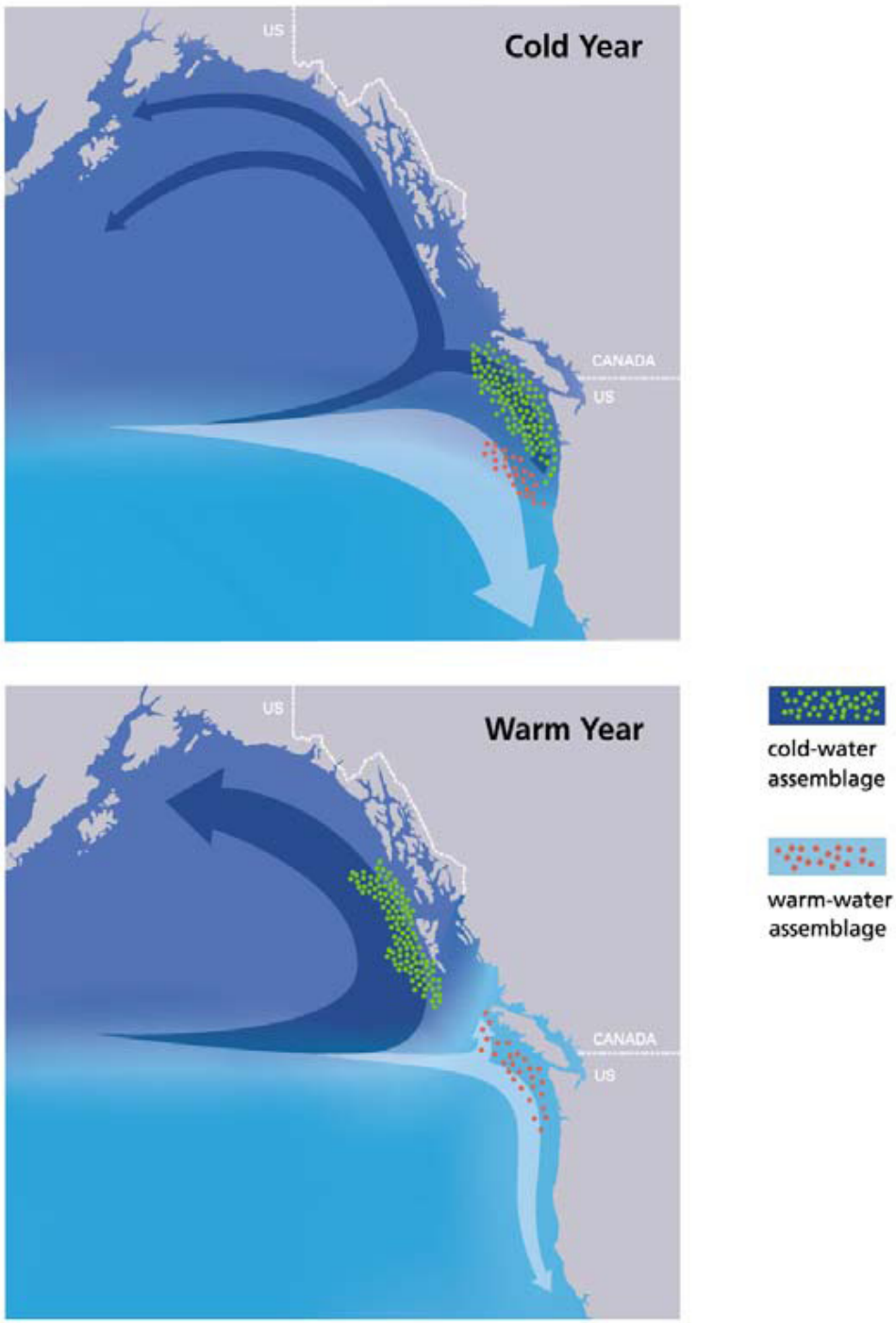


Figure 7-4. Schematic of the Flow of the North Pacific Current South into the California Current and North into the Gulf of Alaska. Cool years (such as La Niña and negative PDO years) are associated with greater flow into the California Current, which favors a southward displacement of coldwater and warmwater species. ***(Source: Osgood 2008)***

Hooff and Peterson (2006) suggest that knowledge of source waters is critical to understanding ecosystem dynamics in the shelf waters of the Northern CCE because waters from the Gulf of Alaska carry large, lipid-rich copepods to the shelf waters, whereas waters coming from an offshore source carry small, oceanic lipid-poor copepods to the shelf waters. Thus, changes reflected by Pacific Decadal Oscillation shifts may result in local food chains that have considerably different bioenergetic content. Given, for example, that: (a) salmon returns are low when the Pacific Decadal Oscillation is in a positive, warm water phase, but high when the Pacific Decadal Oscillation is in a negative, cold-water phase; and (b) salmon returns to Pacific Northwest rivers are highly correlated with copepod community structure (Peterson and Schwing 2003), variations in the bioenergetic content of the food web may represent a mechanistic link between Pacific Decadal Oscillation sign change and salmon survival (Osgood 2008).

Northward shifts in distribution also are possible. Generally warmer conditions could result in a northward shift in the distribution of some species, and possibly the creation of reproductive populations in new regions. Alternatively, if upwelling strengthens due to global climate change, regardless of the sign of the Pacific Decadal Oscillation, cold-water species should still be favored in the coastal upwelling zones (Osgood 2008). However, the onshore-offshore gradients in temperature and species abundance should strengthen if offshore waters become warmer and upwelling becomes stronger, creating stronger upwelling fronts, and perhaps a greater level of mesoscale activity. It is unclear how faunal boundaries might be affected (Osgood 2008).

7.4 Recommended Strategies for Considering Climate Effects and Application to Recovery Planning

While climate change clearly cannot be easily slowed or reversed, its impacts can be identified and mitigated at local scales (Schwing 2009). Based on the information presented above, it is possible to determine a relatively small set of regional physical factors of future climate change, which can be useful in targeting recovery of Chinook salmon and steelhead (Schwing 2009). In consideration of the differences in particular climate impacts to a domain, and the sensitivity of their salmon and steelhead stocks to climate change and other stressors, we can begin to recommend planning actions for each domain.

Compared to marine conditions, differences in the freshwater impacts of climate change are believed to be greater between domains, due largely to regional variability in precipitation and runoff, combined with a wide variety of watershed types and features and a range of other human pressures on those systems (Schwing 2009). As with their ocean phase, salmonid stocks will be more thermally stressed by stream warming at the southern ends of their ranges. Warming also is stressful in systems that are shallow and have lower flows in summer, and where access to cooler reaches is restricted by existing human barriers. Increased sedimentation will occur in concert with shifting forest and vegetation patterns, but will be less of a concern in shorter and stronger flowing streams and greater in systems where the other consequences of climate change will be formidable to salmonids. All domains are threatened by future alterations in flow regimes, and more so when there are other demands for water resources. Domains dependent on runoff from Sierra snowmelt are at greatest risk of seasonal change (Schwing 2009).

From this broad and initial assessment, and other information presented in this Recovery Plan in the Watershed Profiles (Appendix A), the Threats Assessment (Appendix B) and the Recovery Scenarios (Chapter 5), it appears that the combination of climate change impacts to freshwater and marine habitats utilized by Chinook salmon and steelhead, as well as the long history of a variety of human stresses, pose some of the greatest threats to the Central Valley

ESUs/DPS. The steelhead DPS and the Chinook salmon ESUs possess an elastic life history strategy, and those populations residing in unaltered watersheds are more likely to withstand the pressures of future climate change (Schwing 2009). In addition, Francis and Mantua (2003) offer several recommendations regarding salmonid vulnerabilities to climate fluctuations, and discuss possible strategies to preserve and enhance salmon meta-population resilience in the face of climate fluctuations. These considerations also are useful when planning for recovery, and have been incorporated into the conceptual recovery scenarios developed for winter- and spring-run Chinook salmon and steelhead.

- Climate alone is not likely to tip the balance. However, climate variability clearly has the capacity to amplify the risk and likelihood of extinction when superimposed upon salmonid ecosystems under extreme stress from humans

- Because climate-related effects on salmon appear to be much more significant at interdecadal than annual time scales, and because interdecadal time-scale climate change can only be recognized in hindsight, the effects of climate change need to be incorporated into fishery management policy (e.g., different management strategies and algorithms may be required for different climatic regimes)

- Climate-related negative impacts on salmon production at the regional scale likely have much more severe implications for individual breeding populations than for meta-populations as a whole. Clearly, this has been the case for thousands of years. However, combining the effects of human activities with climate fluctuations likely amplifies a number of these negative influences.

According to Francis and Mantua (2003), it is believed that salmon populations in regions with healthy habitat will probably survive, as long as the time scale of environmental change does not exceed their rate of adaptation. Enhancement of connectivity also will be a vitally important form of restoration in any strategic response to climate change (Bakke 2009). Those populations that are presently stressed by occupying healthy, marginal or fragmented habitat, will most likely face more acute threats of extinction with the additional burden of significant anthropogenic climate changes (Francis and Mantua 2003).

In addition to other restoration and threat abatement actions, recovery efforts should address how human behavior may be used or altered to mitigate and adapt to climate change. It is possible that these anthropogenic changes will be accentuated as the global climate continues to warm, and may lead to impacts to California's water resources and water project operations (Anderson et al. 2008). Examples include changes in water allocation patterns, population shifts and watershed development, and energy production that may further damage habitat (e.g., power generating dams) or provide alternative mechanisms (e.g., tidal and wave energy systems) that will not affect salmon habitat or add to atmospheric greenhouse gas concentrations. Schwing (2009) states that recovery efforts need to include actions that prepare infrastructure for future long-term adaptation and potential mitigation to address future climate change. This includes approaches to habitat restoration, fishing effort and catch limits, and hatchery production. Schwing (2009) also suggests that managers may wish to consider climate impacts in activities such as:

- Ecosystem restoration, including in-river habitat

- Enhancing connectivity between higher quality streams or river segments

- Enhancing restoration recovery programs,

for wild populations and selected habitats (e.g., Delta and river floodplains)

- Hatchery reforms
- Trucking and release of juvenile Chinook salmon populations
- Changes in production of selected threatened and non-threatened runs

As part of recovery planning efforts, future management actions must enhance system and population resilience, and identify the populations that are both most resilient and most vulnerable to environmental factors affected by climate change (Schwing 2009). It will be necessary to commit considerable resources to protect and reduce the threats of climate and other human actions to the least resilient salmonid populations, while it may eventually be determined that the most resilient populations must be protected and sustained in a limited resource environment.

7.5 Climate Change in Relation to Central Valley Domain Recovery

In California, there have been observed changes in air temperatures, annual precipitation, runoff, and sea levels over the past century (Anderson et al. 2008). Regional-scale climate models for California are in broad agreement that temperatures in the future will warm significantly, total precipitation may decline, and snowfall will decline significantly (Lindley et al. 2007). Literature suggests that by 2100, mean summer temperatures in the Central Valley may increase by 2 to 8°C, precipitation will likely shift to more rain and less snow, with significant declines in total precipitation possible, and hydrographs will likely change, especially in the southern Sierra Nevada mountains. Thus, climate change poses an additional risk to the survival of salmonids in the Central Valley. As with their ocean phase, Chinook salmon and steelhead will be more thermally stressed by stream warming at the southern ends of their ranges (e.g., Central Valley Domain). For example, warming at the lower end of the predicted range (about 2°C) may allow spring-run Chinook salmon to persist in some streams, while making some currently utilized habitat inhospitable (Lindley et al. 2007). At the upper end of the range of predicted warming, very little spring-run Chinook salmon habitat is expected to remain suitable (Lindley et al. 2007).

The complex life history of salmonids as well as the complexity of their multiple aquatic habitats makes it difficult to isolate what environmental factors, or drivers, are responsible for variability in these populations (Schwing 2009). Overall, the climate-species linkages for salmon are extremely complex. In a recent report to the Pacific Fishery Management Council, CDFG identified 46 possible reasons for the collapse of the 2004 and 2005 broods of Central Valley fall-run Chinook salmon. It is difficult to isolate the immediate effect of an individual stressor on a species, and most stressors impact many species at multiple trophic levels. Further, it is not likely that there is one single stressor, but a combination of several factors that drive ecosystem variability and change (Schwing 2009). Nevertheless, it is possible to focus on a relatively small number of factors that are sufficiently sensitive to climate change and impact the populations and freshwater and marine ecosystems of California anadromous salmonids.

This Recovery Plan addresses the Central Valley steelhead DPS, and two Chinook salmon ESUs - Sacramento River winter-run Chinook salmon, and Central Valley spring-run Chinook salmon. Because of their extended use of the Sacramento and San Joaquin River systems, they are very dependent on runoff from the Sierra snowpack and the variability of precipitation affecting it (Osgood 2008), as previously discussed. The future climate of the freshwater habitats of the Central Valley Domain is expected to include:

- More frequent intense winter storms, high stream flow events, and floods

- Earlier snowmelt, with higher peak flows in winter, less spring runoff, and much lower summer flows
- Considerably warmer stream, river and ocean water temperatures during the summer
- Greater inter-annual precipitation variability, more frequent wet and drought years, and extended droughts
- Years with weaker fall storms, and delays in the onset of high stream flows
- More frequent wildfires and infestations, and increased erosion and sedimentation
- Delays in the onset of coastal upwelling, and associated delayed biological production
- Declining ocean conditions
- Sea level rise and more saline estuarine and Delta conditions

An important distinction in the winter-run and spring-run Chinook salmon ESUs is the timing of their life history events, which has implications for different climate change impacts. Winter-run Chinook salmon adults return and migrate upstream in winter through early spring, where they hold for several months before spawning in late spring and summer (Williams 2006). This provides an advantage over the spring- and late fall-runs of longer stream rearing times without juvenile fish having to over-summer (Yoshiyama et al. 1998). However, incubation, the most temperature-sensitive life stage, coincides with the time when river temperatures can exceed the lethal range for embryo incubation. Thus, winter-run Chinook salmon occur currently only in the Sacramento River, where summer water temperatures are cool enough to enable successful embryo incubation, but warm enough in winter to support juvenile rearing (Stillwater 2006 in Schwing 2009). They also spawn in deeper water than other populations (Moyle 2002). Juvenile winter-run Chinook salmon have historically exploited the floodplain habitat created by winter flooding in the Sacramento River Basin, which results in higher juvenile growth rates and presumably higher ocean survival (Sommer et al. 2001 in Schwing 2009).

The life history of spring-run Chinook salmon is to migrate upstream in spring, hold through the summer in deep pools, and then spawn in early fall, with juveniles emigrating after either a few months or a year in freshwater. However, they have considerable flexibility in their life history strategies. Age at spawning for spring-run Chinook salmon varies from two to four years.

Central Valley watersheds are fed predominantly by runoff from Sierra snowmelt, which has been historically highest during the late spring and early summer. The resulting high flow allows Chinook salmon to reach their summer holding areas, while the lower flow extending from the summer into early fall is cool enough for spawning. In the San Joaquin River drainage, snowmelt at high elevations produced a long runoff period that benefited Chinook salmon, making them the dominant run in the region. However, the recent trend toward an earlier seasonal runoff and lower flow in spring and summer has reduced the potential for survival in these watersheds, and will make the transit of adults returning to their spawning streams more difficult (see watershed profile information for individual rivers located in the Southern Sierra Nevada Diversity Group).

Because eggs and juveniles are less tolerant of warm water temperatures, spawning occurs during the fall, after streams cool. On their migration to the ocean, juvenile fish access temporary habitats with warmer water temperatures and abundant food in floodplain, tidal marsh, and estuarine habitats. These habitats are very important in smolt growth and survival -

smolt size at ocean entry strongly affects survival during the first year at sea (Williams 2006). After reaching the ocean in the late spring and summer, smolts forage near the coast on crustaceans, euphausids, and prey fishes (MacFarlane and Norton 2002) that is associated with upwelling. Smolt survival over their first winter is dependent on a threshold of prey and the resultant smolt condition after the first summer at sea (Williams 2006).

Because of their close proximity, a relatively small wildfire could simultaneously burn the headwaters of all three remaining spring-run Chinook populations. Such a fire has a 10 percent chance of occurring in any given year in California (Lindley et al. 2007), but this probability will increase due to climate change. Prolonged drought due to lower precipitation shifts in snowmelt runoff, and greater climate extremes could also easily render most existing spring-run Chinook salmon habitat unusable, either through temperature increases or lack of adequate flows.

Increased water temperature, low flow, drought and other climate-related events will compound the threats to Chinook salmon due to human manipulation of their freshwater habitats. Because of these watersheds' great dependence on Sierra snowpack melt, the projected shift toward earlier runoff (Dettinger and Cayan 1995; Cayan et al. 2001) will exacerbate sensitivity to low flow and warm stream conditions at critical lifestages. Winter-run Chinook salmon are especially vulnerable to climate warming, prolonged drought, and other catastrophic climate events, because they have only one remaining population that spawns in the hottest time of the year (also see the conceptual recovery scenario for winter-run Chinook salmon). Additionally, future ocean productivity will decline due to altered upwelling cycles, thus reducing prey availability and salmon ocean survival (NMFS 1997 in Schwing 2009).

Central Valley steelhead also exhibit a flexible life history, allowing them to compensate for the variable conditions and extremes of their habitat (McEwan 2001). Most juveniles remain in their streams for one or two years before becoming smolts and emigrating out to the Delta and ocean (Hallock 1961 in Schwing 2009). Others may remain in the rivers their entire lives. Temperature and water quality are critical factors for fry and juvenile survival (Moyle 2002). Fry move into cooler, deeper, faster-flowing channels in the late summer and fall (Hartman 1965, Everest and Chapman 1972, and Fontaine 1988 in Schwing 2009). Juvenile steelhead prefer deep pools with heavy cover, as well as higher-velocity rapids (Bisson et al. 1982, 1988 and Dambacher 1991 in Schwing 2009).

The distribution of steelhead today is greatly reduced from the historical distribution. Dams and water diversions limit steelhead access to less than 20 percent of their historical spawning and rearing areas in the Central Valley (Yoshiyama et al. 2001; Lindley et al. 2006). Climate warming will further restrict access to cool water streams. Most of the same climate factors that affect other California steelhead populations are critical to Chinook salmon. The diversity and variability of their life history complicates their management. Yet this same attribute reduces their vulnerability to climate change.

Additionally, the Central Valley TRT (Lindley et al. 2007) reports that low flows during juvenile rearing and outmigration are associated with poor survival (Kjelson and Brandes 1989; Baker and Morhardt 2001; and Newman and Rice 2002) and poor returns in subsequent years (Speed 1993). Climate change also may impact Central Valley salmonids through community effects. For example, warming may increase the activity and metabolic demand of predators, reducing the survival of juvenile salmonids (Vigg and Burley 1991).

7.6 Additional Considerations Applied to the Conceptual Recovery Scenarios

Currently, there is little information in the literature on the geomorphic effects of climate change (Bakke 2009). Most of the existing research has focused on the impacts to climate itself and to gross-scale hydrological change. Tools for predicting geomorphic impacts at specific locations are possible, but poorly developed. However, the general principles discussed below can be used to suggest ways to screen the landscape for habitat that is potentially resilient or sensitive to climate change. Development of such screening tools may ultimately provide a systematic and consistent way to address recovery, restoration, and conservation in the context of climate change (Bakke 2009).

Taking into consideration species- and watershed-specific information (see watershed profiles in Appendix A for more detail), each of the concepts described below were either directly or indirectly incorporated in the conceptual recovery scenarios for winter-run Chinook Salmon, spring-run Chinook salmon and steelhead within the Central Valley Domain.

7.6.1 Resiliency

In ecology, resiliency carries the additional meaning of how much disturbance a system can "absorb" without crossing a threshold and entering an entirely different state of equilibrium (e.g., distinctly different physical habitat structure or conditions) (Bakke 2009). In regard to recovery, habitat restoration, and conservation of at-risk aquatic species, resiliency also requires that certain key habitat characteristics or processes will change little, or not at all, in response to climate change. When it comes to stream aquatic habitat, the most important elements to remain steady are temperature and disturbance regime (Bakke 2009). Resiliency is temporally dependent and given enough time, large disturbances are virtually certain to occur on the landscape and to the climate. Resiliency can only function on a landscape scale; there must be enough individual rivers available with the appropriate habitat and connectivity so that a disturbance to one portion of the system has a minimal impact on at-risk aquatic species because other parts of the system are able to support sensitive populations through the recovery and recolonization period (Bakke 2009).

In the long-term, there is no substitute for a landscape that offers redundancy of habitat opportunities. Many of the features that make up high-quality salmonid habitat, such as buried organic matter, large gravel deposits, side channels, and logjams, for example, are relics of the legacy of past disturbances. The issue is not to shun stream reaches that are more prone to disturbance, but to identify and work with stream reaches that are likely to have a consistent disturbance regime as opposed to ones that will drastically change as the climate continues to change. This will assure that the habitat identified retains its physical morphology and patterns of cyclic evolution rather than shifting to some different, and presumably less stable, habitat type. In essence, the strategy suggested is to provide multiple interconnected refugia which undergo severe disturbances at differing periods of time (Bakke 2009).

7.6.2 Refugia

Refugia are places in the landscape where organisms can go to escape extreme conditions (Bakke 2009). Typically, this refers to short-term conditions such as floods or high water temperatures. But in the context of climate change, refugia can also be places where a population may persist through decades and centuries of unfavorable climate conditions and instability. For coldwater obligate fish species, refugia will continue to be areas where groundwater emergence influences water temperature and volume. These refugia will exist on several scales: (1) local areas of cool water emergence within a

reach otherwise insufficiently cool; and (2) entire stream systems where groundwater hydrology is dominant or snowmelt hydrology is preserved due to high elevations. Thus, the same set of circumstances producing cool water conditions in the current landscape may, to varying degrees, produce thermal refugia against global warming. Maintaining connectivity amongst these refugia will be difficult. It will be important to protect these areas and in some cases to enhance them or improve their connectivity (Bakke 2009).

7.6.3 Restoration

Enhancement of connectivity will be a vitally important form of restoration in any strategic response to climate change. Restoration has traditionally been driven by a combination of political and biological considerations. If scarce restoration funds are to be targeted for species recovery in the face of climate change, it is highly important that a site-selection hierarchy based on resource values, and a hierarchy of priority actions based on long-term sustainability be followed. Sustainable restoration includes activities which reestablish the structure and function of the stream ecosystem in a manner that the ecosystem will become self-maintaining. Site selection should prioritize areas of high resource value, tempered by considerations of resiliency to climate change. Areas of high resource value would include strongholds and refugia. Highest priority actions in these areas would be protection of good habitat, improving connectivity and access to existing habitat not currently occupied, and only then followed by process-based restoration of lower quality habitat. All actions should be analyzed in relation to sustainability, resiliency, and threats from climate change.

When river restoration is performed, or when "fish friendly" river engineering is contemplated, the dynamic nature of climate change effects makes redundancy of actions desirable. Redundancy can be applied in both horizontal and vertical dimensions. Building engineered log jam structures higher and bulkier than current design practice to accommodate larger peak flows in the future would be one simple example of vertical redundancy. Horizontal redundancy would include the placement of structures in currently inactive side channels to assure function in the event of channel avulsions or accelerated channel migration.

In addition, restoration site selection will need to consider geomorphic instability. Some of the most productive spawning areas for many fish are in sensitive response reaches, which are likely to undergo an episode of geomorphic instability because of climate change. If active restoration, such as enhancement of instream habitat with large wood, is to be performed in potentially unstable settings, it will be important to design these projects with the appropriate level of redundancy to accommodate greater rates of channel migration and flood magnitudes. This potential needs to be incorporated into discussions of the definition of success, long-term sustainability, and cost of the project. Passive restoration techniques, such as establishment of wider riparian buffers, may be a more sustainable alternative in light of increased geomorphic instability caused by global warming.

8.0 Implementation and Cost Estimates

"Although recovery actions can, and should, start immediately upon listing a species as endangered or threatened under the ESA, prompt development and implementation of a recovery plan will ensure that recovery efforts target limited resources effectively and efficiently into the future."

NMFS 2006. Interim Endangered and Threatened Species Guidance

8.1 Time and Cost

Section 4(f) of the ESA requires that recovery plans include "estimates of the time required and the cost to carry out those measures needed to achieve the Plan's goal and to achieve intermediate steps toward that goal" (16 U.S.C. 1531-1544, as amended). NMFS estimates that recovery for listed Central Valley salmon and steelhead, like for most of the ESA-listed Pacific Northwest salmon and steelhead, could take 50 to 100 years. While there is an extensive list of actions that need to be undertaken to recover the listed Central Valley salmonids, there are many uncertainties involved in predicting the course of recovery and in estimating total costs. Such uncertainties include biological and ecosystem responses to recovery actions as well as long term and future funding.

Obtaining and evaluating cost estimates for recovery actions can be challenging, and projecting costs into the future becomes increasingly imprecise. NMFS believes it is impracticable to estimate all projected actions and costs over 50 to 100 years, given the large number of economic, biological, and social variables involved, and that it is more appropriate to initially focus on the first five or 10 years of implementation.

The Southwest Fisheries Science Center (SWFSC) produced a draft report providing information on costs associated with restoration activities (**Appendix E**). Data from publicly available sources were used to obtain estimates of restoration costs for a variety of restoration activities. All costs described in the report pertain to direct expenditures on restoration and do not include economic opportunity costs (*e.g.*, foregone profits associated with restrictions on livestock grazing, timber harvest and other activities). Many cost estimates for restoration activities in the Central Valley are specifically based on CALFED Ecosystem Restoration Program (ERP) implementation and/or contracted costs (most notably fish screening projects, gravel supplementation, channel restoration, bank stabilization, land acquisition, conservation easements, proposed watershed effectiveness monitoring, and a 5-dam decommissioning and removal project), so are specific to the Central Valley and are referenced as such in the draft report. Also, levee-related and water purchase/lease activity cost estimates for the Central Valley were included in the report, based on information from DWR, county water agencies, and ERP. Irrigation ditch activity costs, including water control structures, were developed from information from county water agencies in the Central Valley. The rest of the draft report contains extensive data from the northernmost part of California, Oregon, Washington, and Idaho, where costs (labor, materials, equipment, *etc.*) may to be lower than in the Central Valley of California.

The report offers ranges of costs applicable at the ESU scale. Actual costs may vary widely from one watershed to another and across the extent of the Central Valley Domain due to potential differences in regional labor costs, property values, availability of expert contractors and materials, and permitting issues, etc.

Many of these costs would likely be born through necessary changes in California's water system as a result of current increased demands or from other ongoing or planned conservation programs or regulatory mechanisms. Many of the recovery actions seek to remedy effects of projects authorized before the country and States cornerstone environmental laws such as the Clean Water Act, the Clean Air Act, the National Environmental Policy Act, the California Environmental Quality Act, and the State and Federal Endangered Species Act.

Recovery of listed Central Valley salmon and steelhead will have significant costs, but will also provide economic benefits. Recovery actions taken on behalf of Sacramento River winter-run and spring run Chinook salmon and Central Valley steelhead are likely to benefit other listed species in the Central Valley Domain, including fall and late-fall-run Chinook salmon, thus increasing the cost effectiveness of the actions. Habitats restored to highly functioning conditions offer tangible benefits such as improved water quality, and less tangible benefits such as reduced expenditures on bank stabilization or flood control. Restoration activities will generate positive socioeconomic benefits. Because of their direct and indirect economic value as a resource for fishing, recreation and tourism related activities, each dollar spent on salmon recovery may generate thousands of dollars for local, state, Federal, and tribal economies. In other words, salmon recovery is best viewed not as a cost, but as an investment and opportunity to derive, diversify, and strengthen the economy. The dollars required to recover salmon should be made available without delay such that the benefits can begin to accrue as soon as possible. Importantly, the general model for viewing cost versus benefits must be viewed in terms of long-term benefits derived from short term costs.

Without factoring the economic benefits associated with recovery, and simply focusing on the cost to implement recovery actions, the cost is estimated to range from $1,040,695,000 to $1,260,695 over the next five years. Extending the 5 year implementation costs over 50 years may cost nearly $10,406,950,000.

8.2 Implementation Table

Information related to the implementation of Priority 1 recovery actions is presented in Table **8-2**. Priority 1 actions are those critical actions that must be taken to prevent extinction or to prevent the species from declining irreversibly. Priority 2 actions must be taken to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction. Priority 2 actions are presented in Appendix C. All priority 1 actions have been assigned a specific number beginning with the number 1 (e.g., 1.1, 1.2, etc.), while all priority 2 actions are identified by a numbering system starting with 2.

Priority 1 recovery actions have been categorized into eleven geographic scales or regions:

1.1 Throughout California

1.2 Throughout the Central Valley

1.3 Pacific Ocean

1.4 San Francisco Bay

1.5 Delta

1.6 Mainstem Sacramento River

1.7 Northwestern California Diversity Group

1.8 Basalt and Porous Lava Diversity Group

1.9 Northern Sierra Nevada Diversity Group

1.10 Mainstem San Joaquin River

1.11 Southern Sierra Nevada Diversity Group

Table 8-2. Implementation table for priority 1 recovery actions.

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
Throughout California	Winter-run Spring-run Steelhead	Water management	1.1.1 Implement Federal, State, and local initiatives and programs to improve water conservation in order to reduce state-wide water use by 20 percent per capita by 2020. This effort should take into account regional differences and find ways to improve agricultural efficiency as well as urban water use efficiency.	Year 1 through year 10	Agriculture industry, city and county planners, DWR, Reclamation, SWRCB	$5 million
Throughout Central Valley	Winter-run Spring-run Steelhead	Harvest, hatchery effects, habitat loss and degradation, and water management	1.2.1 Promote Central Valley resource managers to cooperatively develop and implement an ecosystem based management approach that integrates harvest, hatchery, habitat, and water management, in consideration of ocean conditions and climate change.	Year 5 through year 10	CDFG, DWR, NMFS, PFMC, Reclamation, SWRCB, USFWS	$2 million
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat loss and degradation	1.2.2 Support programs to provide educational outreach and local involvement in restoration, including programs like Salmonids in the Classroom, Aquatic Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land use on anadromous fish survival.	Year 1 through year 20	CDFG, DWR, NMFS, PFMC, Reclamation, SWRCB, USFWS	$500,000
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat degradation	1.2.3 Develop a monitoring program to determine the level of entrainment at individual diversions. Prioritize diversions based on this monitoring and screen those that are determined to have the greatest impacts on juvenile survival.	Year 5 through year 10	CDFG, DWR, NMFS, USFWS	$1 million
Throughout Central Valley	Winter-run Spring-run	Habitat degradation	1.2.4 Provide additional funding for increased law enforcement to reduce illegal take of anadromous fish, stream alteration, and water pollution and to ensure adequate protection for juvenile fish at	Year 1 through year 20	CDFG, NMFS	6.25 million

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
	Steelhead		pumps and diversions.			
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat degradation	1.2.5 Control or relocate the discharge of irrigation return flows and sewage effluent, and restore riparian forests to help provide suitable water temperatures for anadromous salmonids.	Year 2 through year 10	ACOE, City and County planners, NMFS, SWRCB, USFWS	$50 million
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat degradation	1.2.6 Implement and evaluate actions to minimize and/or eliminate the effects of exotic (non-native invasive) species (plants and animals) on production of anadromous fish.	Year 1 through year 10	Department of Boating and Waterways	$2 million
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat degradation	1.2.7 Restore tributaries by evaluating the feasibility of screening or relocating diversions, switching to alternative sources of water for upstream diversions, restoring and maintaining a protected riparian strip, limiting excessive erosion, enforcing dumping ordinances, removing toxic materials or controlling their source, replacing bridge and ford combinations with bridges or larger culverts and installing siphons to prevent truncation of small streams at irrigation canals, and implement actions to address harmful effects.	Year 1 through year 20	Caltrans, USFS, SWRCB	Details provided for specific watersheds below
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat loss	1.2.8 Conduct Central Valley-wide assessment of keystone dams and passage opportunities and implement programs to restore access to properly functioning habitat that was historically available.	Long-term with evaluations beginning in year 1. Long term implementation may begin by year 20	CDFG, DWR, NMFS, Reclamation, USFWS, USFS	Details provided for specific watersheds below

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
Throughout Central Valley	Winter-run Spring-run Steelhead	Habitat loss	1.2.9 Evaluate passage at small dams or other anthropogenic obstructions and implement fish passage per NMFS criteria.	Year 1 through year 10	CDFG, DWR, NMFS, Reclamation, USFWS, USFS	Details provided for specific watersheds below
Throughout Central Valley	Winter-run Spring-run Steelhead	Water management	1.2.10 Increase integration of the State and Federal water projects through shared storage and conveyance agreements.	Year 5 through year 20	DWR, Reclamation	No cost agreements
Throughout Central Valley	Winter-run Spring-run Steelhead	Water management	1.2.11 Secure agreements with or purchase water rights from landowners and Federal and State agencies to provide additional instream flows.	Year 1 through year 10	DWR, Reclamation, county water agencies	No cost agreements
Throughout Central Valley	Winter-run Spring-run Steelhead	Hatchery effects	1.2.12 Form a hatchery science review panel to review Central Valley hatchery practices. The panel should address the issues contained within the following six hatchery-related actions.	Year 1 through year 5	CDFG, DWR, NMFS, Reclamation, USFWS	$1 million
Throughout Central Valley	Winter-run Spring-run Steelhead	Hatchery effects	1.2.13 Evaluate impacts of outplanting and broodstock transfers among hatcheries on straying and population structure and evaluate alternative release strategies.	Year 3 through year 20	CDFG, DWR, NMFS, Reclamation, USFWS	See previous
Throughout Central Valley	Winter-run Spring-run	Hatchery effects	1.2.14 Evaluate whether production levels are appropriate and if they could be adjusted according to expected ocean conditions.	Year 1 through year 10	CDFG, DWR, NMFS, Reclamation, USFWS	See previous

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
	Steelhead					
Throughout Central Valley	Winter-run Spring-run Steelhead	Hatchery effects	1.2.15 Evaluate the potential to modify hatchery procedures to benefit native stocks of salmonids and implement beneficial modifications.	Year 1 though year 5	CDFG, DWR, NMFS, Reclamation, USFWS	See previous
Throughout Central Valley	Winter-run Spring-run Steelhead	Hatchery effects	1.2.16 Evaluate and avoid potential competitive displacement of naturally produced juvenile salmonids with hatchery-produced juveniles by implementing release strategies for hatchery-produced fish designed to minimize detrimental interactions.	Long-term, beginning in year 1	CDFG, DWR, NMFS, Reclamation, USFWS	See previous
Throughout Central Valley	Winter-run Spring-run Steelhead	Hatchery effects	1.2.17 Evaluate and implement specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and natural stocks.	Long-term, beginning in year 1	CDFG, DWR, NMFS, Reclamation, USFWS	See previous
Throughout Central Valley	Winter-run Spring-run Steelhead	Hatchery effects	1.2.18 Evaluate a program to tag and fin-clip all or a significant portion of hatchery-produced fish as a means of collecting better information regarding harvest rates on hatchery and naturally produced fish and effects of hatchery-produced fish on naturally produced fish.	Long-term, beginning in year 1	CDFG, DWR, NMFS, Reclamation, USFWS	See previous
Throughout Central Valley	Steelhead	Lack of data	1.2.19 Implementation of a comprehensive life history monitoring plan for Central Valley steelhead that will result in basin-wide (Sacramento and San Joaquin) estimates of hatchery and wild steelhead population abundance, production, diversity and distribution.	Long-term beginning in year 1	CDFG, NMFS, USFWS	$10 million

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
Ocean	Winter-run Spring-run	Harvest	1.3.1 Work with the PFMC and NMFS to re-evaluate and modify management measures, annual conservation objectives, harvest forecasting techniques, NMFS consultation standards for ESA listed salmon stocks, and consider implementing an ecosystem-based salmon fishery management plan that considers multi-trophic interactions, ocean currents, upwelling patterns, ocean temperatures, and other relevant factors.	Long-term, beginning in year 1	PFMC, NMFS, CDFG	$2 million
Ocean and inland	Winter-run Spring-run	Harvest	1.3.2 Work with PFMC and NMFS to implement restrictions that limit harvest of listed anadromous salmonids in commercial and recreational fisheries considering mechanisms such as: • Genetic Stock Identification (GSI) – Develop a research, testing and monitoring plan to test this technology and establish optimal bycatch levels based on GSI data • Review, assess and modify seasonal and area harvest restrictions and closures • NMFS, CDFG and USFWS coordinate with the Southwest Fisheries Science Center to convene a science panel to review potential measures such as mass marking and mark selective fisheries and make recommendations to improve the identification of listed stocks in the Ocean. • Consider using hot spot closures in commercial and recreational fisheries when large numbers of listed fish	Long-term, beginning in year 1	PFMC, NMFS, CDFG	See previous

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			become congregated in certain areas.			
San Francisco Bay	Winter-run Spring-run Steelhead	Water quality	1.4.1 Implement projects that improve wastewater and stormwater treatment throughout the Bay and surrounding residential and commercial areas.	Long-term, beginning in year 1	SWRCB	$50 million
San Francisco Bay	Winter-run Spring-run Steelhead	Water quality	1.4.2 Increase monitoring and enforcement to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	Long-term, beginning in year 1	CVRWQCB	$1 million
San Francisco Bay	Winter-run Spring-run Steelhead	Water quality	1.4.3 Cities, counties, districts, joint powers authority or other political subdivisions of the State involved with water management should implement agricultural drainage management projects to treat, store, convey, and/or dispose of agricultural drainage.	Long-term, beginning in year 1	CVRWQCB, Agriculture industry	$1 million
Delta	Winter-run Spring-run Steelhead	Water management	1.5.1 Develop alternative water operations and conveyance systems that ensure multiple and suitable salmonid rearing and migratory habitats for all Central Valley salmonids and that restore the ecological flow characteristics of the Delta ecosystem.	Long-term, beginning in year 5	BDCP agencies and stakeholders	Alternatives under review. No cost currently available
Delta	Winter-run Spring-run Steelhead	Habitat loss and degradation	1.5.2 Large-Scale Habitat Restoration – Identify funding and direct restoration of 80,000 acres of tidal marsh, 130,000 acres of terrestrial grasslands, and 60,000 acres of floodplain habitat. Floodplain habitats should be restored to appropriate elevations using Frequently Activated Floodplain principles and modeling. The habitats should be	50 years, beginning in year 1	ACOE, DWR, Reclamation	$135 to 270 million

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			along primary migration and rearing corridors, and connected in ecologically beneficial ways. This will require separating levee systems from active river and estuary channels, restoring dendritic channel systems in areas where this habitat feature existed historically, and allowing for natural developmental processes to maintain habitats.			
Delta	Winter-run Spring-run Steelhead	Habitat loss and degradation	1.5.3 Integrate the Ecosystem Restoration Program and the Calfed Science program into an effort to restore the Delta ecosystem.	Beginning in year 1	USFWS, Calfed	No cost
Delta	Winter-run Spring-run Steelhead	Predation	1.5.4 Implement programs and measures designed to control non-native predatory fish (e.g., striped bass, largemouth bass, and smallmouth bass), including harvest management techniques, non-native vegetation management, and minimizing structural barriers in the Delta, which attract non-native predators and/or that delay or inhibit migration.	Long-term, beginning in year 1	CDFG, Sport fishing community	$5 million
Delta	Winter-run Spring-run Steelhead	Habitat loss and degradation	1.5.5 Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to (1) allow for fish passage through Fremont Weir for multiple species; (2) enhance lower Putah Creek floodplain habitat; (3) improve fish passage along the toe drain/Lisbon weir; (4) enhance floodplain habitat along the toe drain; (5) eliminate stranding events; and (6) create annual spring inundation of at least 8,000 cfs to fully activate the Yolo Bypass floodplain.	Year 5 through 10	Reclamation, DWR	$10 million
Delta	Winter-run	Water management	1.5.6 Implement Actions IV.1 through IV.6 of the	Year 1 through 25	Reclamation, DWR	Costs are currently

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
	Spring-run Steelhead		Reasonable and Prudent Alternative described in the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009): ❑ Action IV.1: Modify DCC gate operations and evaluate methods to control access to Georgiana Slough and the Interior Delta to reduce diversion of listed fish from the Sacramento River into the southern or central Delta. ❑ Action IV.2: Control the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta. ❑ Action IV.3: Curtail exports when protected fish are observed near the export facilities to reduce mortality from entrainment and salvage. ❑ Action IV.4: Improve fish screening and salvage operations to reduce mortality from entrainment and salvage. ❑ Action IV.5: Establish a technical group to assist in determining real-time operational measures, evaluating the effectiveness of the actions, and modifying them if necessary.			being evaluated

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			❑ Action IV.6: Do not implement the South Delta Barriers Improvement Program.			
Delta	Winter-run Spring-run Steelhead	Water management	1.5.7 Develop a comprehensive governance system that has reliable funding, takes advantage of established and effective ecosystem restoration and science programs, and has clear authority to determine priorities and strong performance measures to ensure accountability to the new governing doctrine of the Delta: operation for coequal goals of Delta ecosystem restoration and protection and reliable water supply.	Long-term, beginning in year 2	CDFG, DWR, NMFS, Reclamation, SWRCB, USFWS, water contractors	$2 million
Delta	Winter-run Spring-run Steelhead	Water management	1.5.8 Following the first autumn flows exceeding 15,000 cfs at Wilkins Slough, maintain suitable rearing and migratory habitats for emigrating winter-run salmon throughout the Sacramento River and distributaries in the Delta through the end of April.	Long-term, beginning in year 2	CDFG, DWR, NMFS, Reclamation, SWRCB, USFWS, water contractors	Cost not available
Delta	Winter-run Spring-run Steelhead	Water management	1.5.9 Provide pulse flows of at least 20,000 cfs measured at Freeport periodically during the winter-run emigration season to facilitate outmigration past Chipps Island (i.e., December-April).	Long-term, beginning in year 2	CDFG, DWR, NMFS, Reclamation, SWRCB, USFWS, water contractors	Cost not available
Lower and middle Sacramento River	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.6.1 Restore and maintain a continuous meanderbelt along the Sacramento River from Keswick downstream to Colusa. • Pursue these opportunities, consistent with efforts conducted pursuant to Senate Bill 1086 (SB 1086), to create a meander belt from Keswick Dam to Colusa to recruit gravel and large	Long-term, beginning in year 2	Army Corps, DWR CDFG, TNC, USFWS	$15 million

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			woody debris, to moderate temperatures and to enhance nutrient input. Also pursue actions under the Sacramento River Flood Control Project and the Central Valley Plan for Flood Control.			
Lower and middle Sacramento River	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.6.2 Restore and maintain a continuous 60-mile stretch of riparian habitat and functioning floodplains of an appropriate, science-based width to maintain ecologically viable flood-prone lands along both banks of the Sacramento River between Colusa and Verona. • Separate levee systems from active river channels, restore dendritic channel systems in areas where this habitat feature existed historically, and allow for the natural development of floodplain habitats. Pursue actions under the Sacramento River Flood Control Project and the Central Valley Plan for Flood Control.	Long-term, beginning in year 2	Army Corps, DWR, SAFCA, CDFG, TNC, USFWS	$100 million
Lower and middle Sacramento River	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.6.3 Restore and maintain a continuous 70-mile stretch of riparian habitat and maintain existing floodplain terraces along both banks of the Sacramento River between Verona and Collinsville. Restore floodplain areas as necessary to achieve the restoration targets described in action 1.5.2 • Seek opportunities through the Army Corps of Engineers Sacramento River Bank Protection Project, the Central	Long-term, beginning in year 2	Army Corps, DWR, SAFCA CDFG, CDPR , DWR, USFWS, local agencies, NGOs	$50 million

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			Valley Plan for Flood Control, and other flood management programs and agencies, such as the Sacramento Area Flood Control Agency, to protect existing riparian habitat, restore riparian, protect remaining floodplain terraces, and integrate flood plain bench designs into levee repair projects.			
Middle Sacramento River	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.6.4 Relocate the M&T Ranch fish screen and water diversion from its current location to a downstream, geomorphically stable, river reach and relocate the 300,000 cubic yards of dredged gravel to upstream reaches of the Sacramento River for spawning habitat enhancement.	Within 5 years		$20 million
Lower, middle, and upper Sacramento River	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.6.5 Develop and implement an ecological flow tool for the Sacramento River below Keswick and Shasta Dams and use in conjunction with Frequently Activated Floodplain (FAF) tools and hydrodynamic river models to create and implement a floodplain inundation program that allows for existing functional floodplains to be activated in two out of three years for at least seven days between mid-March to mid-May.	Long-term, Long-term, beginning in year 2 through year 5		$ 2 million development costs
Lower, middle, and upper Sacramento River	Winter-run Spring-run Steelhead	Water management	1.6.6 Implement a river flow management plan that balances carryover storage needs with instream flow and water temperature needs for winter-run, spring-run, and steelhead based on runoff and storage conditions, including flow fluctuation and ramping criteria.	Long-term, beginning in year 1		Costs are in developement

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
Middle Sacramento River, Red Bluff Diversion Dam	Winter-run Spring-run Steelhead	Water management	1.6.7 Implement Action I.3.1 and I.3.2 (Long-term and interim operations of RBDD) of the Reasonable and Prudent Alternative described in the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009) and install NMFS-approved, state-of-the-art fish screens at the Tehama Colusa Canal diversion point.	Beginning in year 1	DWR, Reclamation, TCCA	$120 million
Upper Sacramento River	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.6.8 Develop and implement a long-term gravel augmentation plan to enhance spawning habitat downstream of Keswick and Shasta Dams.	Long-term, Long-term, beginning in year 1	CDFG, NMFS, Reclamation, USFWS	$2 million
Northwestern California diversity group – Clear Creek	Spring-run	Habitat degradation and loss	1.7.1.1 Operate the Clear Creek weir to separate spring-run and fall-run Chinook salmon	Long-term, beginning in year 1	USFWS	$100 thousand
Northwestern California diversity group – Clear Creek	Spring-run Steelhead	Habitat degradation and loss	1.7.1.2 Develop and implement a spawning gravel budget and implement a long-term augmentation plan in Clear Creek.	Long-term, beginning in year 1	Reclamation, USFWS	$2 million
Northwestern California diversity group – Clear Creek	Spring-run Steelhead	Habitat degradation and loss	1.7.1.3 Develop and implement optimal Clear Creek flow schedules to mimic the natural hydrograph (including spring pulse flows and winter spillway releases to restore a proper functioning system) and use instream flow study results to guide flow schedule development.	Long-term, beginning in year 1	Reclamation, USFWS	$ 1 million
Northwestern	Spring-run	Water temperature	1.7.1.4 Develop a real time water temperature	Long-term,	Reclamation,	$ 250 thousand

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
California diversity group – Clear Creek	Steelhead		model to track the coldwater pool in Whiskeytown Reservoir and budget releases to Clear Creek to meet daily water temperature of 60°F at the Igo gauge from June 1 to September 15 and 56°F from September 15 to October 31.	beginning in year 2 through year 5	USFWS	
Basalt and porous lava diversity group – Little Sacramento River	Winter-run Spring-run Steelhead	Habitat loss	1.8.1.1 Develop and implement a salmon reintroduction plan to re-colonize historic habitats above Keswick and Shasta Dams, into the Little Sacramento River. • Conduct feasibility study • Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program	Long-term: Evaluations beginning in year 1 Pilot testing in year 2 through year 5 Long-term passage program beginning in year 10	CDFG, NMFS, Reclamation, USFWS	$50,000,000 50 year costs are not known at this time.
Basalt and porous lava diversity group – McCloud River	Winter-run Spring-run Steelhead	Habitat loss	1.8.2.1 Develop and implement a salmon reintroduction plan to re-colonize historic habitats above Keswick and Shasta Dams, into the McCloud River. • Conduct feasibility study • Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program	Long-term: Evaluations beginning in year 1 Pilot testing in year 2 through year 5 Long-term passage program beginning in year 10	CDFG, NMFS, Reclamation, USFWS	$50 million for feasibility study, habitat evaluations, development of reintroduction plans, and implementation of pilot reintroductions 50 year costs are not known at this time,.
Basalt and porous lava diversity group – Battle Creek	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.8.3.1 Develop and implement a salmon reintroduction plan to re-colonize historic habitats after implementation of the Battle Creek Restoration Project.	Long-term, Beginning in year 1	CDFG, NGOs, NMFS, PG&E, Reclamation, USFWS	$5 million

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
Basalt and porous lava diversity group – Battle Creek	Winter-run Spring-run Steelhead	Habitat degradation and loss	1.8.3.2 Fully fund and implement the Battle Creek Restoration Project through Phase 2	Long-term, beginning in year 1	Reclamation, CDFG, NMFS, PG&E, USFWS	$47 million
Northern Sierra Nevada DG – Antelope Creek	Spring-run Steelhead	Water management	1.9.1.1 Restore instream flows during upstream and downstream migration periods through water exchange agreements and provide alternative water supplies to Edwards Ranch and Los Molinos Mutual Water Company in exchange for instream fish flows.	Long-term	CDFG, Edwards Ranch, Los Molinos Water Company	$2 million
NSN – Antelope Creek	Spring-run Steelhead	Water management	1.9.1.2 Restore connectivity of the migration corridor during upstream and downstream migration periods by implementing Edwards and Penryn fish passage and entrainment improvement projects and identify and construct a defined stream channel for upstream and downstream fish migration	Long-term	CDFG, Edwards Ranch	Costs are in development
NSN – Mill Creek	Spring-run Steelhead	Habitat degradation and loss	1.9.2.1 Implement a Mill Creek anadromous fish passage study (AFRP Website 2005) that will evaluate fish passage at all agricultural diversions to determine if they meet NMFS' fish passage criteria. Design and install state-of-the-art fish passage facilities at diversions that currently do not meet the passage criteria.	Long-term	CDFG, USFWS	$500 thousand
NSN – Mill Creek	Spring-run Steelhead	Habitat degradation and loss	1.9.2.2 Conduct a study designed to determine adult fish passage flows at critical riffles and fish ladders in Mill Creek. Develop a water exchange agreement with all Mill Creek water users to allow implementation of those flows.	Long-term	CDFG, Mill Creek water users	$200 thousand

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
NSN – Mill Creek	Spring-run Steelhead	Habitat degradation	1.9.2.3 Eliminate sources of chronic sediment delivered to Mill Creek from roads and other near stream development by out-sloping roads, constructing diversion prevention dips, replacing under-sized culverts and applying other storm proofing guidelines.	Long-term	CDFG, USFS	$5 million
NSN – Deer Creek	Spring-run Steelhead	Habitat degradation	1.9.3.1 Develop and implement a water exchange agreement with the Deer Creek Irrigation Company and the Stanford-Vina Irrigation District and dedicate fish passage flows. The agreement should identify water infrastructure facilities required meet fish passage needs.	Long-term	CDFG, Deer Creek Irrigation Company, Stanford-Vina Irrigation District, USFWS	$500 thousand Infrastructure costs may exceed $5 million
NSN – Deer Creek	Spring-run Steelhead	Habitat degradation	1.9.3.2 Construct state-of-the-art inflatable dams and install fish ladders that meet NMFS' adult fish passage criteria at the Cone-Kimball Diversion, Stanford-Vina Dam, and the Deer Creek Irrigation District Dam.	Long-term	CDFG, Deer Creek Irrigation Company, Stanford-Vina Irrigation District, USFWS	$3 million
NSN – Deer Creek	Spring-run Steelhead	Habitat degradation	1.9.3.3 Implement the Deer Creek Flood Improvement Project.	Long-term		$10 million
NSN – Deer Creek	Spring-run Steelhead	Habitat degradation	1.9.3.4 Implement watershed restoration actions that reduce sedimentation and thermal loading in low gradient headwater habitats of Deer Creek Meadows, and Gurnsey Creek.	Long-term	CDFG, USFS, Deer Creek landowners	$500 thousand

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
NSN – Butte Creek	Spring-run Steelhead	Water management	1.9.4.1 Develop, implement and evaluate a Butte Creek flow test for the PG&E DeSabla-Centerville Hydroelectric Project to determine the flow conditions that optimize coldwater holding habitat and spawning distribution.	Long-term	CDFG, PG&E	Costs integrated into ongoing project relicensing
NSN – Butte Creek	Spring-run Steelhead	Habitat degradation and loss	1.9.4.2 Install state-of-the-art fish ladders at DWR weir 2 and Willow Slough weir.	Long-term	DWR	$10 million (already obligated)
NSN – Butte Creek	Spring-run Steelhead	Habitat degradation and loss	1.9.4.3 Maintain state-of-the-art fish passage facilities at diversions in Butte Creek to meet NMFS' passage criteria.	Long-term		$20 thousand
NSN – Feather River	Spring-run	Habitat loss	1.9.5.1 Implement the use of a weir in the Feather River to spatially segregate spring-run Chinook salmon and fall-run Chinook salmon during their spawning migrations.	Long-term	DWR	$1 million
NSN – Feather River	Spring-run Steelhead	Hatchery effects	1.9.5.2 Develop a hatchery genetic management plan for the Feather River Fish Hatchery, including specific criteria for operating as either an integrated or segregated hatchery.	Long-term	CDFG, DWR	$100 thousand
NSN – Feather River	Spring-run Steelhead	Water management	1.9.5.3 Develop and implement a spring-run pulse flow schedule that is coordinated with Yuba River operations for dry and critically dry years	Long-term	DWR, YCWA	Costs under development

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
NSN – Feather River	Spring-run Steelhead	Habitat degradation and loss	1.9.5.4 Develop a spawning gravel budget, identify gravel depleted areas, and implement an augmentation plan in the Feather River.	Long-term	DWR	$1 million
NSN – Feather River	Steelhead	Habitat degradation and loss	1.9.5.5 Construct steelhead side channel habitats using carrying capacity models sufficient to support a viable naturally spawning population of steelhead in the lower Feather River.	Long-term	DWR	$5 million
NSN – Feather River	Spring-run Steelhead	Water temperature	1.9.5.6 Implement facilities modifications(s) to achieve Feather River water temperatures at least as protective as those specified in Table 2 of the Settlement Agreement For Licensing of the Oroville Facilities (March 2006)	Long-term	DWR, FERC, SWRCB	Feasibility study to begin in near futures. Costs under development
NSN – Yuba River	Spring-run Steelhead	Habitat degradation and loss	1.9.6.1 Develop and implement a salmon reintroduction plan to re-colonize historic habitats above Englebright Dam. Implement actions to: (1) enhance habitat conditions including providing flows and suitable water temperatures for successful upstream and downstream passage, holding, spawning and rearing; and (2) improve access within the area above Englebright Dam, including increasing minimum flows, providing passage at Our House, New Bullards Bar, and Log Cabin dams, and assessing feasibility of passage improvement at natural barriers. • Conduct feasibility study • Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program	Long-term: Evaluations beginning in year 1 Pilot testing in year 2 through year 5 Long-term passage program beginning in year 10	CDFG, NMFS, PG&E, USFWS, YCWA	$50 million for feasibility study, habitat evaluations, development of reintroduction plans, and implementation of pilot reintroductions 50 year costs are not known at this time.

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
NSN – Yuba River	Spring-run Steelhead	Habitat degradation	1.9.6.2 Improve spawning habitat in the lower river by gravel restoration program below Englebright Dam and improve rearing habitat by increasing floodplain habitat availability.	Long-term	CDFG, NMFS, PG&E, USFWS, YCWA	$2 million
NSN – American River	Steelhead	Habitat degradation and loss	1.9.7.1 Develop and implement a steelhead reintroduction plan to re-colonize historic habitats above Nimbus and Folsom dams. • Conduct feasibility study • Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program	Long-term: Evaluations beginning in year 1 Pilot testing in year 2 through year 5 Long-term passage program beginning in year 10	CDFG, NMFS, Reclamation, USFWS	$50 million for feasibility study, habitat evaluations, development of reintroduction plans, and implementation of pilot reintroductions 50 year costs are not known at this time.
NSN – American River	Steelhead	Water temperature	1.9.7.2 Implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management	Long-term	ACOE, CDFG, NMFS, Reclamation, USFWS	
NSN – Mokelumne River	Spring-run Steelhead	Habitat degradation and loss	1.9.8.1 Evaluate and, if feasible, develop and implement a fish passage program for Camanche and Pardee dams • Conduct feasibility study • Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program	Long-term	CDFG, NMFS, Reclamation, USFWS	$2 million for feasibility study and habitat evaluations 50 year costs are not known at this time.

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
NSN – Mokelumne River	Spring-run Steelhead	Water temperature	1.9.8.2 Manage cold water pools in Camanche and Pardee Reservoirs to provide suitable water temperatures for all downstream life stages	Long-term	CDFG, EBMUD, NMFS, Reclamation, USFWS	
Mainstem San Joaquin River downstream from the Merced River	Spring-run Steelhead	Habitat degradation and loss; water quality	1.10.1 Develop and implement a suite of actions to improve salmon and steelhead outmigration survival through the lower San Joaquin River by: ❑ Restoring floodplain habitat, and implementing ecological flow schedules to create frequently activated floodplain; ❑ Reducing contaminants; ❑ Implementing remedies for the biological oxygen demand and low dissolved oxygen levels in the Stockton Deep Water Ship channel that delay of impede fish migration	Long-term	CDFG, DWR, NMFS, Reclamation, SWRCB, USFWS, water districts	$10 million
Mainstem San Joaquin River downstream from the Merced River	Spring-run Steelhead	Water management	1.10.2 Implement Action IV.2.1 (San Joaquin River Inflow to Export Ratio) of the Reasonable and Prudent Alternative described in the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009) to improve juvenile outmigration for steelhead and future spring-run Chinook salmon.	Long-term	CDFG, DWR, NMFS, Reclamation, SWRCB, USFWS, water districts	
Southern Sierra Nevada diversity group – Stanislaus	Spring-run	Habitat loss	1.11.1.1 Evaluate and, if feasible, develop and implement a fish passage program for Goodwin, New Melones and Tulloch	Long-term	CDFG, NMFS, Reclamation,	$2 million for feasibility study and

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
River	Steelhead		dams. • Conduct feasibility study • Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program		USFWS	habitat evaluations 50 year costs are not known at this time
SSN – Stanislaus River	Spring-run Steelhead	Water temperature	1.11.1.2 Manage cold water pools behind Goodwin, New Melones and Tulloch dams to provide suitable water temperatures for all downstream life stages.	Long-term	CDFG, NMFS, Reclamation, USFWS	Costs under development <$ 10 million
SSN – Calaveras River	Steelhead	Water management	1.11.2.1 Develop and implement long-term instream flow schedules and requirements based on physical habitat modeling and critical riffle analysis.	Long-term	CDFG, NMFS, USFWS	<$ 10 million
SSN – Calaveras River	Steelhead	Water management	1.11.2.2 Establish a minimum carryover storage level at New Hogan Reservoir that meets the instream flow and water temperature requirements in the lower Calaveras River	Long-term	ACOE, CDFG, NMFS, USFWS	<$ 10 million
SSN – Calaveras River	Steelhead	Habitat degradation and loss	1.11.2.3 Remove or modify all fish passage impediments in the lower Calaveras River to meet NMFS fish passage criteria	Long-term	ACOE, CDFG, NMFS, USFWS	$ 5 million
SSN – Tuolumne River	Spring-run Steelhead	Habitat loss	1.11.3.1 Evaluate and, if feasible, develop and implement a fish passage program for La Grange and Don Pedro dams. • Conduct feasibility study	Long-term	CDFG, Modesto Irrigation District, NMFS, Turlock Irrigation District, USFWS	$2 million for feasibility study and habitat evaluations 50 year costs are not

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			• Conduct habitat evaluations • Conduct 3-5 year pilot testing program • Implement long-term fish passage program			known at this time
SSN – Tuolumne River	Spring-run Steelhead	Water temperature	1.11.3.2 Manage cold water pools behind La Grange and Don Pedro dams to provide suitable water temperatures for all downstream life stages	Long-term	CDFG, Modesto Irrigation District, NMFS, Turlock Irrigation District, USFWS	<$ 10 million
SSN - San Joaquin River from Friant Dam to confluence with Merced River	Spring-run	Habitat degradation and loss	1.11.4.1 Implement the San Joaquin Settlement Agreement: • Implement interim and long-term settlement flows • Develop and implement a spring-run Chinook salmon reintroduction strategy • Construct channel modifications to increase the channel capacity from 475 cfs to 4,500 cfs. • Minimize entrainment and fish losses to non-viable migration pathways ◦ Screen Arroyo Canal ◦ Retrofit Sack Dam to ensure unimpeded fish passage ◦ Construct Mendota Pool Bypass	Long-term	CDFG, DWR, NMFS, Reclamation, USFWS	$100 to 120 million Total 20 year cost of the San Joaquin River Restoration Program is estimated between $400 and $500 million.

LOCATION	SPECIES	THREAT CATEGORY	PRIORITY 1 RECOVERY ACTIONS	DURATION	INVOLVED PARTIES	5 YEAR COST ESTIMATES
			◦ Fill and isolate high priority gravel pits ◦ Implement temporary barriers at Mud and Salt Sloughs			

8.3 Integrating Recovery into NMFS Actions

It is a challenging undertaking to facilitate a change in practice and policy that reverses the path towards extinction of a species to one of recovery. This change can only be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift agency and societal attitudes, practices and understanding.

Implementation of the recovery plan by NMFS will take many forms and is generally and specifically described in the NMFS Protected Resources Division Strategic Plan 2006 (NMFS 2006a). The Recovery Planning Guidance (NMFS 2006b) also outlines how NMFS shall cooperate with other agencies regarding plan implementation. These documents, in addition to the ESA, shall be used by NMFS to set the framework and environment for plan implementation. The PRD Strategic Plan asserts that species conservation (in implementing recovery plans) by NMFS will be more strategic and proactive, rather than reactive. To maximize existing resources with workload issues and limited budgets, the PRD Strategic Plan champions organizational changes and shifts in workload priorities to focus efforts towards "…*those activities or areas that have biologically significant beneficial or adverse impacts on species and ecosystem recovery*" (NMFS 2006a). The resultant shift will reduce NMFS engagement on those activities or projects not significant to species and ecosystem recovery.

NMFS actions to promote and implement recovery planning shall include:

- Formalizing recovery planning goals on a program-wide basis to prioritize work load allocation and decision-making (to include developing the mechanisms to make implementation (*e.g.*, restoration) possible).
- Conduct an aggressive outreach and education program.
- Facilitate a consistent framework for research, monitoring, and adaptive management that can directly inform recovery objectives and goals.
- Establish an implementation tracking system that is adaptive and pertinent to support the annual reporting for the Government Performance and Results Act, Bi-Annual Recovery Reports to Congress and the 5-Year Status Reviews.

NMFS' efforts must be as far-reaching (beyond those under the direct regulatory jurisdiction of NMFS) as the issues adversely affecting the species. Thus, to achieve recovery, NMFS will need to promote the recovery plan and provide needed technical information and assistance to other entities that implement actions that may impact the species' recovery. For example, NMFS will work with key partners on high priorities such as facilitating passage assessment and working with Counties to ensure protective measures consistent with recovery objectives are included in their General Plans.

While recovery plans are guidance documents not regulatory documents, the intent is that they are used to prioritize and target necessary actions for the survival and recovery of the species. The Recovery Planning Guidance (NMFS 2006b) specifically outlines NMFS' obligations:

> "...the ESA clearly envisions recovery plans as the central organizing tool for guiding each species' recovery process. They should also guide Federal agencies in fulfilling their obligations under section 7(a)(1) of the ESA… and provide context and a framework for implementing other provisions of the ESA such as section 7(a)(2), development of Habitat Conservation Plans or Safe Harbor agreements under section 10, special rules for threatened species under section 4(d)".

Furthermore, recovery plans should guide enhancement provisions of sections 4 and 5, take prohibitions through sections 4(d) and 9, cooperation with state(s) under section 6, needed research under section 10, fishery management actions taken and Essential Fish Habitat (EFH) consultations conducted under the provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

The approaches NMFS intends to use when implementing various sections of the ESA and MSFCMA are discussed in detail and are summarized in **Table 8-3**. These approaches are intended to formalize the recovery plans in the daily efforts and decision-making at NMFS in the Southwest Region. Of necessity, some of these methods address the urgent issues of staffing and workload that NMFS faces. As a result, our commitment to implementing recovery plans extends to the ways in which we prioritize the many requests for consultations and permits we receive. The discussion below outlines the specific action recommendations found the highest priorities in the recovery planning process for the Domain.

8.3.1 Working with Constituents and Stakeholders

NMFS commits to using recovery plans as the guiding mechanism for its daily endeavors. Successful implementation of this recovery plan will require the support, efforts and resources of many entities, from Federal and state agencies to individual members of the public. NMFS' efforts must be as far-reaching as the issues adversely affecting the species, extending beyond the direct regulatory jurisdiction of NMFS. NMFS commits to working cooperatively with other individuals and agencies to implement recovery actions and to encourage other Federal agencies to implement actions where they have responsibility or authority.

8.3.2 ESA Section 4

Section 4 provides the mechanisms to list new species as threatened or endangered, designate critical habitat, develop protective regulations for threatened species, and develop recovery plans. Critical habitat designations may be revised as needed to reflect recovery strategies.

Critical habitat is designated in specific geographical areas where physical or biological features essential to the species are found and where special management considerations or protections may be needed to preserve and protect them. Sacramento River winter-run Chinook salmon critical habitat was designated on June 16, 1993, and includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge (58 FR 33212). CV spring-run Chinook salmon and CV steelhead critical habitat was designated on September 2, 2005, and includes and includes stream reaches such as those of the Feather and Yuba Rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear Creeks, the Sacramento River, as well as portions of the northern Delta. (70 FR 52488).

NMFS will reevaluate the designation in light of the data and criteria developed for this plan, and may designate additional habitat (including marine habitat), or currently unoccupied habitat deemed essential for the conservation of the species. The key recovery areas, special management considerations and recovery priorities identified in this recovery plan are the benchmark for making future critical habitat designations. Certain unoccupied historic habitats may be essential for recovery, and that are recommended for future critical habitat consideration include:

Sacramento River winter-run Chinook salmon

- Little Sacramento River
- McCloud River
- Battle Creek
- Non-natal rearing tributaries to the middle Sacramento River

These areas provide several primary constituent elements (PCE) that are necessary for the survival and recovery of the species. In the Little Sacramento and McCloud Rivers and Battle Creek, PCE's include freshwater rearing, migration and spawning habitats. Although these habitats are currently blocked by dams, the many miles of relatively unimpaired cold water habitats, and the potential to establish up to two viable spawning populations in the Basalt Lava Diversity Group (assuming that the little Sacramento and McCloud Rivers would be considered a single population) the makes these areas highly valuable to the recovery of the species. In the non-natal rearing tributaries to the Sacramento River, the PCEs include freshwater rearing habitat. Some non-natal rearing areas have a high value because they provide critical and improved growing conditions during high winter flow events on the Sacramento River.

CV spring-run Chinook salmon and CV steelhead

- Little Sacramento River
- McCloud River
- North Fork Feather River
- North, Middle and South Yuba River
- Upper American River
- Mokelumne River
- North Fork Stanislaus River
- Tuolumne River
- Merced River
- San Joaquin River (CV spring-run Chinook salmon only)

This list represents the unoccupied historic habitat identified in the Recovery Footprint maps. These areas provide several primary constituent elements (PCE) that are necessary for the survival and recovery of the species. It is important to note that these areas are candidate areas for reintroduction and it may not be necessary to reintroduce fish to all of these systems to meet the recovery criteria for CV spring-run Chinook salmon or CV steelhead. It may not be necessary to re-establish populations to all of these rivers. The highest priority areas are the Little Sacramento River, the McCloud River, the North Fork American River, and the San Joaquin River. In the Little Sacramento, McCloud, Yuba Rivers, and Battle Creek, PCE's include freshwater rearing, migration and spawning habitats. Although these habitats are currently blocked by dams, the many miles of relatively unimpaired cold water habitats, and the potential to establish additional viable spawning populations in the Basalt Lava, and Northern Sierra Diversity Groups makes these areas highly valuable to the recovery of the species.

The existing PCEs in the American and San Joaquin Rivers are not in the same high quality condition as the previously described rivers, but the cold waters, deep pools and abundant spawning sized gravels of the upper American River could provide extensive high quality summer holding and spawning habitat and contribute significantly to the production and abundance of the species, while buffering against the effects of climate change. The San Joaquin is currently heavily degraded and does not support PCEs for CV spring-run Chinook salmon. However, the San Joaquin River Restoration Program is currently undertaking an ambitious effort to create a population of CV spring-run Chinook salmon below Friant Dam by 2020. We expect that implementation of this project will re-establish historic PCEs in the river including freshwater rearing and migration, freshwater holding and freshwater spawning.

Under ESA section 4(d), tailored section 9 take prohibitions and regulatory limits that are deemed advisable to contribute to the recovery of the

species, may be developed for species that are listed as threatened. Such rules currently are in place for Central Valley spring-run Chinook salmon and CV steelhead. These rules do not apply to endangered species; therefore winter-run Chinook salmon do not qualify unless they are reclassified as a threatened species. To authorize take of Sacramento River winter-run Chinook salmon, section 7(a)(2) or 10 (a)(1)(B) processes are the legal mechanism available under the ESA.

Based on our review of the special management considerations necessary to implement recovery actions, the following additional 4(d) prohibitions and limits are recommended for consideration:

<u>4(d) limits for CV spring-run Chinook salmon and CV steelhead</u>

- ❑ Fish screen construction and operation that is consistent with NMFS fish screen design criteria
- ❑ Fish passage facilities that are consistent with NMFS fish passage criteria
- ❑ Watershed or fishery restoration actions that are identified in comprehensive watershed or fishery plans
- ❑ Levee construction or maintenance activities that meet the following requirements:
  - ▪ Part of a comprehensive flood management program that has been approved by NMFS and includes a detailed conservation strategy for implementing recovery actions for floodplain and riparian habitat restoration
  - ▪ Levee relocations that reclaim or create frequently activated floodplain areas, and minimize the potential for the stranding of juvenile fish
  - ▪ Slurry wall construction within urban river corridors
  - ▪ In-river repair and maintenance actions within urban flood corridor that meet NMFS design and maintenance criteria for urban levees
- ❑ Spawning gravel augmentation projects below dams
- ❑ Adult and juvenile fish collection and relocation actions that are part of NMFS-approved fishery reintroduction program

8.3.3 ESA Section 5

Section 5 is a program that applies to land acquisition with respect to the National Forest System. Multiple National Forests lands are present within the Central Valley domain.

8.3.4 ESA Section 6

Section 6 describes protocols for consultation and agreements between NMFS and the states for the purpose of conserving threatened or endangered species.

Congress established the Pacific Coast Salmon Recovery Fund (PCSRF) to contribute to the restoration and conservation of Pacific salmon and steelhead populations and their habitats. The states of Washington, Oregon,

Table 8-3. Summary of approaches NMFS intends to use when implementing various sections of the ESA and MSFCMA.

Authority	Description	Implementation Actions
ESA Section 7	Section 7(a)(1) Interagency Cooperation (Use of authorities)	Use threats assessments and recovery actions to guide Federal partners to further the conservation of listed Central Valley salmon and steelhead.
ESA Section 7	Section 7(a)(2) Interagency Cooperation (Consultation)	Use recovery criteria and objectives as a reference point to determine effects of proposed actions on the likelihood of species' recovery.
	Note: Permits issued under section 10(a)(1) of the ESA also undergo section 7 consultation prior to issuance.	Use threats assessments and recovery strategy as a guide to prioritizing consultations when making workload decisions.
		Place high priority on consultations for actions that implement recovery strategy or specific actions.
		Streamline consultations for those actions with little or no effect on recovery areas or priorities.
ESA Section 9	Section 9 Enforcement	Prioritize those actions and areas deemed of greatest threat or importance for focused efforts to halt illegal take of listed species.
ESA Section 10	Section 10(a)(1)(B) Incidental Take Permits	Prioritize permit applications that address identified research and monitoring needs in the recovery plan.
		Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
		Standardize monitoring methods in HCPs to the TRT research needs and the recovery plan template.
Magnuson-Stevens Fishery Management	Fishery Management	Implement fishery regulations to maintain salmon harvest levels at or below those necessary to allow for the recovery of listed salmon and steelhead.
		Implement fishery regulations to reduce bycatch of salmon in federally-managed fisheries.

California, Idaho, and Alaska, and the Pacific Coastal and Columbia River tribes receive Congressional PCSRF appropriations from NMFS each year. The fund supplements existing state, tribal, and local programs to foster development of federal-state-tribal-local partnerships in salmon and steelhead recovery and conservation. NOAA Fisheries Service has established memoranda of understanding (MOU) with the states of Washington, Oregon, California, Idaho, and Alaska, and with three tribal commissions on behalf of 28 Indian tribes. The MOUs establish criteria and processes for funding priority PCSRF projects.

8.3.5 ESA Section 7

Section 7(a)(1) provides that all Federal agencies shall "…in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species…." "Conservation" is defined in the ESA as those measures necessary delist a species. In other words, the theme is *recovery*. To date, other Federal agencies have not complied with the section 7(a)(1) requirement to develop conservation programs for listed Central Valley salmon and steelhead. To prompt Federal agencies to develop conservation programs, NMFS shall:

1. Encourage development of a SWR Sacramento Office or Regional Memorandum of Understanding (MOU) similar to a 1994 MOU [Daily Env't Rep. (BNA) No. 188, at E-1] between Agencies (which expired in 1999), establishing a framework for cooperation and participation to further the purposes of the ESA that specifically outlines a process for coordinating and implementing appropriate recovery actions identified in recovery plans.

2. Prepare, and send after recovery plan approval, a letter to all other appropriate Federal agencies outlining section 7(a)(1) obligations and meet with these agencies to discuss listed salmonid conservation and recovery priorities.

3. Encourage development of Conservation Bank Agreements for creating an array of individual conservation bank sites that will provide credits as compensation for actions that may affect anadromous salmonids within the Central Valley recovery domain. Focus conservation bank sites in key listed Central Valley salmon and steelhead watersheds.

4. Encourage meaningful and focused mitigation, in alignment with recovery goals for restoration and threat abatement, for all actions that incidentally take listed Central Valley salmon and steelhead or affect their habitat.

5. Encourage Federal partners to include recovery actions in project proposals.

6. Conduct outreach to Federal partners, and provide an outline of 7(a)(1) obligations.

7. The purpose of section 7(a)(2) is to "insure that any action authorized, funded, or carried out by [a Federal agency] is not likely to jeopardize the continued existence of any [listed species] or result in the destruction or adverse modification of [a listed species' critical habitat]." The theme is not one of recovery but of "no jeopardy" or "adverse modification." Federal agencies request interagency consultation with NMFS (and/or FWS) when they determine an action may affect a listed species or its critical habitat. NMFS then conducts an analysis of potential effects of the action. In the process of consultation, NMFS currently expends considerable effort to assist agencies in avoiding and

minimizing the potential effects of proposed actions, and to ensure agency actions do not jeopardize a species or destroy or degrade habitat. Consultations have helped prevent and minimize direct take but have not led to recovery.

To improve the section 7(a)(2) consultation process, NMFS will utilize its authorities to:

- Use recovery criteria and objectives as a reference point to determine effects of proposed actions on the likelihood of species' recovery.
- Place high priority on consultations for actions that implement recovery strategy or specific actions.
- Develop and maintain databases to track the amount of incidental take authorized and effectiveness of conservation and mitigation measures.
- Provide recommended actions in recovery plan as section 7(a)(1) conservation recommendations.
- Prioritize staff time to address and minimize short- and long-term effects of all actions occurring in listed Central Valley salmon and steelhead habitats.
- Focus staff priorities, to the extent possible, away from section 7 compliance in watersheds not designated as a priority for recovery and direct efforts to recovery implementation
- Streamline consultations for those actions with little or no effect on recovery areas or priorities.
- Prioritize staff efforts to carefully and consistently consider short-term and long-term impacts to watershed processes when conducting jeopardy analysis for Federal actions in key listed Central Valley salmon and steelhead watersheds.
- Apply the VSP framework and recovery priorities to evaluate population and area importance in jeopardy and adverse modification analysis.
- Work with established conservation bank programs to influence conservation bank agreements and actions that provide measurable contributions to threats abatement and recovery.

Within this framework NMFS will utilize its authorities to encourage:

- Amendments to the Corps section 404 Clean Water Act exemptions for farming, logging, and ranching activities. Terminating section 404(f) exemptions for discharges of dredged or fill material into waters of the United States associated with certain normal agricultural activities (defined as logging, ranching, and farming) will allow interagency consultations in key Dependent and Independent watersheds and provide incidental take coverage for individuals/corporations/agencies engaged in those activities.
- The Federal Emergency Management Agency (FEMA) to fund upgrades for flood-damaged facilities to meet the requirements of the ESA and facilitate recovery.
- The Environmental Protection Agency (EPA) to prioritize action on pesticides known to be toxic to fish and/or are likely to be found in fish habitat; and to take protective actions, such as restrictions on pesticide use near water.
- The FHWA and Caltrans develop pile driving guidelines, approved by NMFS, for all bridge construction projects in Key Dependent, Independent, and other watersheds with extant listed Central Valley

salmon and/or steelhead populations.

- Development of section 7 Conservation Recommendations to help prioritize Federal funding towards recovery actions (NFMS, USFWS, NRCS, EPA, etc) during formal consultations.
- All Federal agencies who designate a non-Federal representative to conduct informal consultation or prepare a biological assessment ensure the associated documentation comports to 50 CFR 402.14(c) prior to initiating consultations with NMFS.
- All Federal agencies, or their designated representatives, to field review projects and actions upon project completion to determine whether or not the projects were implemented as planned and approved. Encourage all Federal agencies, or their designated representatives to report the initial findings of field review to NMFS.
- Encourage Federal agencies to coordinate and develop programmatic incidental take authorization for activities that contribute to the recovery of listed Central Valley salmon and steelhead, to streamline their permitting processes.
- Encourage all consulting agencies to provide biological assessments that comport to 50 CFR 402.14(c) for all projects in all watersheds where listed Central Valley salmon and/or steelhead are present and/or with designated critical habitat.

8.3.6 ESA Section 9

Section 9 prohibits any person from harming members of listed species including direct forms of harm such as killing an individual, or indirect forms such as destruction of habitat where individual rear or spawn. The recovery plan will assist NMFS' Enforcement personnel by targeting key watersheds essential for species recovery. Core recovery areas identified in this plan should be considered the highest priority areas. NMFS PRD staff will work closely with NMFS Enforcement regarding the identification of threats and other activities believed to place Chinook salmon at high risk of take and/or extirpation. Actions will include the following:

- NMFS will conduct outreach and provide enforcement a summary of the recovery priorities and threats.
- NMFS will prioritize those actions and areas deemed of greatest threat or importance for focused efforts to halt illegal take of listed species.
- NMFS will develop a plan to outline responsibilities and priorities between PRD and enforcement to ensure activities by NMFS staff, when supporting enforcement, are focused on the highest recovery priorities.
- When a take threat has occurred in a high priority area, NMFS PRD will work with NMFS enforcement, to the extent feasible, with the development of a take statement.
- NMFS enforcement will work with the California Department of Fish and Game, in conjunction with the Joint Enforcement Agreement to increase patrols and landowner outreach in critical watersheds, particularly during droughts, when listed Central Valley salmon and steelhead are potentially at greater threat of unauthorized taking.
- Regular meetings between recovery staff and Enforcement will occur. NMFS Enforcement will place a high priority on identification and curtailment of threats in key populations identified for recovery.

8.3.7 ESA Section 10

Section 10 (a)(1)(A) provides permits for the authorization of take for scientific research, or to enhance the propagation or survival of listed species. Typically NMFS has authorized conservation hatcheries and research activities

under section 10(a)(1)(A). Section 10(a)(1)(B) authorized take that is incidental to otherwise lawful activities for non-federal entities. Requests for such a permit must be accompanied by a conservation plan that describes how the entity will minimize and mitigate take and the effects of the take. To improve the section 10 authorization process, NMFS will utilize it authorities to:

Section 10(a)(1)(a) Research Permits

- Prioritize permit applications that address identified research and monitoring needs in the recovery plan.
- Evaluate all proposed activities against the identified threats, recovery strategy, and recovery actions identified in the plan.
- Develop and maintain databases to tracks the amount of incidental take authorized and the effectiveness of conservation and mitigation measures.

Section 10(a)(1)(B) Habitat Conservation Plans

We recommend all future HCPs, where listed Central Valley salmon and steelhead are covered species, adopt the viability and threats assessment guidelines described in this recovery plan. Adoption of these guidelines will facilitate standardization and could help in the tracking of recovery actions and threats abatement. Additionally, adoption of the assessment protocols should streamline jeopardy analysis and assist applicants in identification of limiting factors and strategically targeting beneficial and conservation and mitigation opportunities and locations. Finally, adoption of the assessment protocols will facilitate consistency in the development of standards to determine the appropriate levels of mitigation necessary to ensure the continued existence of listed Central Valley salmon and steelhead. The Habitat Conservation Planning Handbook stresses the need for consistency of mitigation measures for a species and for specific standards. Although, not a preferred option (according to the USFWS/NMFS HCP Handbook), if offsite mitigation is necessary this recovery plan can be used to target watersheds for recovery actions. In some circumstances off-site mitigation may provide greater opportunity for recovery than onsite mitigation (*i.e.*, if an HCP's covered activities occur in a non-focus watershed).

Within this framework NMFS will utilize its authorities to:

- Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
- Standardize monitoring methods in HCPs to the TRT research needs and the recovery plan template. Consistent data collection techniques and the ability to compare similar data sets over space and time will set the framework for the five year review and help track recovery progress.

Section 10(j) Experimental Populations

Among the significant changes made in the 1982 amendments to the ESA was the creation of section 10(j), which provides for the designation of specific populations of species listed as "experimental populations" so long as they are wholly separate from other non-experimental populations. Under section l0(j), reintroduced populations of endangered or threatened species established outside the current range but within the species' historical range may be designated, at the discretion of NMFS, as "experimental," lessening the ESA's regulatory authority over such populations. Because these populations are not provided full ESA protection, management flexibility is increased, local opposition is reduced, and more reintroductions are possible.

Two types of experimental population designations exist: essential and nonessential. An essential experimental population is a reintroduced population whose loss would be likely to appreciably reduce the likelihood of the survival of the species in the wild. These

populations are treated as threatened species (with special rules) for the purposes of section 9 of the Act. Therefore, they can be managed with greater flexibility with regard to incidental take and regulated take.

A nonessential experimental population is a reintroduced population whose loss would not be likely to appreciably reduce the likelihood of the survival of the species in the wild. These populations, besides being treated as threatened species, are treated as proposed species for the purposes of section 7. The establishment of experimental populations is a valuable tool for use in the recovery of some listed species

To facilitate the implementation of species reintroduction, and to minimize the regulatory prohibitions that may create opposition to reintroduction programs, all candidate reintroduction areas in the Recovery Footprint should be considered for 10(j) rule proposals. Additional analysis is needed to determine if specific populations should be proposed as essential or non-essential. However, we have evaluated reintroduction potential for several historic, currently unoccupied habitats and recommend that 10(j) rules be developed for the following areas:

Little Sacramento and McCloud Rivers

Species: Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, and CV steelhead.

The 2009 NMFS biological opinion on OCAP includes an RPA requiring the U.S. Bureau of Reclamation to begin the reintroduction of Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, and CV steelhead to the Little Sacramento and McCloud Rivers in 2012. The engineering, biological, cultural and sociopolitical challenges associated with reintroducing populations above one of the largest dams in the country highlights the need to tailor flexible regulatory prohibitions. These populations should be considered for designation as experimental through section 10(j).

Upper Yuba River

Species: CV spring-run Chinook salmon, and CV steelhead

The upper Yuba River has long been recognized for offering perhaps the best opportunity to create a viable population in the Northern Sierra Diversity Group, that is wholly separate from other populations and many of the catastrophic risk factors other populations face. Several initiatives are underway to develop engineering alternatives to allow upstream passage, develop reintroduction plans, and collaborate with watershed stakeholders to develop a reintroduction strategy. Similar to passage challenges at Keswick and Shasta Dams, reintroducing fish above Englebright Dam on the Yuba River will require specific and flexible regulatory prohibition. These populations should be considered for designation as experimental through section 10(j).

American River

Species: CV steelhead

The 2009 NMFS biological opinion on OCAP includes an RPA requiring the U.S. Bureau of Reclamation to begin the reintroduction of CV steelhead to the upper American River in 2012. Similar to passage challenges at Keswick and Shasta Dams, reintroducing fish above Folsom Dam on the American River will require specific and flexible regulatory prohibition. These populations should be considered for designation as experimental through section 10(j).

San Joaquin River

Species: CV spring-run Chinook salmon

The San Joaquin River Settlement Agreement 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 spring-run Chinook salmon. With implementation of these actions, the San Joaquin River Watershed below Friant Dam has a high potential to support a spawning population of reintroduced spring-run Chinook salmon. However, this reintroduction is outside of the existing ESU boundaries, and implementation will face numerous challenges in terms of engineering, biology, and public support; requiring the need to consider specific and flexible regulatory prohibition. The reintroduced population of spring-run Chinook salmon should be considered for designation as experimental through section 10(j).

The San Joaquin River Settlement Agreement requires the USFWS to submit a permit to NMFS for reintroduction of spring-run to the San Joaquin River no later than Sept 30, 2010. NMFS is required to issue a permit by April 30, 2012, and for reintroduction no later than 12-31-2012.

8.3.8 Fisheries Management and EFH

Much of listed Central Valley salmon and steelhead habitat is located in areas identified as Essential Fish Habitat (EFH) for the Pacific Coast Salmon Fishery Management Plan (FMP) under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). NMFS will implement fishery regulations, through coordination with PFMC, to maintain salmon harvest levels at or below those necessary to allow for the recovery of listed salmon. NMFS anticipates the objectives and recovery strategies will serve as a guide when providing conservation recommendations for actions that may adversely affect EFH. In addition, NMFS will work to implement fishery regulations to reduce bycatch of salmon in federally-managed fisheries.

8.3.9 Coordination with other NMFS Divisions and the PFMC

Other divisions within NOAA can contribute significantly to recovery. NMFS PRD staff will coordinate closely with the SWFSC, Habitat Conservation Division, and NOAA Restoration Center to assist in the development, review and funding of restoration projects.

In addition NMFS PRD staff will need to coordinate closely with the PFMC for establishing an ecosystem-based fishery management plan to prevent overfishing of listed Chinook salmon. The current management measures serve to:

- apportion ocean harvest equitably among treaty Indian, non-treaty commercial and recreational fisheries
- provide in-season adjustment flexibility so that the fishing can provide for spawning escapement that meets replacement curves
- provide in-season adjustments to manage for ESA listed species

Additional changes in management may be required to meet recovery directives.

8.3.10 Technical Assistance

Beyond NMFS' statutory authorities and obligations we are engaged in a significant amount of outreach to various constituencies where we provide technical assistance regarding listed salmon, their habitat needs, and various life history requirements. Due to the large proportion of private lands and the limited contributions of section 7, developing partnerships through providing technical assistance will be critical for recovery. Through this role NMFS shall focus efforts in key areas

critical for recovery through the following actions:

- Work with the individual cities and counties throughout the Central Valley to recommend city and county planning and policies protective of listed Central Valley salmon and steelhead.
- Continue working with Natural Resource Conservation Service, Resource Conservation Districts, and Reclamation Districts, to encourage improved agricultural practices as well as land use practices of rural residential landowners.
- Encourage Smart Growth policies and provide outreach and education to urban planners and builders. Encourage planning that accounts for natural events such as droughts, storm, flooding and climate change.
- Encourage State wide policies for urban and rural roads.
- Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
- Establish policies and compliance that preserve and protect stream flows required by specific life stages of listed Central Valley salmon and steelhead.
- Assemble a NMFS Water Rights Team that focuses on restoring and maintaining natural streamflow regimes across the ESUs/DPS.
- Work to assure funding and staff for full enforcement of laws, codes, regulations and ordinances across the listed Central Valley salmon ESUs and steelhead DPS.

9.0 Glossary

Adaptive management An action-oriented approach to resource management that brings science and management together and allows managers to move forward in the face of uncertainty when dealing with complex ecological problems. Adaptive management tackles uncertainty about the system head-on by identifying clear objectives, developing conceptual models of the system, identifying areas of uncertainty and alternative hypotheses, learning from the system as actions are taken to manage it, updating the conceptual models, and incorporating what is learned into future actions.

Alevin Newly hatched salmon that have not yet adsorbed their yolk sac. The alevin life stage comes before the fry stage.

Alleles Any of the alternative forms of a gene that may occur

Anadromous Fish Fish that are hatched in freshwater, then spend a part of their life cycle in the sea and return to their natal streams to spawn.

California Central Valley Project Improvement Act Passed by the State legislature in 1933, authorized the sale of bonds to pay for the Central Valley Project. The Project was taken over by the Federal Government under the Rivers and Harbors Act of 1935(from Wikipedia). (CVPIA) - This federal legislation, signed into law on October 30, 1992, mandates major changes in the management of the federal Central Valley Project. The CVPIA puts fish and wildlife on an equal footing with agricultural, municipal, industrial, and hydropower users.

CALFED Bay/Delta Authority A California State agency that coordinates the efforts of both the State and the Federal Government addressing hydrologic concerns within the Sacramento/San Joaquin River Delta System. This entity was begun in 1994 to streamline efforts to ensure water quality standards, reliability of water supplies, viability of native and protected species, eradication/control of invasive species, as well as the integrity of levees within the Delta system.

Central Valley Project Now run by the U.S. Department of Reclamation, this entity controls water resources by impounding water from snowpack runoff for hydroelectric power generation, municipal and agricultural supplies and to control flooding as well as provide recreational opportunities to all. A primary function of the CVP is to move water from the north where

there is an abundance to the southern part of the Central Valley where there are chronic shortages. **(CVP)** - Federally operated water management and conveyance system that provides water to agricultural, urban, and industrial users in California.

Channel Complexity Measure of multiple components determining the makeup of a given waterway. Some of these would include slope, meander, bedload/substrate makeup (*i.e.* gravel, cobble, boulder, combination), presence/absence large instream woody material, thalweg, *etc*.

Cladocerans Small aquatic crustaceans (*i.e.* "water fleas")

Conceptual Model A qualitative model of the system and species life stages with the interrelations between the system and threats shown in diagrammatic form. Several threats are interlinked or independent and these can be illustrated on the model of the system. "(1) "Explicit statements of the hypothesized fundamental relationships underlying management decisions regarding environmental resources." [A Proposal for the Development of a Comprehensive Monitoring Assessment and Research Program, April 24, 1998, page 30]; (2) "A simple non-quantitative model, developed for the purpose of building a consensus regarding the most important ecological elements and linkages that characterize a stressed ecosystem." [Nick Aumen, Conceptual Modeling Workshop, UC Davis, June 17-18, 1998]

Congressional Federal Register Daily publication of the official journal of the U.S. Government, containing public notices and other routine publications.

Connectivity Spatial structure should have permanent or appropriate seasonal connectivity to allow adequate migration between spawning, rearing, and migration patches.

Conservation-Reliant Species are dependent on enforced protections for survival.

Conveyance A pipeline, canal (natural or artificial), or similar conduit that transports water from one location to another.

Copepod Small aquatic crustacean.

Crepuscular Relating to twilight.

Critical Habitat The specific areas within the geographical areas occupied by the species, at the time it is listed, on which are found those physical or biological features (i) essential to the conservation of the species and (ii) which may require special management considerations or protection.

	Importantly, critical habitat "shall not include the entire geographical area which can be occupied by threatened or endangered species".
Delist	To remove an animal or plant from the list of endangered and threatened wildlife and plants thereby removing the accompanying protection.
Deme:	**A** local population of organisms of one species that actively interbreed with one another and share a distinct gene pool. When demes are isolated for a very long time they can become distinct subspecies or species
Diversity Group (Recovery Unit)	Populations are categorized into diversity groups based on the geographical structure described in Lindley *et al.* (2007) (diversity group ≈ recovery unit)
Distinct Population Segment (DPS)	A subdivision of a vertebrate species that is treated as a species for purposes of listing under the Endangered Species Act (ESA). To be so recognized, a potential distinct population segment must satisfy standards specified in a FWS or NOAA Fisheries policy statement (See the February 7, 1996, Federal Register, pages 4722 – 4725). The standards require it to be separable from the remainder of and significant to the species to which it belongs.
Efficacy	Measure of the ability to produce desired outcome.
Effluent	Discharge or emission of a liquid or gas (usually waste material)
Endangered Species	Species that are at significant risk of extinction throughout all or much of its range.
Endangered Species Act	Federal legislation that provides protection for species at risk of extinction. Through federal action and by encouraging the establishment of state programs, the 1973 Endangered Species Act provides for the conservation of ecosystems upon which threatened and endangered species of fish, wildlife, and plants depend. Section 7 of the Endangered Species Act requires Federal agencies to insure that any action authorized, funded or carried out by them is not likely to jeopardize the continued existence of listed species or modify their critical habitat.
Entrainment	To draught and transport by the flow of a fluid.
Ephemeral	Transient, Brief, Temporary, Eposidic.
Escapement: ***Spawning Escapement***	Adult fish that "escape" fishing gear to migrate upstream to spawning grounds. The quantity of sexually mature adult salmon (typically

measured by number or biomass) that successfully pass through a fishery to reach the spawning grounds. This amount reflects losses resulting from harvest, and does not reflect natural mortality, typically partitioned between enroute and pre-spawning mortality. Thus, escaped fish do not necessarily spawn successfully.

Essential Fish Habitat (EFH): Those waters and substrate necessary for fish spawning, incubation, breeding, feeding, or growth to maturity. These areas include migration corridors and adult holding areas. Essential Fish Habitat must also include wetland/riparian shore that supports vegetation that projects shade/cover over waterways used by listed species.
"**waters**": aquatic areas and associated physical, chemical, and biological properties used by fish.
"**substrate**": includes sediment, hard bottom, structures underlying the waters, and associated biological communities.
"**necessary**": habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem.
"**spawning, breeding, feeding or growth to maturity**": covers a species' full life cycle.

Estuarine: Relating to an estuary.

Estuary: That area of water, usually at least partially enclosed, which joins marine and freshwater components. As such, these areas are heavily influenced by both tidal and riverine inputs. Commonly an arm of the sea at the lower end of a river. Estuaries are often enclosed by land except at channel entrance points.

Evolutionarily Significant Unit (ESU) A Pacific salmonid stock that is substantially reproductively isolated from other stocks of the same species and which represents an important part of the evolutionary legacy of the species. Life history, ecological, genetic, and other information can be used to determine whether a stock meets these two criteria. NOAA Fisheries uses this designation. NMFS definition of a distinct population segment that is smallest biological unit that will be considered to be a "species" under the ESA. A population will be is considered to be an ESU if 1) it is substantially reproductively isolated from other conspecific population units, and 2) represents an important component in the evolutionary legacy of the species.

Exotic Species (Also called Non-Indigenous Species or Non-Native Invasive Species [**NIS**]):
Plants and animals that originate elsewhere and migrate or are brought into an area. They may dominate the local species or have other negative impacts on the environment because they can often outcompete native species and they typically have no natural predators.

Extant	Existing, Surviving.
Extirpation:	Loss of a taxon from all of its range.
Extirpated Species	A species that no longer survives in regions that were once part of its range, but that still exists elsewhere in the wild or in captivity.
Fish Ladder	Structure that allows fish passage to areas upstream of obstructions (*e.g.* dams, locks). Fish ladders employ a series of stepped, terraced pools fed with spillover water cascading down the ladder. This allows fish to make incremental leaps upstream from pool to pool to access historical/ancestral habitat upstream. Water-filled staircase that allows migrating fish to swim upstream around a dam or obstacle.
Fish Screens	Physical exclusion structures placed at water diversion facilities to keep fish from becoming entrained, trapped and dying in a given water body.
Fry	The life stage of salmonids between alevin and parr. (sac fry or alevin) – The stage in the life of a fish between the hatching of the egg and the absorption of the yolk sac. From this stage until they attain a length of one inch the young fish are considered advanced fry. Early lifestage of salmonids. Typically, juveniles that can swim and catch their own food. Next life stage after alevin, and before smolt. The third freshwater stage of salmonid development; when egg mass is no longer present and fish develops characteristic markings. (upon reaching 1.25 inches in length, they are sometimes called "fingerlings".
Genetic Drift	The random change of the occurrence of a particular gene in a population; genetic drift is thought to be one cause of speciation when a group of organisms is separated from its parent population. Birgid Schlindwein's Hypermedia; the random fluctuation of an allele frequencies in a population resulting from the sampling of gametes to produce a finite number of individuals in the next generation.
Gene(tic) Flow	The rate of entry of non-native genes into a population, measured as the proportion of the alleles at a locus in a generation that originated from outside of the population. Can be thought of as the genetically successful stray rate into a population. See also stray rate and homing rate.
Genetic Divergence	The process of one species diverging over time into more than one species. Passing small random advantages characteristic changes over time from one generation to the next generations
Genetic Fitness	Generally depicted as n: The reproductive success of a genotype, usually measured as the number of offspring produced by an individual that survive to reproductive age relative to the average for the population.

Genetic Introgression Introduction by interbreeding or hybridization of genes from one population or species into another.

Genetic Robustness Demographic Robustness

Habitats Areas that provide specific conditions necessary to support plant, fish, and wildlife communities. Habitat elements identified in the Ecosystem Restoration Program Plan include tidal perennial aquatic habitat, nontidal perennial aquatic habitat, delta sloughs, midchannel islands and shoals, saline emergent wetland, fresh emergent wetland, seasonal wetlands, riparian and riverine aquatic habitats, inland dune scrub habitat, perennial grassland, agricultural lands, freshwater fish habitat, and essential fish habitat. The natural abode of a plant or animal, including all biotic, climatic, and soil conditions, or other environmental influences affecting life.

Heavy Metal A group that includes all metallic elements with atomic numbers greater than 20, the most familiar of which are chromium, manganese, iron, cobalt, nickel, copper and zinc but that also includes arsenic, selenium, silver, cadmium, tin, antimony, mercury, and lead, among others.

Habitat Is the area where a particular species lives.

Hybridization Is the process of mixing different species or varieties of organisms to create a hybrid.

Hydrologic Unit A definitive geographical area, typically an entire watershed defined by the United States Geological Survey (USGS).

Hyporheic Hyporheic describes that flow of water through the interstitial spaces in the substrate beneath the stream (river) bed. It is vitally important because of the function that hyporheic flow performs in bringing oxygen and other nutrients to developing eggs and alevins, and in removing wastes from redds.

Immediacy There are varying degrees of immediacy, including, a species is intrinsically vulnerable to threats, or identifiable threats can be "mapped" and seen as increasing or decreasing, or the threats are reasonably predictable.

Inbreeding Depression Is reduced fitness in a given population as a result of breeding of related individuals

Independent Population: An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals

with other populations. In other words, if one independent population were to go extinct, it would not have much impact on the 100-year extinction risk experienced by other independent populations. Independent populations are likely to be smaller than a whole ESU and they are likely to inhabit geographic ranges on the scale of entire river basins or major sub-basins.

Instream Flow Incremental Methodology Equation to derive the **flow** needed for spawning and rearing salmon and steelhead

Invasive Species See exotic species.

Irreversibility The trend/probability of a process to continue in only one direction once a tipping threshold has been crossed or met

Iteroperous The term iteroperous describes the condition in which a fish may spawn multiple times. Steelhead (*Oncorhynchus mykiss*) and Atlantic Salmon (*Salmo salar*) display this trait routinely while Pacific Salmon (*Oncorhynchus tshawytscha, O. gorbuscha, O. keta, O nerka., O. kisutch*) without exception expire after spawning only once.

Jacks Jacks are male salmonids that have spent only a year at sea but have returned to spawn. A less frequently used term for these individuals is *grilse*.

Jills Jills (sometimes also called "jennys") are female salmonids that have spent only a year at sea but have returned to spawn. This is a relative rarity within the population.

Kelt "Spawned out" salmonid fish. Salmon or trout that remains in freshwater after spawning in the fall. A salmonid that survives spawning and may return to the ocean. This is extremely rare in salmon and uncommon in trout.

Metapopulation(s) A population of sub-populations which are in turn comprised of local populations or demes. Individual sub-populations can be extirpated and consequently recolonized from other sub-populations. Stability in a metapopulation is maintained by a balance between rates of sub-population extinction and colonization.

Parr First part of the smoltification stage in salmonid life history occurring after natal yolk sac has been re-absorbed and before the distinctive parr marks have completely faded. During this time the fish is actively feeding and growing while outmigrating from its natal stream on its way to the ocean.

Parr Marks Parr marks are vertical oval bars on the flanks of salmon fry that fade completely as the fish go through the smoltification process

Phenotypic Expression of (a) particular trait(s) in a particular specimen.

Population(s) Multiple types (e.g. persistent, viable, independent, dependent)

- **Functionally Independent Populations:** have a high likelihood of persisting over 100-year time scales and conform to the original definition of independent "viable salmonid population."
- **Potentially Independent Populations:** have a high likelihood of persisting in isolation over 100-year time scales, but are too strongly influenced by immigration from other populations to exhibit independent dynamics.
- **Dependent Population:** At risk group that has a substantial likelihood of going extinct within a 100-year time period in isolation, yet receives sufficient immigration to alter their dynamics and extinction risk, and presumably increase persistence or occupancy.

Predation: The act of acquiring sustenance and nutrition by killing and consuming living animals.

Primary Constituent Elements (PCE) A physical or biological feature essential to the conservation of a species for which its designated or proposed critical habitat is based on, such as space for individual and population growth, and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing of offspring, and habitats that are protected from disturbance or are representative of the species' historic geographic and ecological distribution.

Pyroclastic Flow Superheated mixture of debris, vapor, mud, *etc.* flowing downhill/away from a volcanic vent during an eruption event.

Random-Walk-With-Drift Model A model that incorporates density independence and has often been used in population viability analysis. It is an important tool in conservation biology partly because its parameters are easily estimated from periodic observations of population size.

Recovery Priority Number (RPM) A rank, ranging from a low of 18 to a high of 1C, whereby priorities are assigned to listed species and recovery tasks; assignment of rank is based on degree of threat, recovery potential, taxonomic distinctiveness, and presence of an actual or imminent conflict between the species and development activities.

Recovery Viability Potential The potential of a population to be restored to viability using the four parameters that indicate viability. Viability of populations and ESUs

depends on the demographic properties of the population or ESU, such as population size, growth rate, the variation in growth rate, and carrying capacity

Redd Nest depression constructed by female salmonids facilitating increased hyporheic flow for alevins. A type of fish-spawning area associated with running water and clean gravel.

Restoration Feasibility If the threats have undermined the integrity of the system to the point that it cannot be recovered, then the restorability has been reduced. The other end of the scale is if the system can be recovered once the threat is removed.

Restoration Potential The potential for returning a damaged watershed or ecosystem to a condition or function that is (1) similar to pre-disturbance, or (2) self-sustaining and in equilibrium with the surrounding landscape and ecological processes necessary for carrying out the basic life history functions of target organisms. An area characterized as having a high restoration potential would be considered to have a high likelihood of returning to this condition or function. Conversely, an area with low restoration potential would have little to no likelihood of returning to this condition or function.

Riparian The strip of land adjacent to a natural water course such as a river or stream. Often supports vegetation that provides the best fish habitat values when growing large enough to overhang the bank.

Riverine Habitat within or alongside a river or channel.

Scope The geographic area of the threat to the species or system. Impacts can be widespread or localized.

Severity A measure of the level of damage to species or system(s) that can reasonably be expected within 10 years under current circumstances. Range of severity from total destruction down to slight impairment.

Smolt: An anadromous fish that is physiologically ready to undergo the transition from fresh to salt water; age varies depending on species and environmental conditions.

Smoltification Describes the process by which salmonid fish acclimate metabolically over time from aquatic to marine environments as they emigrate from their natal streams to the ocean. During this process, parr marks fade and the fish takes on a silver color.

Species group Certain species or groups of species are given a particular attention based on three criteria that might be met by a species: 1) it is threatened,

	endangered, or a species of special concern; 2) it is economically important, supporting a sport or commercial fishery; or 3) it is an important prey species"
Stochastic Events	Random, unpredictable events.
Straying	Occurs when some adult spawners spawn in a stream other than the one they were born in. Straying may be influenced by hatchery practices, water quality or water diversions.
***Thalweg*:**	Defines the deepest continuous portion of a stream or waterway. Sometimes referred to as the "valley line" is often undercuts structures embedded in the streambank.
Thermocline	That layer in a body of water where the temperature difference is greatest per unit of depth. It is the layer in which the drop in temperature equals or exceeds one degree C. (1.8 degrees F) per meter (39.37 inches).
Threat Abatement	To reduce the amount, intensity or degree of a threat
***Trophic Levels*:**	Hierarchical tiers within a food web system (*e.g.* top predator or primary producer).
Viable Salmonid Population (VSP)	An independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation (random or directional), local environmental variation, and genetic diversity changes (random or directional) over a 100-year time frame.
Weir	A fence-like fish trap placed across a stream or outlet forces fish to swim into waiting traps.

Literature Cited

AFRP. 2005. Anadromous Fish Restoration Program: Mill Creek Watershed Information. U.S. Fish and Wildlife Service. URL = http://www.fws.gov/stockton/afrp.

Airola, D. 1983. A survey of spring-run Chinook salmon and habitat in Antelope Creek, Tehama County, California. Unpublished report. Lassen National Forest.

Albers, J. P. and J. F. Robertson. 1961. Geology and ore deposits of East Shasta copper-zinc district. Shasta Co., California: U.S. Geological Survey Professional Paper 338.

Allen, M. V. 1979. Where The 'Ell is Shingletown? Press Room Inc., Redding, CA, USA.

Allendorf, F. W., D. Bayles, D. L. Bottom, K. P. Currens, C. A. Frissell, D. G. Hankin, J. A. Lichatowich, W. Nehlsen, P. C. Trotter, and T. H. Williams. 1997. Prioritizing Pacific Salmon Stocks for Conservation. Conservation Biology Volume 11: 140-152.

Alt, D. D., and D. W. Hyndman. 1975. Roadside Geology of Northern California. Mountain Press Publishing Co., Missoula, MT, USA.

Arkush, K. D., M. A. Banks, D. Hedgecock, P. D. Siri, and S. Hamelberg. 1997. Winter-Run Chinook Salmon Captive Broodstock Program: Progress Report Through April 1996. Technical Report 49. Interagency Ecological Program for the San Francisco Bay/Delta Estuary.

Armentrout, S., H. Brown, S. Chappell, M. Everett-Brown, J. Fites, J. Forbes, M. McFarland, J. Riley, K. Roby, A. Villalovos, R. Walden, D. Watts, and M. R. Williams, 1998. Watershed Analysis for Mill, Deer and Antelope Creeks. Almanor Ranger District. Lassen National Forest.

Bailey, E. D. 1954. Time Pattern of 1953-54 Migration of Salmon and Steelhead into the Upper Sacramento River. California Department of Fish and Game. Unpublished report.

Bakker, Elna S. 1971. An island called California; an ecological introduction to its natural communities, University of California Press, Berkeley, California.

Banks, M. A., V. K. Rashbrook, M. J. Calavetta, C. A. Dean, and D. Hedgecock. 2000. Analysis of Microsatellite DNA Resolves Genetic Structure and Diversity of Chinook Salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Canadian Journal of Fisheries and Aquatic Science Volume 57: 915-927.

Barnhart, R. A. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) - Steelhead. Biological Report 82 [11.60], TR EL-82-4.

Barron, F. 2005. Lead Forester, Crane Mills, Corning, CA. Personal Communication.

Bauer, M.1992. History of the Los Molinos Land Company and of Early Los Molinos Tehama County Museum, Tehama, CA.

Bear River Watershed Group Website. 2009. Bear River Awakening. Available at: http://bearriver.us/index.php Accessed May 8, 2009

Bear River Watershed Group Website. 2009. Bear River Awakening. Site accessed July 10, 2009. URL = http://bearriver.us/index.php.

Bell, M. C. 1986. Fisheries Handbook of Engineering Requirements and Biological Criteria. Sacramento, CA: U. S. Army Corps of Engineers, Fish Passage Development and Evaluation Program.

Brandes, P. L. and J. S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 39-136.

Brown, C. B., and Thorpe, E.M. 1947. Reservoir Sedimentation in the Sacramento-San Joaquin Drainage Basins, California, U.S. Department of Agriculture, Soil Conservation Service Special Report No. 10, 69 p.

Brown, C. J., Smith, E.D., Siperek, J.M., Villa, N.A., Reading, H.H., and Finn, J.P. 1983. Thomes-Newville Unit Fish and Wildlife Evaluation. California Department of Fish and Game.

Brown, M. 2009. Fisheries Biologist, Red Bluff Fish and Wildlife Office, U.S. Fish and Wildlife Service. Personal communication with Bruce Oppenheim. Biweekly Kayak Survey Results and Snorkel Survey Results. February 13, 2009.

Brown, R. and F. Nichols. 2003. The 2003 CALFED Science Conference: A Summary of Key Points and Findings. Submitted to CALFED Science Program, Sam Luoma, Lead Scientist, May 2003.

Bruin, D. and B. Waldsdorf. 1975. Some Effects on Rainbow Trout Broodstock, of Reducing Water Temperature from 59ºF to 52ºF. Hagerman, ID: U.S. Fish and Wildlife Service, National Fish Hatchery.

Bull, W. B., and E. R. Miller, 1975. Land settlement due to groundwater withdrawal in the Los Banos-Kettleman City area, California. Part 1: Changes in the hydrologic environment due to subsidence. U.S. Geologic Survey Professional Paper 437-E, E1–E71.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Report No. NMFS-NWFSC-27. NOAA Technical Memorandum. U.S. Department of Commerce.

Butte Creek Watershed Conservancy. 1998. Butte Creek Watershed Project: Existing Conditions Report. Butte Creek Watershed Project, California State University, Chico, 229 pp. Available at: http://buttecreekwatershed.org/Watershed.htm

Butte Creek Watershed Conservancy. 1999. Butte Creek Watershed Project: Existing Conditions Report. Butte Creek Watershed Project, California State University, Chico. URL = http://buttecreekwatershed.org/Watershed.htm (Accessed May 5, 2009).

CALFED. 1999a. Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration.

CALFED. 1999b. Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration, Draft Programmatic EIS/EIR Technical Appendix.

CALFED. 2000a. CALFED Bay-Delta Program Multi-Species Conservation Strategy Final Programmatic EIS/EIR Technical Appendix.

CALFED. 2000b. North of the Delta Offstream Storage Investigations. Integrated Storage Investigations. CALFED Bay-Delta Program.

CALFED. 2000c. Ecosystem Restoration Program Plan Volume 2. Ecological Management Zone Visions Final Programmatic EIS/EIR Technical Appendix. July 2000.

CALFED. 2006. Ecosystem Restoration Program Plan Year 7, Year 6 Annotated Budget, and Milestones Update (State FYs 2006-07; Federal FYs 2007). Implementing Agencies: CDFG, USFWS, NMFS.

CALFED. 2006b. Ecosystem Restoration: Spring-Run Chinook Salmon in Butte Creek.

CALFED. 2007. Ecosystem Restoration Program Plan Year 8 and Year 8 Annotated Budget (State FYs 2007-08; Federal FY 2008).

CALFED Ecosystem Restoration Program (CALFED ERP). 1998. CALFED Ecosystem Restoration Proposal Solicitation Submitted by the Sacramento Watersheds Action Group for the Sulphur Creek Coordinated Resource Management Planning Group.

CALFED and YCWA. 2005. Draft Implementation Plan for Lower Yuba River Anadromous Fish Habitat Restoration. Prepared on Behalf of the Lower Yuba River Fisheries Technical Working Group by SWRI.

CALFED and YCWA. 2005a. Draft Implementation Plan for Lower Yuba River Anadromous Fish Habitat Restoration. Prepared on Behalf of the Lower Yuba River Fisheries Technical Working Group by SWRI.

California Association of Resource Conservation Districts. 2005. A District Runs Through It. A Guide to Locally Led Conservation Projects.

California Department of Fish and Game (CDFG). 1961. King salmon spawning stocks of the California Central Valley, 1940-1959 Cal. Fish and Game Quarterly 47(1): 55-71.

California Department of Fish and Game (CDFG). 1978. Correspondence to Mr. D.B. Draheim, California Fisheries Restoration Foundation, Oakland, California, from A.E. Naylor. Dated January 31, 1978. On file in CDFG, Region 1 Office, Redding, California. 2pp.

California Department of Fish and Game (CDFG). 1988. California Advisory Committee on Salmon and Steelhead. 1988. Restoring the balance. CDFG, Sacramento.

California Department of Fish and Game (CDFG). 1989. Annual Report Chinook Salmon Spawner Stocks in California's Central Valley, 1989. Edited by Robert M. Kano, Inland Fisheries Division.

California Department of Fish and Game (CDFG). 1991a. Lower Yuba River Fisheries Management Plan.

California Department of Fish and Game (CDFG). 1991b. Steelhead Restoration Plan for the American River. Prepared by D. McEwan and J. Nelson.

California Department of Fish and Game (CDFG). 1993. Restoring Central Valley streams: A plan for action. State of California, Resources Agency, Department of Fish and Game, Inland Fisheries Division. November 1993.

California Department of Fish and Game (CDFG). 1994c. Central valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. Third Draft Inland Fisheries Technical Report August 1994. 70 pp.

California Department of Fish and Game (CDFG). 1995. Adult steelhead counts in Mill and Deer Creeks, Tehama County, October 1993-June 1994. Inland Fisheries Administrative Report Number 95-3.

California Department of Fish and Game (CDFG). 1996. Steelhead Restoration and Management Plan for California. Prepared by D. McEwan and T.A. Jackson. California Department of Fish and Game.

California Department of Fish and Game (CDFG). 1998. Report to the Fish and Game Commission: 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. Sacramento, CA: Department of Fish and Game.

California Department of Fish and Game (CDFG). 1998a. Dry Creek Steelhead Status Report 1997-1998.

California Department of Fish and Game (CDFG). 2000. Lower American River Pilot Salmon and Steelhead Spawning Habitat Improvement Project. Quarterly Status Report July 1999-March 2000. U.S. Fish and Wildlife Service.

California Department of Fish and Game (CDFG). 2001. Evaluation of Effects of Flow Fluctuations of the Anadromous Fish Populations in the Lower American River. Prepared for: U.S. Bureau of Reclamation. Stream Evaluation Program Technical Report No. 01-2.

California Department of Fish and Game (CDFG). 2001a. Re: Stanislaus River, Goodwin Dam New Melones Dam historical blockage.

California Department of Fish and Game (CDFG). 2004. Letter to the Bureau of Land Management Regarding Salmon Creek Resources, Inc. Notice of Exchange Proposal. November 9, 2004.

California Department of Fish and Game (CDFG). 2004a. Sacramento River spring-run Chinook salmon 2002-2003 biennial report. Prepared for the California Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. Sacramento, California.

California Department of Fish and Game (CDFG). 2005. Unpublished data. Auburn Ravine electrofishing data. Microsoft Excel worksheet.

California Department of Fish and Game (CDFG). 2006 AFRP. Appendix B - FY 2006 AFRP Restoration and Research Gap Analysis. Available at: www.delta.dfg.ca.gov/AFRP/documents/FY05_Gap_Analysis.pdf

California Department of Fish and Game (CDFG). 2007. Anderson-Cottonwood Irrigation District and Olney Creek Watershed Restoration Project. Project Summary Sheet. Available at: http://www.water.ca.gov/floodmgmt/fpo/sgb/fpcp/prop84/comp_sol/2008_selections/low_benefit/14_olney_creek_project_summary.pdf

California Department of Fish and Game (CDFG). 2007. California Steelhead Fishing Report- Restoration Card. A Report to the Legislature. July.

California Department of Fish and Game (CDFG). 2007a. Grandtab spreadsheet of adult Chinook salmon escapement in the Central Valley. February.

California Department of Fish and Game (CDFG). 2007b. Grandtab, Unpublished Data, Summaries of Salmon and Steelhead Populations in the Central Valley of California.

California Department of Fish and Game (CDFG). 2007a. AFRP. Anadromous Fish Restoration Program Workplan for Fiscal Year 2007. Available at: www.delta.dfg.ca.gov/AFRP/planningdocs.asp. (Accessed on October 25, 2007)

California Department of Fish and Game (CDFG). 2007b. AFRP. Appendix A - FY 2006 AFRP Program Status by Watershed. Available at: http://www.delta.dfg.ca.gov/AFRP/documents/FY05_Program_Status_Accomp.pdf. Accessed on October 25, 2007.

California Department of Fish and Game (CDFG). 2007c. California's Plants and Animals: Chinook Salmon - Winter-Run. Available at www.dfg.ca.gov. Accessed on April 27, 2007.

California Department of Fish and Game (CDFG). 2008. Draft Minimum Instream Flow Recommendations: Butte Creek, Butte County. CDFG. Water Branch, Instream Flow Program.

California Department of Fish and Game (CDFG). 2008a. Review of Present Steelhead Monitoring Programs in the California Central Valley. California Department of Fish and Game. May 2008.

California Department of Fish and Game (CDFG). 2009. Central Valley Chinook Salmon Escapement. Fisheries Branch Anadromous Assessment - GrandTab. Date compiled: 2/18/2009.

California Department of Fish and Game and National Marine Fisheries Service. 2001. Joint Hatchery Review Committee Final Report on Anadromous Salmonid Fish Hatcheries in California.

California Department of Water Resources (DWR). 1966. Department of Water Resources Bulletin No. 137. Sacramento Valley.

California Department of Water Resources (DWR). 1992. Sacramento Valley Westside Tributary Watersheds Erosion Study, Executive Summary.

California Department of Water Resources (DWR). 1993. Red Bank Project Pre-feasibility Design Alternatives Report.

California Department of Water Resources (DWR). 2000. Biological Opinion on Operation of the Federal Central Valley Project and the California State Water Project From December 1, 1999 Through March 31, 2000.

California Department of Water Resources (DWR). 2001. Initial Information Package, Relicensing of the Oroville Facilities. Oroville Facilities Relicensing, FERC Project No. 2100. Sacramento, California. January 2001.

California Department of Water Resources (DWR). 2002. Evaluation of the Feather River Hatchery Effects on Naturally Spawning Salmonids. SP-F9. Oroville Facilities Relicensing FERC Project No. 2100.

California Department of Water Resources (DWR). 2002a. Miners Ravine Habitat Assessment. Available at: http://www.watershedrestoration.water.ca.gov/fishpassage/docs/miners_final-draft-2.pdf Accessed May 8, 2009

California Department of Water Resources (DWR). 2003. Evaluation of Project Effects on Natural Salmonid Populations. Interim Literature Review, SP-F9. Oroville Facilities Relicensing FERC Project No. 2100.

California Department of Water Resources (DWR). 2004. Evaluation of the Feather River Hatchery Effects on Naturally Spawning Salmonids.

California Department of Water Resources (DWR). 2005. Application for New License Oroville Facilities FERC Project No. 2100 Volume V PDEA Appendices Part 2 - Appendix G.

California Department of Water Resources (DWR). 2005a. Bulletin 250 Fish Passage Improvement 2005b. An Element of CALFED's Ecosystem Restoration Program.

California Department of Water Resources (DWR). 2005b. Collection, handling, transport, release (CHTR) new technologies Proposal: Phase 1 Baseline conditions. May 2005. vii + 72 + appendices.

California Department of Water Resources (DWR). 2006. Progress of Incorporating Climate Change into Management of California's Water Resources. Available at http://baydeltaoffice.water.ca.gov/climatechange

California Department of Water Resources (DWR). 2007. Upper Yuba River Watershed Chinook Salmon and Steelhead Habitat Assessment. Prepared by the Upper Yuba River Studies Program Study Team. California Department of Water Resources. November 2007.

California Department of Water Resources (DWR). 2007a. Thomes Creek. Site accessed June 26, 2007. URL = http://www.nd.water.ca.gov.

California Department of Water Resources (DWR). 2009. Fish Passage Improvement - Upper Yuba River Studies Program. Available at: http://www.watershedrestoration.water.ca.gov/fishpassage/projects/upperyuba.cfm

California Department of Water Resources (DWR). 2009b. Tributary Monitoring Stations. California Department of Water Resources. Planning and Local Assistance, Northern District. URL= http://www.nd.water.ca.gov/PPAs/WaterQuality/RiversStreams/SacramentoRiver (Accessed May 1, 2009).

California Department of Water Resources and U.S Bureau of Reclamation. 1999. Biological Assessment: Effects of the Central Valley Project and State Water Project Operations from October 1998 Through March 2000 on Steelhead and Spring-Run Chinook Salmon.

California Department of Water Resources (DWR) Website. 2009. Tributary Monitoring Stations. Planning and Local Assistance. Northern District. Available at: http://www.nd.water.ca.gov/PPAs/WaterQuality/RiversStreams/SacramentoRiver/ Accessed May 1, 2009

California Division of Mines (CDM). N.d. California Geology. Bulletin 190.

California Energy Commission. 2003. Climate Change and California Staff Report. Prepared in Support of the 2003 Integrated Energy Policy Report Proceeding (Docket # 02-IEO-01).

Cech, J. J. and C. A. Myrick. 1999. Steelhead and Chinook Salmon Bioenergetics: Temperature, Ration, and Genetic Effects. Technical Completion Report- Project No. UCAL-WRC-W-885. University of California Water Resources Center.

CH2MHILL. 2002. Cottonwood Creek Watershed Assessment. July 2002. Available online at: http://www.sacriver.org/documents/watershed/cottonwoodcreek/assessment/CottonwoodCrk_Watershed_Assessment.pdf Accessed April 29, 2009

CH2MHILL. 2007. Cottonwood Creek Watershed Management Plan. Prepared for Cottonwood Creek Watershed Group. September 2007. Available online at: http://www.cottonwoodcreekwatershed.org/nodes/aboutwatershed/reports/documents/ccwmp.pdf Accessed April 29, 2009

Childs, J.R., Snyder, N.P., and Hampton, M.A., 2003, Bathymetric and Geophysical Surveys of Englebright Lake, Yuba–Nevada Counties, California: U. S. Geological Survey Open-File Report 2003-383. (http://geopubs.wr.usgs.gov/open-file/of03-383/)

Clark, G.H. 1929. Sacramento-San Joaquin Salmon (*Oncorhynchus tschawytscha*) fishery of California. California Fish and Game Bulletin 17:1- 73.

County of Placer. 2002. Auburn Ravine/Coon Creek Ecosystem Restoration Plan. Available at http://www.placer.ca.gov. June 2002.

County of Placer. 2009. Auburn Tunnel Outlet Modification Project. Initial Study/Mitigated Negative Declaration. Prepared by HDR/SWRI.

Cramer, F.K., and D.F. Hammack. 1952. Salmon research at Deer Creek, California, U.S. Fish and Wildlife Service. Special Scientific Report. Fisheries No. 67.

Cramer, S. P. and D. B. Demko. 1997. The Status of Late-Fall and Spring Chinook Salmon in the Sacramento River Basin Regarding the Endangered Species Act. Special Report submitted to National Marine Fisheries Service on behalf of Association of California Water Agencies and California Urban Water Agencies. Sacramento CA.

Curtis, J.A., Flint, L.E., Alpers, C.N., and Yarnell, S.M., 2005, Conceptual model of sediment processes in the upper Yuba River watershed, Sierra Nevada, CA: Geomorphology, v. 68, p. 149–166. doi:10.1016/ j.geomorph.2004.11.019.

Curtis, J.A., Flint, L.E., Alpers, C.N., Wright, S.A., and Snyder, N.P., 2006, Use of Sediment Rating Curves and Optical Backscatter Data to Characterize Sediment Transport in the Upper Yuba River Watershed, California, 2001–03: U.S. Geological Survey Scientific Investigations Report 2005–5246, 74 p.

CUWA and SWC. 2004. Responses to Interagency Project Work Team Comments On the Integrated Modeling Framework for Winter-Run Chinook. Prepared by S.P. Cramer & Associates, Inc. June 2004.

Delano, A. 1936. Across the Plains and Among the Diggings. Wilson-Erickson, Inc. New York.

Dendy, F.E., and Champion, W.A., 1978, Sediment Deposition in U.S. Reservoirs: Summary of Data Reported Through 1975: U.S. Department of Agriculture Miscellaneous Publication, 1362.

Dupras, Don. 1997. Mineral Land Classification of Alluvial Sand and Gravel, Crushed Stone, Volcanic Cinders, Limestone, and Diatomite within Shasta County, CA. Department of Conservation Divisions of Mines and Geology. DMG Open File Report 97-03.

Eagan, S. M. 1998 *Modeling Floods in Yosemite Valley, California Using Hydrologic Engineering Center's River Analysis System*. Master's Thesis, University of California, Davis.

East Bay Municipal Utility District (EBMUD). 2008. Mokelumne Watershed Master Plan Final Programmatic Environmental Impact Report. April 2008. Available at: http://www.ebmud.com/water_&_environment/environmental_protection/mokelumne_environment/mokelumne_master_plan/MWMP%20Final%20PEIR.pdf
East Side Investigation. Appendix C, Fish and Wildlife.

Eaton, H. A. 1941. Investigation of the Water Supply of the Los Molinos Land Company.

EBMUD. 2008a. Mokelumne Watershed Master Plan. April 2008. Available on the Internet at: http://www.ebmud.com/water_&_environment/environmental_protection/mokelumne_environment/mokelumne_master_plan/Mokelumne%20MP_Ttv3.pdf

EBMUD. 2009. Draft Program Environmental Impact Report. Water Supply Management Program 2040. State Clearinghouse No. 2008052006. February 2009.

EBMUD, USFWS, and CDFG. 2008. Lower Mokelumne River Project Joint Settlement Agreement Ten-Year Review. Partnership Steering Committee.

ECORP Consulting 2003. Dry Creek Watershed Coordinated Resource Management Plan. Available at: http://www.drycreekconservancy.org/
Accessed May 5, 2009

Ecosystem Restoration Program plan. Volume II: Ecological management zone visions. July 2000. Sacramento, CA.

Eigenmann, C. H. 1890. On the egg membranes and micropyle of some osseous fishes. *Bulletin.* 19 (2).

Federal Register. 1989. NMFS. Endangered and Threatened Species; Critical Habitat; Winter-run Chinook Salmon. Vol 54:32085-32068. August 4, 1989.

Federal Register. 1990. NMFS. Endangered and Threatened Species; Sacramento River Winter-run Chinook Salmon Final Rule. Vol 55:46515-46523. November 5, 1990.

Federal Register. 1992. NMFS. Endangered and Threatened Species: Endangered Status for Winter-Run Chinook Salmon. Vol 57:27416-27423. June 19, 1992.

Federal Register. 1992a. NMFS. Designated Critical Habitat; Sacramento River Winter-Run Chinook Salmon Proposed Rule. Vol 57:36626-36632. August 13, 1992.

Federal Register. 1993. NMFS. Designated Critical Habitat; Sacramento River Winter-Run Chinook Salmon. Vol 58:33212-33219. June 16, 1993.

Federal Register. 1994. NMFS. Endangered and Threatened Species; Status of Sacramento River Winter-run Chinook Salmon Final Rule. Vol 59:440-450. January 4, 1994.

Federal Register. 1996. NMFS. Endangered and Threatened Species: Proposed Endangered Status for Five ESUs of Steelhead and Proposed Threatened Status for Five ESUs of Steelhead in Washington, Oregon, Idaho, and California. Vol 61:41541-41561. August 1996.

Federal Register. 1998. NMFS. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Vol 63:13347-13371. March 19, 1998.

Federal Register. 1999. NMFS. Endangered and Threatened Species: Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California; Final Rule. Vol 64:50394-50415. September 16, 1999.

Federal Register. 2000. NMFS. Endangered and Threatened Species; Salmon and Steelhead; Final Rule. Vol 65:42421-42481. July 10, 2000.

Federal Register. 2002. NMFS. Endangered and Threatened Species; Final Rule Governing Take of Four Threatened Evolutionarily Significant Units (ESUs) of West Coast Salmonids. Vol 67:1116-1133. January 9, 2002.

Federal Register. 2004. NMFS. Endangered and Threatened Species: Extension of Public Comment Period and Notice of Rescheduled Public Hearing on Proposed Listing Determinations for West Coast Salmonids. Vol 69:61348-61349. October 18, 2004.

Federal Register. 2004. NMFS. Endangered and Threatened Species: Proposed Listing Determinations for 27 ESUs of West Coast Salmonids. Vol 69:33102-33179. June 14, 2004.

Federal Register. 2005. NMFS. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. Final Rule. Vol 70:37160. June 28, 2005.

Federal Register. 2006. NMFS. Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead, Final Rule. Vol 71:834-862. January 5, 2006.

FERC. 2007. Final Environmental Impact Statement, Oroville Facilities, California (FERC Project No. 2100). FERC/FEIS-0202F, Final Environmental Impact Statement for Hydropower License. May 18, 2007.

FERC. 2008. Environmental Assessment for Minor-Part Hydropower License. DeSabla-Centerville Hydroelectric Project. Federal Energy Regulatory Commission Project No. 803-087. December 2008.

Fishbio. 2008. California Tributaries – East-Side Tributaries. Calaveras River Report. URL = http://www.fishbio.com/fisheries-biology-research/fisheries-biology-california-tributaries.html.

Fisher, F. W. 1994. Past and Present Status of Central Valley Chinook Salmon. Conservation Biology Volume 8: 870-873.

Fishery Foundation of California (FFC). 2004. Lower Calaveras River Chinook salmon and steelhead limiting factors analysis. First Year Report. Fair Oaks, CA. In preparation.

Fry D. H. and E. P. Hughes. 1951. The California salmon troll fishery. Pacific Marine Fisheries Commission. Bulletin.

Fry, D. H. 1961. King Salmon Spawning Stocks of the California Central Valley, 1940-1959. Calif. Fish and Game Volume 47: 55-71.

Fukushima, M., T. P. Quinn, and W. W. Smoker. 1998. Estimation of Eggs Lost from Superimposed Pink Salmon (*Oncorhynchus gorbuscha*) Redds. Canadian Journal of Fisheries and Aquatic Science Volume 55: 618-625.

FWUA and NRDC (Friant Water Users Authority and Natural Resources Defense Council). 2002. San Joaquin River Restoration Study Background Report.

Gerstung, E. 1971. Fish and Wildlife Resources of the American River to be affected by the Auburn Dam and Reservoir and the Folsom South Canal, and measures proposed to maintain these resources. California Department of Fish and Game.

Glenn County Resource Conservation District. 2009. Lower Stony Creek Restoration Plan. January 12, 2009. Also available online at: http://www.glenncountyrcd.org/nodes/educationoutreach/documents/DWR_Report_30_draftPlan.pdf
Accessed April 30, 2009

Good, T. P., R. S. Waples, and P. Adams. 2005. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. U.S. Dept. of Commerce, NOAA Technical Memorandum NMFS-NWFSC-66, 598 p.

Graham Matthews & Associates (GMS). 2006. 2006 Update to the Clear Creek Gravel Management Plan. Report submitted to Western Shasta Resource Conservation District and Clear Creek Restoration Team.

Groot, C. and L. Margolis.' (ed.). 1991. Pacific Salmon Life Histories. ~: ~.

Gutierrez, R. A., R. J. Orsi. 1998. Contested Eden: California before the gold rush. University of California Press. Berkeley, California.

H.T. Harvey & Associates. 2007a. Stony Creek Watershed Assessment, Volume 2. Existing Conditions Report. Prepared for Glenn County Resource Conservation District. Available online at: http://www.glenncountyrcd.org/nodes/educationoutreach/LowerStonyCreekWatershed.htm (Accessed April 30, 2009)

H.T. Harvey & Associates. 2007b. Stony Creek Watershed Assessment, Volume 1. Lower Stony Creek Watershed Analysis. Prepared for Glenn County Resource Conservation District. Available online at: http://www.glenncountyrcd.org/nodes/educationoutreach/LowerStonyCreekWatershed.htm (Accessed April 30, 2009)

Hallock, R. J. 1989. Upper Sacramento River steelhead (*Oncorhynchus mykiss*) 1952-1988. Prepared for the U.S Fish and Wildlife Service. California Department of Fish and Game, Sacramento

Hallock, R. J. and D. H. Fry 1967. Five species of salmon, *Oncorhynchus*, in the Sacramento River. Red Bluff - California Department of Fish Game 53:5-22.

Hallock, R. J., D. H. Fry, Jr., and D. A. LaFaunce. 1957. The Use of Fyke Traps to Estimate the Runs of Adult Salmon and Steelhead in the Sacramento River. California Fish and Game Volume 43: 271-298.

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 No. 114. Sacramento, CA: Department of Fish and Game.

Hannon, J. and B. Deason. 2008. American River Steelhead Spawning 2001 – 2007. U.S. Bureau of Reclamation, Central Valley Project, American River, California Mid-Pacific Region.

Hannon, J., Healey, M., and Deason, B. 2003. American River Steelhead Spawning 2001 – 2003. U.S. Bureau of Reclamation, Central Valley Project, American River, California Mid-Pacific Region.

Hanson, H.A., O.R. Smith and P.R. Needham. 1940. An investigation of fish-salvage problems in relation to Shasta Dam. U.S. Fish and Wildlife Service. Special Scientific Report No. 10.

Harvey-Arrison, C. 2008. Summary of Mill and Deer Creek Juvenile Salmonid Emigration Monitoring from October 2007 thru June 2008. Memorandum. California Department of Fish and Game, Northern Region. September 3, 2008.

Hayes, J.M. 1965. Water temperature observations on some Sacramento River tributaries 1961-1964. California Department of Fish and Game. Water Projects Administrative Report No. 65-1.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*) *in* Pacific Salmon Life Histories. Groot, C. and Margolis, L. (ed.), Vancouver B.C.: UBC Press, pp 311-393.

Healey, T. P. 1979. The Effect of High Temperature on the Survival of Sacramento River Chinook (King) Salmon, *Oncorhynchus tshawytscha*, Eggs and Fry. California Department of Fish and Game, Anadromous Fisheries Branch Administrative Report No. 79-10.

Hedgecock, D., M. A. Banks, V. K. Rashbrook, C. A. Dean, and S. M. Blankenship. 2001. Applications of Population Genetics to Conservation of Chinook Salmon Diversity in the Central Valley *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 45-70.

Hilborn, R. 1992. Hatcheries and the Future of Salmon in the Northwest. Fisheries Volume 17: 5-8.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic Effects of Cultured Fish on Natural Populations. Canadian Journal of Fisheries and Aquatic Science Volume 48: 945-957.

Huber, N. K. 1989 *The Geologic Story of Yosemite National Park*. Yosemite: Yosemite Association.

Janda, R. J. 1965. *Pleistocene history and hydrology of the upper San Joaquin River, California*, Ph.D. Dissertation, University of California, Berkeley.

Jones & Stokes Associates, Inc. 1999. City of Lincoln Wastewater Treatment and Reclamation Facility Draft Environmental Impact Report. SCN #98122071.

Jones & Stokes Associates, Inc. 2002. Foundation Runs Report for Restoration Action Gaming Trials. Prepared for Friant Water Users Authority and Natural Resources Defense Council

JSA. 2004. Bear River and Western Pacific Interceptor Canal Levee Improvements Project Environmental Impact Report. Draft. Prepared by Jones & Stokes Associates. Prepared for Three Rivers Levee Improvement Authority. Sacramento, CA. State Clearinghouse No. 2004032118.

Kastner, A. 2003. Feather River Hatchery- Draft Annual Report 2002-2003. Wildlife and Inland Fisheries Division Administrative Report. California Department of Fish and Game.

KDH Environmental Services. 2008. Lover's Leap Restoration Project. Salmon Habitat Restoration in the Lower Stanislaus River. Final Report. July 16, 2008.

Killam, D. 2009. California Department of Fish and Game. Personal Communication.

Killam, D. and Johnson, M. 2008. The 2007 Mill Creek Video Station Steelhead and Spring-Run Chinook Salmon Counts. SRSSAP Technical Report No. 08-1. California Department of Fish and Game: Northern Region Sacramento River Salmon and Steelhead Assessment Project.

Kimmerer, W., and J. Carpenter. 1989. Desabla-Centerville Project (FERC 803) Butte Creek Interim Temperature Modeling Study. BioSystems Analysis, Inc., Tiburon, CA. Report J-271, prepared for Pacific Gas and Electric Co. 35 pages plus appendices.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1981. The Life History of Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary of California. Estuaries Volume 4: 285.

Knowles, N., M. Dettinger, and D. Cayan. 2006. Trends in Snowfall Versus Rainfall in the Western United States. Journal of Climate Volume 19: 4545-4559.

Kondolf, M.G., Cada, G.F., Sale, M.J., and Felando, T. 2001. Distribution and Stability of Potential Salmonid Spawning Gravels in Steep Boulder-Bed Streams of the Eastern Sierra Nevada. Transaction of the American Fisheries Society 120:177-186.

Leary, R. F., F. W. Allendorf, and G. K. Sage. 1995. Hybridization and Introgression Between Introduced and Native Fish. American Fisheries Society Symposium Volume 15: 91-101.

Lindley, S. T., R. S. Schick, A. Agrawal, M. Goslin, T. E. Pearson, E. Mora, J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical Population Structure of Central Valley Steelhead and its Alteration by Dams. San Francisco Estuary and Watershed Science 4(1)(3):1-19. February 2006. http://repositories.cdlib.org/jmie/sfews/vol4/iss1/art3

Lindley, S. T., Schick, R., May, B.P., Anderson, J.J., Greene, S., Hanson, C., Low, A., McEwan, D., MacFarlane, R.B., Swanson, C., and Williams, J.G. 2004. Population Structure of Threatened and Endangered Chinook Salmon ESUs in California's Central Valley Basin. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-360. April 2004.

Lindley, S.T., R.S. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary & Watershed Science Volume 5, Issue 1. Article 4: California Bay-Delta Authority Science Program and the John Muir Institute of the Environment.

Lower Putah Creek Coordinating Committee. 2005. Lower Putah Creek Watershed Management Action Plan, Phase 1. Resource Assessments. December 2005. Available online at: http://lpccc.watershedportal.net/Lower_Putah_WMAP_Vol_I_12-05.pdf Accessed April 30, 2009

Lufkin, A. (ed.). 1996. California's Salmon and Steelhead, The Struggle to Restore an Imperiled Resource. Berkeley: University of California Press.

MacFarlane, R. B. and E. C. Norton. 2002. Physiological Ecology of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) at the Southern End of Their Distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fisheries Bulletin Volume 100: 244-257.

Marsh, G.D. 2006. Historical Presence of Chinook Salmon and Steelhead in the Calaveras River. Prepared for the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program. Available at: http://www.delta.dfg.ca.gov/crfg/docs/Historic_Cala_River_Final_Report_June_06.pdf Accessed May 10, 2009

Marsh, G.D. 2007. Historic and Present Distribution of Chinook Salmon and Steelhead in the Calaveras River. San Francisco Estuary and Watershed Science. Volume 5, Issue 3, Article 3. July 2007.

Martin, C. D., P. D. Gaines, and R. R. Johnson. 2001. Estimating the Abundance of Sacramento River Juvenile Winter Chinook Salmon With Comparisons to Adult Escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. Red Bluff, CA: U.S. Fish and Wildlife Service.

Maslin, P., J. Kindopp, and M. Lennox. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon *(Oncorhynchus tshawytscha): 1998 Update*. California State University, Chico, February 28 1998. Available from: http://www.csuchico.edu/~pmaslin/rsrch/Salmon98/abstrct.html.

Maslin, P., J. Kindopp, M. Lennox, and C. Storm. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon *(Oncorhynchus tshawytscha): 1999 Update*. California State University, Chico, December 23 1999. Available from: http://www.csuchico.edu/~pmaslin/rsrch/Salmon99/abstrct.html.

Maslin, P., J. W. McKinney, and T. Moore. 1995. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon. California State University, Chico. Available on the Internet at: http://www.csuchico.edu/~pmaslin/rsrch/Salmon/Abstrt.html

Maslin, P., M. Lennox, J. Kindopp, and W. McKinney. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon *(Oncorhynchus tshawytscha): 1997 Update*. California State University, Chico, August 10 1997. Available from: http://www.csuchico.edu/~pmaslin/rsrch/Salmon97/Abstrct.html.

McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids - Issue Paper 5. Report No. EPA-910-D-01-005. United States Environmental Protection Agency.

McElhany, P., Backman, T., Busack, C., Heppell, S., Kiolmes, S., Maule, A., Myers, J., Rawding, D., Shively, D., Steel, A., Steward, C., and Whitesel, T. 2003. Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids. National Marine Fisheries Service. Seattle, WA.

McElhany, P., Ruckelshaus, M.H., Ford, M.J., Wainwright, T.C., and Bjorkstedt, E.P. 2000. Viable Salmonid Populations and the Conservation of Evolutionarily Significant Units. U.S. Department of Commerce. NOAA Technical Memorandum. NMFS-NWFSC-42. Seattle, WA.

McEwan, D. 2001. Central Valley steelhead, *In* Contributions to the biology of Central Valley salmonids, R. L. Brown, editor, CDFG, Sacramento, CA, *Fish Bulletin,* Vol. 179, pp. 1-44.

McEwan, D.R. and T. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game, February 1996. 234 p.

McEwan, D. and T. A. Jackson. 1996a. Steelhead Restoration and Management Plan for California. California Department of Fish and Game, Inland Fisheries Division. Sacramento, CA.

McEwan, D. and J. Nelson. 1991. Steelhead Restoration Plan for the American River. Calif. Dept. of Fish and Game. 40 pp.

McReynolds, T. R., C. E. Garman, P. D. Ward, and M. C. Schommer. 2005. Butte and Big Chico Creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha* life history investigation, 2003-2004. California Department of Fish and Game, Inland Fisheries Administrative Report No. 2005-1.

Meehan, W.R., editor. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Spec. Publ. 19.

Metropolitan Water District. 2005. Potential for Re-Establishing a Spring-Run Chinook Salmon Population in the Lower Feather River. Prepared by Surface Water Resources, Inc. June 2005.

Mills, T.J. and P.D. Ward. 1996. Status of Actions to Restore Central Valley Spring-run Chinook Salmon. A Special Report to the Fish and Game Commission. California Department of Fish and Game, Inland Fisheries Division.

Moffett, J. A. 1949. The First Four Years of King Salmon Maintenance Below Shasta Dam, Sacramento River, California. California Fish and Game Volume 35.

Moore, T.L. 2001. Steelhead Survey Report for Antelope, Deer, Beegum, and Mill Creeks, 2001.

Moulton, L. E. 1969. The Vina District, Tehama County, California: Evolution of Land Utilization in a Small Segment of the Middle Sacramento Valley. Thesis, California University Chico, Chico, CA.

Moyle, P. B. 2002. Inland Fishes of California. Berkeley, CA: University of California Press.

Moyle, P.B. and J.J. Cech. 1988. Fishes, an Introduction to Ichthyology. Prentice Hall, Englewood Cliffs, NJ. 559.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status Review of Chinook Salmon From Washington, Idaho, Oregon, and California. Report No. NMFS-NWFSC-35. NOAA Tech. Memo. U.S. Department of Commerce.

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

National Marine Fisheries Service (NMFS). *Date Unknown.* Central Valley Chinook Salmon Current Stream Habitat Distribution Table. Available online at: http://swr.nmfs.noaa.gov/hcd/dist2.htm Accessed May 4, 2009

National Marine Fisheries Service (NMFS). 1993. Biological Opinion: Sacramento River Winter-Run Chinook Salmon.

National Marine Fisheries Service (NMFS). 1996. Factors For Steelhead Decline: A Supplement to the Notice of Determination for West Coast Steelhead Under the Endangered Species Act.

National Marine Fisheries Service (NMFS). 1996a. Recommendations for the Recovery of the Sacramento River Winter-Run Chinook Salmon. Prepared by the Sacramento River Winter-run Chinook Salmon Recovery Team under the direction of National Marine Fishery Service, Southwest Region.

National Marine Fisheries Service (NMFS). 1996b. Status Review of West Coast Steelhead From Washington, Idaho, Oregon, and California. Technical Memorandumn - NOAA Fisheries-NWFSC-27.

National Marine Fisheries Service (NMFS). 1997. Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon. Long Beach, CA: National Marine Fisheries Service, Southwest Region.

National Marine Fisheries Service (NMFS). 1998. Factors Contributing to the Decline of Chinook Salmon: An Addendum to the 1996 West Coast Steelhead Factors for Decline Report. Portland, Oregon: Protected Resources Division, National Marine Fisheries Service.

National Marine Fisheries Service (NMFS). 1998b. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-35.

National Marine Fisheries Service (NMFS). 1999. Recovery Planning for West Coast Salmon.

National Marine Fisheries Service (NMFS). 2003. Preliminary Conclusions Regarding the Updated Status of Listed ESUs of West Coast Salmon and Steelhead. West Coast Salmon Biological Review Team. Steelhead. Co-manager Review Draft. Primary contributors: Thomas P. Good and Robin S. Waples. Available on the Internet at: http://www.nwfsc.noaa.gov/trt/brt/steelhead.pdf

National Marine Fisheries Service (NMFS). 2004. Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan. Prepared by National Marine Fisheries Service, Southwest Region.

National Marine Fisheries Service (NMFS). 2006b. Interim Endangered and Threatened Species Recovery Planning Guidance. Available at: http://www.nmfs.noaa.gov/pr/pdfs/recovery/guidance.pdf

National Marine Fisheries Service. 2006a. Protected Resources Strategic Plan.

National Marine Fisheries Service (NMFS). 2007a. Biological Opinion on the Operation of Englebright and Daguerre Point Dams on the Yuba River, California, for a 1-Year Period. National Marine Fisheries Service, Southwest Region.

National Marine Fisheries Service (NMFS). 2007b. Central Valley Steelhead Recovery Breakout Group Notes. Notes from Central Valley Steelhead Recovery Workshop, May 21, 2007.

National Marine Fisheries Service (NMFS). 2007c. 2007 Federal Recovery Outline for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. National Marine Fisheries Service, Southwest Region. Sacramento, CA.

National Marine Fisheries Service (NMFS). 2007d. Monitoring and Research Needed to Manage the Recovery of Threatened and Endangered Chinook and Steelhead in the Sacramento-San Joaquin Basin. Prepared by J.G. Williams, J.J. Anderson, S. Greene, C. Hanson, S.T. Lindley, A. Low, B.P. May, D. McEwan, M.S. Mohr, R. B MacFarlane, C. Swanson. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFSC-399.

National Marine Fisheries Service (NMFS). 2007e. Summary of Threats and Recovery Actions for Spring-Run and Winter-Run Chinook Salmon. Notes from Sacramento Salmon and Steelhead Recovery Workshop, May 22, 2007.

National Marine Fisheries Service (NMFS). 2009. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. National Marine Fisheries Service, Southwest Region. June 4, 2009.

National Marine Fisheries Service (NMFS). 2009b. Letter from Rodney R. McInnis (NMFS), to Donald Glaser (U.S. Bureau of Reclamation), transmitting: (1) Biological and conference opinion on the long-term operations of the Central Valley Project and State Water Project, plus 5 appendices; and (2) Essential Fish Habitat Conservation Recommendations. NMFS, Southwest Region, Long Beach, California. June 4.

National Marine Fisheries Service Website. 2005. Central Valley Chinook Salmon Historic Stream Habitat Distribution Table. Available at http://swr.nmfs.noaa.gov. Accessed on April 13, 2005.

National Park Service. circa 1998. The mountain reawakens: pamphlet describing the geology of Lassen Volcanic National Monument.

National Park Service. 2005. Merced Wild and Scenic River Revised Comprehensive Management Plan and Supplemental Environmental Impact Statement. Available at: http://www.nps.gov/archive/yose/planning/mrp/
Accessed May 8, 2009

Needham, P.R., and H.A. Hanson, and L.P. Parker. 1943. Supplementary report on investigations of fish-salvage problems in relation to Shasta Dam. U.S. Fish and Wildlife Service. Special Scientific Report No. 26.

Newton, J.M., Stafford, L.A., and Brown, M.R. 2008. Monitoring Adult Chinook Salmon Rainbow Trout and Steelhead in Battle Creek, California, from March through November 2007. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office. Red Bluff, California.

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

Nobriga, M. P. 2001. differences Among Hatchery and Wild Steelhead: Evidence of Delta Fish Monitoring Programs. Interagency Ecological Program for the San Francisco Estuary Newsletter. 14:2:30:38.

Nobriga, M., and P. Cadrett. 2003. Differences among hatchery and wild steelhead: evidence from Delta fish monitoring programs. Interagency Ecological Program for the San Francisco Estuary Newsletter 14:3:30-38.

North Fork Associates. 2003. Recognized Aquatic and Wetland Resources in Western Placer County, California. Prepared for Placer County Planning Department. Auburn, California. Available at: http://www.placer.ca.gov/Departments/CommunityDevelopment/Planning/PCCP/BackgroundData/~/media/cdr/Planning/PCCP/BioStudies/aquaticresourcesinwplacer%20pdf.ashx
Accessed May 4, 2009

Painter, R. E., L. H. Wixom, and S. N. Taylor. 1977. An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River.

PCWA and Reclamation. 2002. American River Pump Station Project Final Environmental Impact Statement/Environmental Impact Report. State Clearinghouse Number 1999062089. Placer County Water Agency and U.S. Bureau of Reclamation.

Pearcy, W. G. 1997. Salmon Production in Changing Ocean Regimes. In Pacific Salmon and Their Ecosystems, Status and Future Options Stouder, D. J., Bisson, P. A., and Nuiman, R. J. (ed.), Chapman and Hall, New York, NY

Peninou, E. P. 1991. Leland Stanfords Great Vina Ranch 1881-1919. Yolo Hills Viticultural Society, San Francisco.

PG&E. 2005. DeSabla-Centerville Project FERC No. 803 Biological Assessment: Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*).

Plumas County Flood Control and Water Conservation District. 2004. Feather River Watershed Management Strategy for Implementing the Monterey Settlement Agreement. Available at: http://www.des.water.ca.gov/mitigation_restoration_branch/rpmi_section/projects/docs/FeatherRiverStrategy.pdf
Accessed May 7, 2009

Read, G. W & R. Gaines, eds. 1944. Gold Rush: The Journals, Drawings, and Other Papers of J. Goldsborough Bruff. 2 vol. New York: Columbia University Press.

Reclamation. 1992. Biological Assessment for USBR Long-Term Central Valley Project Operations Criteria and Plan (OCAP).

Reclamation. 1996. American River Water Resources Investigation Planning Report and Draft Environmental Impact Statement Report/Environmental Impact Statement Appendices Volume 1.

Reclamation. 2001. Supplemental Environmental Impact Statement and Environmental Impact Report Acquisition of Additional Water for Meeting the San Joaquin River Agreement Flow Objectives, 2001-2010. Prepared by URS. March 13, 2001.

Reclamation. 2003. Shasta Lake Water Resources Investigation, Ecosystem Restoration Opportunities Office Report. November 2003. Available on the Internet at: http://www.usbr.gov/mp/slwri/docs/office_rpt_ecosystems/05_chap2.pdf

Reclamation. 2008. Biological Assessment on the Continued Long-Term Operations of the Central Valley Project and the State Water Project. Available at: http://bdcpeireis.com/section.do?action=display&file=5116.

Reclamation. 2008. Operations Criteria and Plan Biological Assessment. August 2008.

Reclamation, PG&E, NMFS, USFWS, and CDFG. 2004. Draft Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan. Prepared by Terraqua, Inc. April 2004.

Rectenwald, H. 1998. Draft Antelope Creek Report. California Department of Fish and Game.

Redding, J. M. and C. B. Schreck. 1979. Possible Adaptive Significance of Certain Enzyme Polymorphisms in Steelhead Trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 36:544-551.

Reiser, D. W., C. M. Huang, S. Beck, M. Gagner, and E. Jeanes. 2006. Defining Flow Windows for Upstream Passage of Adult Anadromous Salmonids at Cascades and Falls. Transactions of the American Fisheries Society Volume 135: 668-679.

Resource management International, Inc. (RMI). 1987. Environmental Impact Report for the XTRA Power Gravel Extraction Project Cottonwood Creek. Prepared for the Tehama County Planning Department.

Reynolds, F. L., T. Mills, R. Benthin, and A. Low. 1993. Central Valley Anadromous Fisheries and Associated Riparian and Wetlands Areas Protection and Restoration Action Plan Draft.

Reynolds, F.L., Mills, T.J., Benthin, R., and Low, A. 1993. Restoring Central Valley Streams: A Plan for Action. California Department of Fish and Game, Inland Fisheries Division. Sacramento, California.

Rich, A. A. 1987. Water Temperatures Which Optimize Growth and Survival of the Anadromous Fishery Resources of the Lower American River.

Rombough, P. J. 1988. Growth, Aerobic Metabolism, and Dissolved Oxygen Requirements of Embryos and Alevins of Steelhead, Salmo gairdneri. Canadian Journal of Zoology 66:651-660.

Ruckelshaus, M., K. Currens, R. Fuerstenberg, W. Graeber, K. Rawson, N. Sands, and J. Scott. 2002. Planning Ranges and Preliminary Guidelines for the Delisting and Recovery of the Puget Sound Chinook salmon evolutionarily significant unit. U.S. Dept. Commer. NOAA Tech. Memo.

Rutter, C. 1904. Notes on fishes from the Gulf of California, with the description of a new genus and species. San Francisco: The Academy.

Rutter, C. 1904. The fishes of the Sacramento-San Joaquin Basin, with a study of their distribution and variation. Bill of U.S. Bureau of Fisheries. 27:103-152.

Rutter, C. 1908. The fishes of the Sacramento-San Joaquin basin, With a study of their distribution and variation. Washington: Government Print. Off.

Sacramento Watersheds Action Group (SWAG). 2004. Sulphur Creek Watershed Analysis. Available on the Internet at: http://www.watershedrestoration.org/projects/proj_watershed_analysis.html

San Francisco Bay RWQCB. 2006. Water Quality Control Plan for the San Francisco Bay Basin. December 2006. Available at: http://www.waterboards.ca.gov.

SARSAS (Save Auburn Ravine Salmon and Steelhead) 2009. Blog/Media. April 1, 2009 – Update. Available at: http://www.sarsas.org/Blog_Media.html

Schaffter, R. 1980. Fish Occurrence, Size, and Distribution in the Sacramento River Near Hood, California During 1973 and 1974. California Department of Fish and Game.

Seesholtz, A., B. Cavallo, J. Kindopp, R. Kurth, and M. Perrone. 2003. Lower Feather River Juvenile Communities: Distribution, Emigration Patterns, and Association With Environmental Variables. *In* Early Life History of Fishes in the San Francisco Estuary and Watershed: Symposium and Proceedings Volume American Fisheries Society, Larval Fish Conference, August 20-23, 2003, Santa Cruz, California.

Shapovalov, L. 1946. Report on fisheries resources in connection with the proposed Solano Project of the United States Bureau of Reclamation. Bureau of Fisheries Conservation, California Division of

Fish and Game. As Cited in: USFWS. 1993. Reconnaissance planning report: fish and wildlife resource management options for Lower Putah Creek, California. 128 pp. Sacramento, CA.

Shapovalov, L. and A. C. Taft. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*). Fish Bulletin No. 98. State of California Department of Fish and Game.

SHN. 2001. Cow Creek Watershed Assessment. Prepared for Western Shasta Resource Conservation District and Cow Creek Management Group.

Sierra Business Council. 2003. Streams of Western Placer County: Aquatic Habitat and Biological Resources Literature Review.

SJRRP. 2009. Draft Fisheries Management Plan: A Framework for Adaptive Management in the San Joaquin River Restoration Program. San Joaquin River Restoration Program. June 2009.

Skinner, John E. 1962. An historical review of the fish and wildlife resources of the San Francisco Bay area. California Department of Fish and Game, Water Projects Branch Report no. 1. Sacramento, California: California Department of Fish and Game. 226 p.

Snider, B. and R. G. Titus. 2000a. Timing, Composition, and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River Near Knights Landing October 1996 - September 1997.

Snider, B. and R. G. Titus. 2000b. Timing, Composition and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River Near Knights Landing October 1998 - September 1999.

Snider, B. and R. G. Titus. 2000c. Lower American River Emigration Survey October 1996 - September 1997. Stream Evaluation Program Technical Report No. 00-2. California Department of Fish and Game.

Snider, B., B. Reavis, and S. Hill. 2001. Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey May-August 2000. Stream Evaluation Program Technical Report No. 01-1.

Snyder, N.P., Allen, J.R., Dare, C. Hampton, M.A., Schneider, G., Wooley, R.J., Alpers, C.N., and Marvin-DiPasquale, M.C., 2004a, Sediment Grain-size and Loss-on-ignition Analyses from 2002 Englebright Lake Coring and Sampling campaigns: U.S. Geological Survey Open-File Report 2004-1080 (http://pubs.usgs.gov/of/2004/1080/).

Snyder, N.P., Alpers, C.N., Flint, L.E., Curtis, J.A., Hampton, M.A., Haskell, B.J., and Nielson, D.L., 2004b, Report on the May–June 2002 Englebright Lake deep coring campaign: U.S. Geological Survey Open-File Report 2004-1061 (http://pubs.usgs.gov/of/2004/1061/).

Snyder, N.P., Rubin, D.M., Alpers, C.N., Childs, J.R., Curtis, J.A., Flint, L.E., Wright, S.A., 2004c, Estimating Rates and Physical Properties of Sediment Behind a Dam: Englebright Lake, Yuba River, Northern California: Water Resources Research v. 40, p. W11301, doi:10.1029/2004WR003279.

Sommer, T., B. Harrell, M. Nobiga, R. Brown, W. Kimmerer, and L. Schemel. 2001a. California's Yolo Bypass: Evidence That Flood Control Can Be Compatible With Fisheries, Wetlands, Wildlife, and Agriculture. Fisheries 26:(8) 6-16.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001b. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. Canadian Journal of Fisheries and Aquatic Science Volume 58: 325-333.

South Yuba River Citizens League (SYRCL). 2009. About the Yuba website. Available on the Internet at: http://www.syrcl.org/river/river-facts.asp

S.P. Cramer & Associates. Inc. 1995. The Status of Steelhead Populations in California in Regards to the Endangered Species Act. Report Submitted to the National Marine Fisheries Service on Behalf of the Association of California Water Agencies. Gresham, OP: S.P. Cramer & Associates, Inc.

S.P. Cramer & Associates, Inc. 2000. Stanislaus River data report. Oakdale, California

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. The Man Tech Report No. TR-4501-96-6057. December 1996. Corvallis, OR: ManTech Environmental Research Services Corp. Available at: http://bdcpeireis.com/section.do?action=display&file=3759.

SRFG (Stanislaus River Fish Group), Carl Mesick Consultants, S.P. Cramer and Associates, Inc., and the California Rivers Restoration Fund. 2003. A Plan to Restore Anadromous Fish Habitat in the Lower Stanislaus River. Review Draft.

Staley, J.R. 1976. American River steelhead (*Salmo gairdnerii gairdnerii*) management, 1956-1974. (Administrative Report No. 76-2.) California Department of Fish and Game.

Stillwater Sciences. 2001. Merced River Corridor Restoration Plan Baseline Studies. Volume II: Geomorphic and Riparian Vegetation Investigations Report. April 18, 2001.

Swanson, M.L. and G.M. Kondolf. 1991. Geomorphic Study of Bed Degradation in Stony Creek, Glenn County, California. Prepared for California Department of Transportation, Division of Structures, 15 May 1991.

SWRCB. 2003. Revised Water Right Decision 1644 in the Matter of Fishery Resources and Water Right Issues of the Lower Yuba River.

SWRCB. 2008. Stillwater-Churn Creek Watershed Action Plan. Prepared by the Stillwater-Churn Creek Watershed Alliance, Stillwater-Churn Creek Technical Advisory Committee, and the Western Shasta Resource Conservation District. Funded by the SWRCB.

SWRCB. 2009. State Water Resources Control Board. Site accessed July 2009. URL = http://www.swrcb.ca.gov.

SWRI. 2001. Aquatic Resources of the Lower American River: Baseline Report Draft. Prepared for Lower American River Fisheries And Instream Habitat (FISH) Working Group. Prepared by Surface Water Resources, Inc. February 2001. Available in March 2001.

SWRI. 2002. Implementation Plan for Lower Yuba River: Anadromous Fish Habitat Restoration (Draft - Unpublished Report).

SWRI, JSA, and I. BE. 2000. Hearing Exhibit S-YCWA-19. Expert Testimony on Yuba River Fisheries Issues.

Taylor, E. B. 1991. A Review of Local Adaptation in Salmonidae, with Particular Reference to Pacific and Atlantic Salmon. Aquaculture Volume 98: 185-207.

Tehema County Resource Conservation District (TCRCD). 2006. Tehama West Watershed Assessment – Final Draft. Tehama County Resource Conservation District. April 2006. URL = http://www.tehamacountyrcd.org/ixwa.htm (Accessed May 4, 2009).

Tehama County Resource Conservation District (TCRCD). 2008. Tehama East Community Wildfire Protection Plan And Risk Assessment With Recommendations for Fire And Pre-Fire Fuels Treatment Opportunities. Report to the California Fire-Safe Council, Tehama County Resource Advisory Committee, Lassen National Forest, Bureau of Land Management, Tehama-Glenn Fire Safe Council, and Manton Fire Safe Council.

Tehama County. 2008. Draft Environmental Impact Report for the Tehama County 2008-2028 General Plan. Prepared by PMC. State Clearinghouse Number 2007072062. September 2008.

The Calaveras River Watershed Stewardship Group. 2007. Website. Available at: http://www.calaverasriver.com/
Accessed May 11, 2009

The Trust for Public Land. 2009. Central Valley Basin. Mokelumne River. Available on the Internet at: http://www.tpl.org/tier3_cdl.cfm?content_item_id=9460&folder_id=1685
Thesis. College of Civil Engineering, University of California.

Thompson, K. 1972. Determining Stream Flows for Fish Life *in* Pacific Northwest River Basins Commission Instream Flow Requirement Workshop, March 15-16, 1972.

TID/MID. 2005. Ten Year Summary Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. Volume 1. Turlock Irrigation District and Modesto Irrigation District. March 2005.

TID/MID. 2009. FERC Project No. 2299: 2008 Annual Summary Report. March 2009.

TPL (The Trust for Public Land). 2009. Central Valley Basin. Calaveras River. Available at: http://www.tpl.org/tier3_cdl.cfm?content_item_id=9460&folder_id=1685
Accessed May 11, 2009

Tuolumne River Preservation Trust. 2002. Proposal Titled, Tuolumne River - La Grange Floodplain Restoration.

U.S. Army Corps of Engineers (USACE). 1971. Flood Plain Information – Cow Creek, Palo Cedro, California. Prepared for Shasta County by Sacramento District. Sacramento, California. June 1971. Available online at: http://www.sacriver.org/documents/watershed/cowcreek/erosion/CowCreek_FloodPlain_Information_ACOE_Jun71.pdf
Accessed May 8, 2009

U.S. Army Corps of Engineers (USACE). 1999. Sacramento and San Joaquin River Basins, California. Post-Flood Assessment, Sacramento, CA, 150 p.

U.S. Army Corps of Engineers (USACE)and Reclamation Board. 1999b. Sacramento and San Joaquin River Basins Comprehensive Study Interim Report.

U.S. Department of Agriculture (USDA). 1901. Report on Irrigation Investigations in California. Bulletin No. 100. Government Printing Office.

U.S. Department of Agriculture (USDA), Forest Service. 1995. Watershed Analysis Report, Grindstone Creek Watershed Analysis Area.

U.S. Department of Interior, Bureau of Reclamation (USBR). 1998. Lower Stony Creek Fish, Wildlife and Water Use Management Plan. U.S. Bureau of Reclamation, Northern California Area Office, Mid-Pacific Region.

U.S. Fish and Wildlife Service (USFWS). 1984. Evaluation report of the potential impacts of the proposed Lake Red Bluff water power project on the fishery resources of the Sacramento River. U. S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, California. 89 pp (plus appendices).

U.S. Fish and Wildlife Service (USFWS). 1993. Memorandum from W. S. White to David Lewis, Regional Director, Bureau of Reclamation, Sacramento, California. USBR - Stanislaus River Basin Calaveras River Conjunctive Use Water Program Study; a preliminary evaluation of fish and wildlife impacts with emphasis on water needs of the Calaveras River. January 28, 1993. Sacramento Field Office, Sacramento, California.

U.S. Fish and Wildlife Service (USFWS). 1995. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Volume 2. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

U.S. Fish and Wildlife Service (USFWS). 1998. Central Valley Project Improvement Act Tributary Production Enhancement Report. U.S. Fish and Wildlife Service. Central Valley Fish and Wildlife Restoration Program Office. Sacramento, CA.

U.S. Fish and Wildlife Service (USFWS). 1999. Draft Programmatic Environmental Assessment Anadromous Fish Restoration Actions in Lower Deer Creek Tehama County, California.

U.S. Fish and Wildlife Service (USFWS). 2000. Final Report - Preliminary Water Quality Assessment of Cow Creek Tributaries. A reported submitted by Morgan J. Hannaford and North State Institute

for Sustainable Communities to USFWS. Available online at: http://www.sacriver.org/documents/watershed/cowcreek/general/cowcrkrpt.pdf

U.S. Fish and Wildlife Service (USFWS). 2001. Final Restoration Plan for the Anadromous Fish Restoration Program: A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California. Prepared for the Secretary of the Interior by the U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service (USFWS). 2003. Draft Plan of Actions to Restore Salmon and Steelhead Populations in the Lower Calaveras River. Prepared by The Fishery Foundation of California. Stockton, California. September 2003.

U.S. Fish and Wildlife Service (USFWS). 2003. Flow-Habitat Relationships for Spring-run Chinook Salmon Spawning in Butte Creek. U.S. Fish and Wildlife Service, SFWO, Energy Planning and Instream Flow Branch, Butte Creek 2-D Modeling Final Report. August 29, 2003. 86pp.

U.S. Fish and Wildlife Service (USFWS). 2007. Central Valley steelhead and late fall-run Chinook salmon redd surveys on Clear Creek, California. Prepared by Sarah Giovannetti and Matt Brown, Red Bluff, California.

U.S. Fish and Wildlife Service (USFWS). 2007b. Using Rotary Screw Traps to Determine Juvenile Chinook Salmon Out-Migration Abundance, Size and Timing in the Lower Merced River, California 2007. Annual Data Report. Anadromous Fish Restoration Program Grant No. 813326G009. Prepared by Cramer and Associates.

U.S. Fish and Wildlife Service (USFWS). 2008a. Steelhead and Late-Fall Chinook Salmon Redd Surveys on Clear Creek, California. 2008 Annual Report. Red Bluff Fish and Wildlife Office. Red Bluff, California. December 2008.

U.S. Fish and Wildlife Service (USFWS). 2008b. Anadromous Fish Restoration Program, Mokelumne River Watershed Information. November 2008.

U.S. Fish and Wildlife Service (USFWS). 2008c. Anadromous Fish Restoration Program, Stanislaus River Watershed Information. Site accessed June 17, 2009. URL = http://www.fws.gov/stockton/afrp/ws_stats.cfm?code=STANR.

U.S. Fish and Wildlife Service (USFWS). 2008d. Anadromous Fish Restoration Program, Tuolumne River Watershed Information. Site accessed June 17, 2009. URL = http://www.fws.gov/stockton/afrp/ws_stats.asp?code=TUOLR.

U.S. Forest Service (USFS). 1997. Beegum Watershed Analysis. Yolla Bolla Ranger District South Fork Management Unit, Shasta-Trinity National Forest.

U.S. Geologic Survey (USGS). 1956. Manton Quadrangle Map.

U.S. Geologic Survey (USGS). 1995. Water Resources Data California: Water Year 1994. USGS Water-Data Report CA-94-4

U.S. Geologic Survey (USGS). 1988. Channel Morphology of Cottonwood Creek near Cottonwood, California, from 1940 to 1985. USGS Water Resources Investigations Report 87-4251.

U.S. Geologic Survey (USGS). 2009. Website. National Water Information System: Web Interface. USGS 11447293 DRY C A VERNON ST BRIDGE A ROSEVILLE CA. Available at: http://waterdata.usgs.gov/nwis/rt
Accessed May 5, 2009.

Velsen, F. P. 1987. Temperature and Incubation in Pacific Salmon and Rainbow Trout: Compilation of Data on Median Hatching Time, Mortality and Embryonic Staging. Canadian Data Report of Fisheries and Aquatic Sciences 626. Nanaimo, BC: Department of Fisheries and Oceans, Fisheries Research Branch.

Vestra Resources, Inc. 2006. Shasta West Watershed Assessment. Prepared for Western Shasta Resource Conservation District. URL = http://sacriver.org (Accessed April 17, 2009).

Vogel, D.A., K. R. Marine, and J. G. Smith. 1988. Fish passage action program for Red Bluff Diversion Dam. Final Report on Fishery Investigations, USFWS Report No. FR1/FAO-88-1. U. S. Fish and Wildlife Service, Red Bluff CA. 77 p. plus appendices.

Ward, M.B. and Kier, W.M. 1999. Battle Creek Salmon and Steelhead Restoration Plan. Report by Kier Associates to Battle Creek Working Group.

Ward, M.B. and Moberg, J. 2004. Battle Creek Watershed Assessment: Characterization of stream conditions and an investigation of sediment source factors in 2001 and 2002.. Terraqua, Inc. Wauconda, WA. 72 pp. Available online at:
http://www.usbr.gov/mp/battlecreek/pdf/docs/environ/BCWA_Report_Final1.pdf Accessed May 4, 2009

Ward, P., T. McReynolds, and C. Garman. 2003. Butte and Big Chico Creeks Spring-Run Chinook Salmon, *Oncoryhnchus Tshawytscha*, Life History Investigations 2001-2002. Prepared for CDFG.

Ward, P. D., T. R. McReynolds, and C. E. Garman. 2004. Butte and Big Chico Creeks Spring-Run Chinook Salmon, *Oncoryhnchus Tshawytscha*, Life History Investigation 2002-2003. CDFG Inland Fisheries Administrative Report No. 2004-6.

Water Engineering and Technology, Inc. (WET). 1991. Analysis of Cottonwood Creek near Cottonwood, California. Project No. 91-001.

Water Forum. 2005. Lower American River State of the River Report.

Water Forum. 2005a. Impacts on Lower American River Salmonids and Recommendations Associated with Folsom Reservoir Operations to Meet Delta Water Quality Objectives and Demands (Draft Report). Prepared by Surface Water Resources, Inc. January. Available at www.waterforum.org.

Water Forum. 2005b. Lower American River State of the River Report.

Western Shasta Resource Conservation District. 2005. Shasta West Watershed Assessment. Available on the Internet at: http://www.sacriver.org/documents/watershed/shastawest/assessment/ShastaWest_WatershedAssessment_Jun05.pdf. June 2005.

Western Shasta Resource Conservation District. 2008. Churn Creek Fisheries Restoration Assessment: Constraints and Restoration Opportunities. A Reconnaissance Level Geomorphic Assessment and Limiting Factors Analysis. Prepared by Graham Matthews & Associates. March 2008. Available on the Internet at: http://www.westernshastarcd.org/GMA_ChurnCreekAssessment_Report_March2008.pdf

Williams, J.G. 2006. Central Valley Salmon. A Perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science. Volume 4, Issue 3, Article 2.

Williams, T.H., B.C. Spence, W. Duffy, D. Hillemeier, G. Kautsky, T.E. Lisle, M. McCain, T.E., Nickelson, E. Mora, T. Pearson. 2008. Framework for assessing viability of threatened coho salmon in the southern Oregon/Northern California coast evolutionarily significant unit. NOAA Technical Memorandum-NMFS-SWRSC-432.

Workman, M.L., Merz, J.E., and Heady, W.N. 2008. Abstract Prepared for the October 22-24, 2008 CALFED Science Conference.

YCWA, Reclamation, and DWR. 2007. Draft Environmental Impact Report/ Environmental Impact Statement for the Proposed Lower Yuba River Accord. Prepared by HDR|Surface Water Resources, Inc., June 2007.

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

Yuba County Water Agency (YCWA), 1989, Cleanup and Abatement of Sediments Sluiced from Our House Reservoir: Technical Report, Continued Streambed Monitoring Program 1988/1989, 69 p.

Zimmerman, C.E., G.W. Edwards, and K. Perry. 2008. Maternal origin and migratory history of Oncorhynchus mykiss captured in rivers of the Central Valley, California. Final Report prepared for the California Department of Fish and Game. Contract P0385300. 54 pages.