CENTRAL VALLEY
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2012 Central Valley Flood Protection Plan

A Path for Improving Public Safety, Environmental Stewardship, and Long-Term Economic Stability

Volume V
Attachment 9

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

PUBLIC SAFETY ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

Cover Photo: Sacramento Weir (December 24, 1964), DWR Photo Lab

The Sacramento Weir and Bypass discharges excess flows from the Sacramento River (on the left) into the Yolo Bypass (not shown). The 1964-65 water year was marked by one of the most disastrous floods in California's history.

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2012 Central Valley Flood Protection Plan

Attachment 9: Supporting Documentation for Conservation Framework

January 2012

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Table of Contents

1.0 Introduction 1-1
1.1 Background 1-1
1.2 CVFPP Planning Areas 1-2
1.3 2012 CVFPP Planning Goals 1-4
1.4 2012 CVFPP Planning Approaches 1-4
1.5 Report Organization 1-5

2.0 Attachment Summary 2-1
2.1 Regional Advance Mitigation Planning 2-1
2.2 Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area 2-1
2.3 Fish Passage Assessment 2-2
2.4 Improving Vegetation Data 2-3
2.5 Existing Conservation Objectives from Other Plans 2-4
2.6 Floodplain Restoration Opportunity Analysis 2-4
2.7 Regional Permitting Options 2-5

3.0 References 3-1

4.0 Acronyms and Abbreviations 4-1

List of Figures

Figure 1-1. Central Valley Flood Protection Plan Planning Areas..... 1-3

Figure 1-2. Formulation Process for State Systemwide Investment Approach..... 1-5

List of Attachments

Attachment 9A – Regional Advance Mitigation Planning

Attachment 9B – Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area

Attachment 9C – Fish Passage Assessment

Attachment 9D – Improving Vegetation Data

Attachment 9E – Existing Conservation Objectives from Other Plans

Attachment 9F – Floodplain Restoration Opportunity Analysis

Attachment 9G – Regional Permitting Options

1.0 Introduction

As part of the development of the Conservation Framework and the 2012 Central Valley Flood Protection Plan (CVFPP), supporting technical analyses and research efforts were conducted to evaluate conditions within the flood management system and to support formulation of conservation improvements. These efforts were conducted in the Sacramento River Basin, San Joaquin River Basin, and Sacramento-San Joaquin Delta (Delta).

This Supporting Technical Documentation for Conservation Framework provides an overview of the technical analyses and research efforts supporting the formulation and evaluation of the Conservation Framework that, in turn, supports formulation of the State Systemwide Investment Approach presented in the 2012 CVFPP. Detailed descriptions of these supporting documents are attached.

1.1 Background

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, the California Department of Water Resources (DWR) has prepared a sustainable, integrated flood management plan called the CVFPP, for adoption by the Central Valley Flood Protection Board (Board). The 2012 CVFPP provides a systemwide approach to protecting lands currently protected from flooding by existing facilities of the State Plan of Flood Control (SPFC), and will be updated every 5 years.

The Conservation Framework is an integral part of the State of California's (State's) preferred approach to flood management in the Central Valley. To help meet the required objectives of the Central Valley Flood Protection Act of 2008 and the goals of the CVFPP (particularly regarding public safety), the Conservation Framework outlines the State's intent to accomplish the following:

- Improve and enhance natural dynamic hydrologic (flow) and geomorphic processes in the flood management system
- Increase and improve the quantity, diversity, quality, and connectivity of riverine habitats in the flood management system

- Contribute to the recovery and stability of native species populations and overall biotic community diversity associated with the flood management system

The Conservation Framework is the first phase of more comprehensive and integrated planning within the flood management system, leading to a longer term Central Valley Flood System Conservation Strategy (Conservation Strategy). The Conservation Strategy will be consistent with the Conservation Framework and will provide more specifics about integrating flood and conservation actions. This Conservation Strategy may include regional permitting plans, such as Natural Community Conservation Plans or Habitat Conservation Plans.

1.2 CVFPP Planning Areas

For planning and analysis purposes, and consistent with legislative direction, two geographical planning areas were important for CVFPP development (Figure 1-1):

- **SPFC Planning Area –** This area is defined by the lands currently receiving flood protection from facilities of the SPFC (see *State Plan of Flood Control Descriptive Document* (DWR, 2010)). The State of California's (State) flood management responsibility is limited to this area.

- **Systemwide Planning Area –** This area includes the lands that are subject to flooding under the current facilities and operation of the Sacramento-San Joaquin River Flood Management System (California Water Code Section 9611). The SPFC Planning Area is completely contained within the Systemwide Planning Area which includes the Sacramento River Basin, San Joaquin River Basin, and Delta regions.

Planning and development for the CVFPP occurs differently in these planning areas. The CVFPP focused on SPFC facilities; therefore, evaluations and analyses were conducted at a greater level of detail within the SPFC Planning Area than in the Systemwide Planning Area.

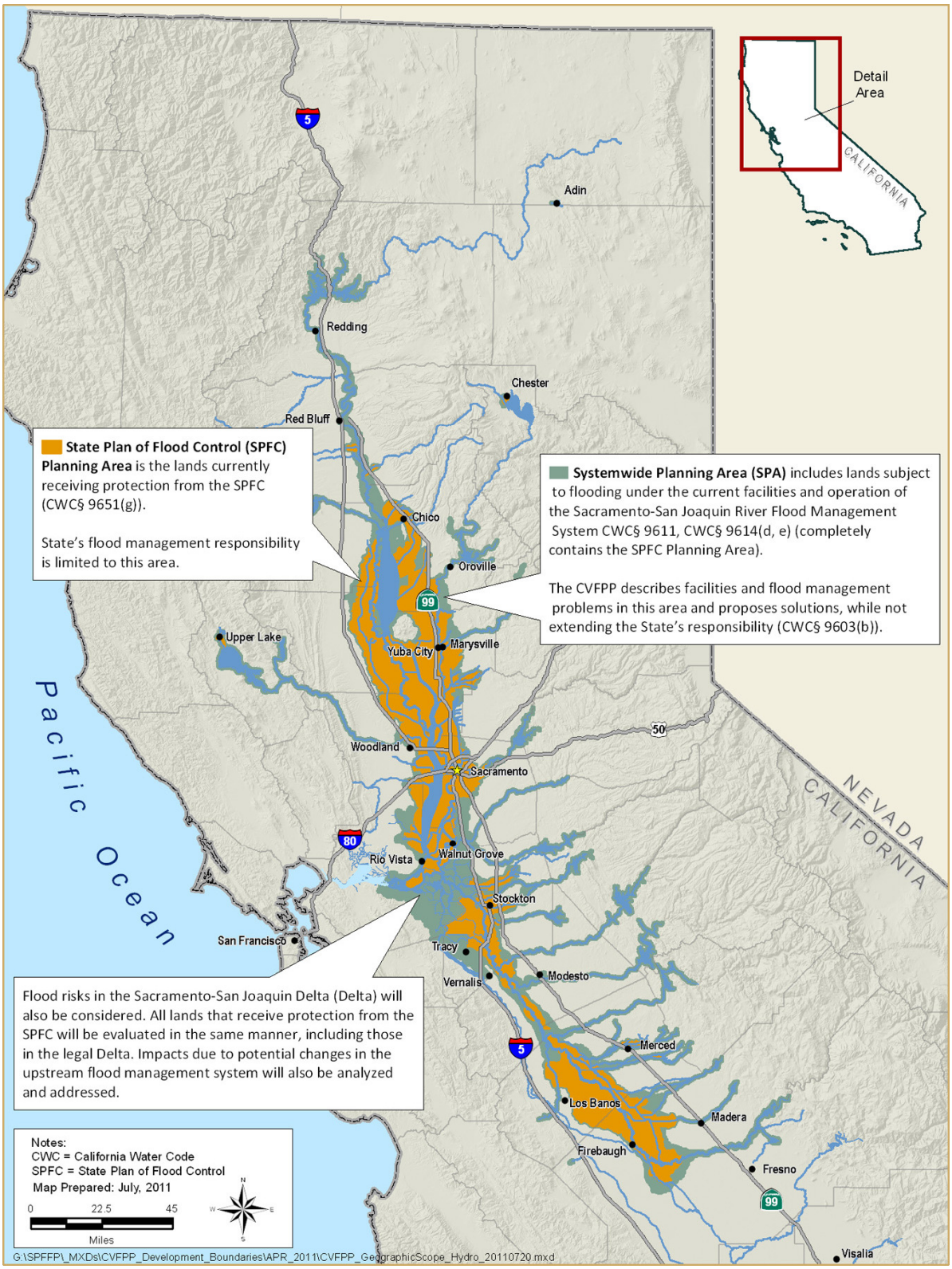

Figure 1-1. Central Valley Flood Protection Plan Planning Areas

1.3 2012 CVFPP Planning Goals

To help direct CVFPP development to meet legislative requirements and address identified flood-management-related problems and opportunities, a primary and four supporting goals were developed:

- **Primary Goal** – Improve Flood Risk Management
- **Supporting Goals**:
  - Improve Operations and Maintenance
  - Promote Ecosystem Functions
  - Improve Institutional Support
  - Promote Multi-Benefit Projects

1.4 2012 CVFPP Planning Approaches

In addition to **No Project**, three fundamentally different approaches to flood management were initially compared to explore potential improvements in the Central Valley. These approaches are not alternatives; rather, they bracket a range of potential actions and help explore trade-offs in costs, benefits, and other factors important in decision making. The approaches are as follows:

- **Achieve SPFC Design Flow Capacity** – Address capacity inadequacies and other adverse conditions associated with existing SPFC facilities, without making major changes to the footprint or operation of those facilities.
- **Protect High Risk Communities** – Focus on protecting life safety for populations at highest risk, including urban areas and small communities.
- **Enhance Flood System Capacity** – Seek various opportunities to achieve multiple benefits through enhancing flood system storage and conveyance capacity.

Comparing these approaches helped identify the advantages and disadvantages of different combinations of management actions, and demonstrated opportunities to address the CVFPP goals to different degrees.

Based on this evaluation, a **State Systemwide Investment Approach** was developed that encompasses aspects of each of the approaches to balance achievement of the goals from a systemwide perspective, and includes integrated conservation elements. Figure 1-2 illustrates this plan formulation process.

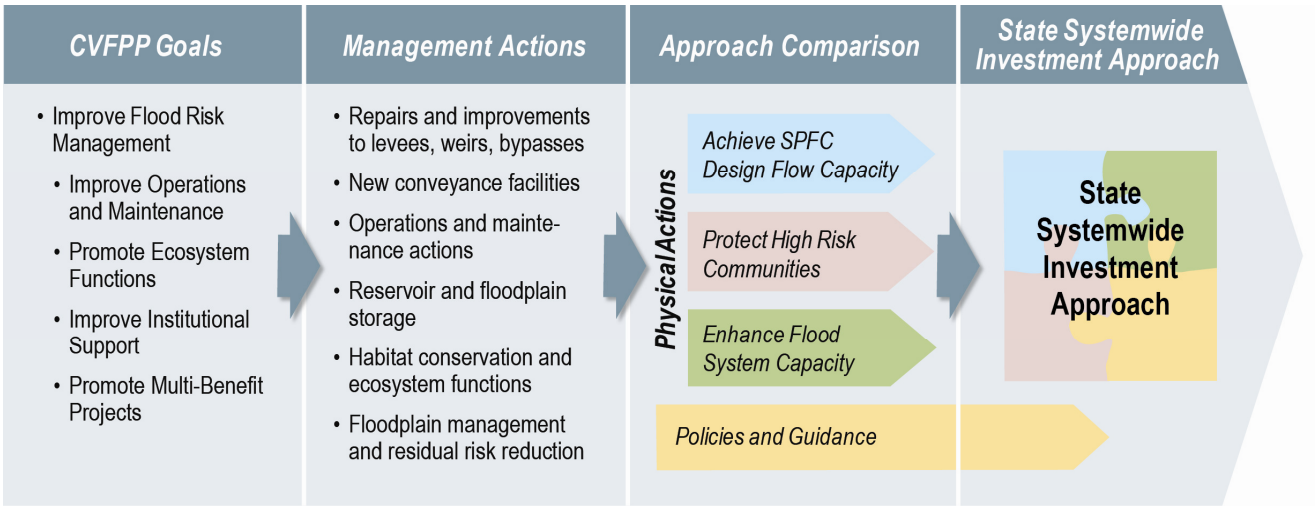

Figure 1-2. Formulation Process for State Systemwide Investment Approach

1.5 Report Organization

Organization of this document is as follows:

- Section 1 introduces and describes the purpose of this report.
- Section 2 briefly summarizes each of the attachments
- Section 3 contains references for the sources cited in this document.
- Section 4 lists acronyms and abbreviations used in this document.

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2.0 Attachment Summary

This section summarizes the supporting attachments informing development of the Conservation Framework and the Conservation Strategy.

2.1 Regional Advance Mitigation Planning

Attachment 9A: Regional Advance Mitigation Planning focuses on efforts to develop a mitigation approach that (1) integrates project-specific mitigation with regional and statewide conservation priorities, and (2) offsets unavoidable impacts of planned infrastructure projects before the projects are constructed. Regional Advance Mitigation Planning (RAMP) has been in preparation by a multiagency work group since 2008. To develop advance mitigation in the Systemwide Planning Area, the State would work with regulatory agencies to estimate potential mitigation needs early in the timelines of multiple projects. This process minimizes permitting and regulatory delays and reduces mitigation costs by securing and conserving valuable natural resources at an economically efficient scale and before potential mitigation lands are converted to incompatible land uses. Having RAMP-sponsored mitigation sites in strategic locations throughout the Systemwide Planning Area could speed approvals for the State's infrastructure agencies when the agencies seek permits for "take" of endangered species, fill of wetlands, or disturbance to streambeds and their banks. Adopting a strategic, forward-looking, and regional approach, in which natural resources agencies are encouraged to identify mitigation needs early, can provide a vehicle for identifying solutions that address conservation priorities in ways that are coordinated and take into account agricultural communities and land uses.

2.2 Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area

Attachment 9B: Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area summarizes the current status and historical trends of riparian and riverine ecosystems in the Systemwide Planning Area for the CVFPP. The summary of status and trends in this report is intended to document the need for and support the

development of the Conservation Framework that will be a component of the 2012 CVFPP and the Conservation Strategy. This attachment accomplishes the following:

- Describes the ecological history of the Sacramento Valley's and San Joaquin Valley's riparian and riverine ecosystems, how these ecosystems historically functioned, and early stressors on these ecosystems that have contributed to their current status and observed trends.

- Describes the ecological relevance of the hydrologic and geomorphic processes emphasized in the report and the mechanisms by which these processes interact with each other and affect the ecosystem functions of Sacramento Valley and San Joaquin Valley riparian and riverine habitats. Additionally, it describes the mechanisms by which specific stressors negatively affect hydrologic, geomorphic, and ecosystem processes.

- Assesses the status and trends of Sacramento Valley and San Joaquin Valley hydrologic and geomorphic processes, and related habitats through a series of metrics calculated from readily available data. Each metric is described in a concise summary that identifies the rationale for selecting that metric to illustrate a particular process or habitat status, trend, or stressor; describes how the metric was developed and analyzed; and identifies the primary conclusion that can be drawn from each metric. The assessment relies heavily on graphical representations of each metric (e.g., charts or maps).

- Summarizes data gaps documented during the analysis of status, trends, and stressor metrics and highlights the potential for conceptual ecological models as planning tools for the Conservation Strategy.

2.3 Fish Passage Assessment

Attachment 9C: Fish Passage Assessment identifies fish passage obstacles and recommends actions for modifying the Central Valley flood management system that could contribute to the recovery of native anadromous[1] fish in the Central Valley. Within the geographical context of the CVFPP Systemwide Planning Area, this report discusses the following:

- Importance of ecological flows and floodplain flooding for fish

[1] Anadromous fish hatch from eggs laid in freshwater streams, migrate as juveniles to saltwater, and after living and growing in ocean waters, then return as adults to spawn in freshwater to complete their life cycle.

- Anadromous species present
- Anadromous fish population status and the reduction from their historical ranges
- Reasons for their decline, with a particular focus on physical passage barriers and stranding related to flood management
- Implications of passage barriers under climate change effects
- Identification and ranking of passage barriers and stranding areas
- Description of tested approaches for improving passage around major dams

Fish passage barriers can include, but are not limited to, dams, weirs, grade control structures, pumping stations, flood control gates, levees that cross or block stream channels, road crossings, and features of the flood control channels and bypasses that strand fish. Fish passage actions include identifying barriers, evaluating the magnitude that each barrier impedes migration, and modifying barriers to allow unimpeded migration. These actions will assist in increasing and improving habitat connectivity and promoting the recovery of anadromous fish populations in the Sacramento-San Joaquin River Flood Management System.

2.4 Improving Vegetation Data

Attachment 9D: Improving Vegetation Data describes the importance of high-quality vegetation data for improving flood management and ecosystem conditions in the Central Valley; summarizes other related mapping efforts; and describes DWR's approach, progress, and future steps for improving the quality of vegetation data.

DWR is in the process of completing a seamless riparian vegetation map for the Sacramento and San Joaquin main-stems and tributaries within the CVFPP Systemwide Planning Area. Before this effort, most vegetation data for these areas was incomplete, or conducted at a variety of scales and resolutions. This mapping effort provides baseline data for impact analysis, and conservation and restoration area planning.

2.5 Existing Conservation Objectives from Other Plans

Attachment 9E: Existing Conservation Objectives from Other Plans contains information on other conservation planning efforts (both completed and ongoing) with regional, geographically based, and/or quantifiable conservation measures potentially relevant to the Conservation Strategy. The Conservation Strategy, in conjunction with the CVFPP, will overlap with multiple regional and collaborative conservation plans that have either been previously implemented or are planned for the Sacramento and San Joaquin valleys. Regional planning is most effective when coordinated with similar programs and plans to the maximum extent possible. Coordination among the Conservation Strategy and similar, related conservation and collaborative planning efforts is essential to determine if the Conservation Strategy, in meeting its conservation objectives, can contribute to the shared conservation objectives of other plans or programs. Plans and programs were selected for inclusion that overlapped at least partially with the SPFC Planning Area or Systemwide Planning Area, and that included conservation objectives likely to be related to the Conservation Strategy. The list is not comprehensive, but includes examples of the types of efforts that should be considered in developing the Conservation Strategy.

2.6 Floodplain Restoration Opportunity Analysis

Ecosystem restoration is a key component of the CVFPP, and management actions related to habitat restoration have been drafted as part of the CVFPP planning process. Further refinement of these management actions will be informed by an understanding of habitat restoration opportunities, in terms of the location, acreage, and expected ecosystem benefits of each management action that are possible within the context of the SPFC.

Attachment 9F: Floodplain Restoration Opportunities Analysis (FROA) supports this refinement of management actions by identifying areas with the greatest and/or most extensive potential opportunities for floodplain restoration. To identify and quantify potential opportunities for floodplain restoration, the following process has been followed:

- Identification of areas of physical suitability using the Floodplain Inundation Potential (FIP) tool
- Identification of other opportunities and constraints using land use-land cover data, conserved areas, location and physical condition of project and non-project levees, locations of other major infrastructure, and

areas planned or desired for restoration, as identified by other plans or stakeholder interest

- Evaluation of relationships among physical suitability and other opportunities and constraints

- Identification of river reaches with the greatest and/or most extensive potential opportunities for floodplain restoration

Results of the FROA support the identification, prioritization, and further development of specific restoration opportunities. In conjunction with the Conservation Strategy, these specific opportunities will be identified, prioritized, and developed on the basis of their potential ecological, flood management, and other benefits (e.g., reduced maintenance and regulatory compliance costs); cost; and regulatory, institutional, technological, and operational feasibility.

2.7 Regional Permitting Options

Programmatic approaches to permitting and other regulatory authorizations for flood management activities (e.g., regional permitting mechanisms) are an important part of improving and integrating flood management and ecosystem conservation in the Central Valley. To support both the CVFPP and the linked Conservation Strategy, Attachment 9G: Regional Permitting Options, does the following:

- Describes the benefits of programmatic authorizations (as compared to project-by-project permitting)

- Identifies the types of flood management activities that could potentially be covered by such programmatic authorizations

- Describes and evaluates several options for developing programmatic authorization mechanisms for the flood management system, and identifies other important environmental regulations that apply

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3.0 References

California Department of Water Resources (DWR). 2010. State Plan of Flood Control Descriptive Document. November.

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4.0 Acronyms and Abbreviations

Board .....Central Valley Flood Protection Board

Conservation Strategy .....Central Valley Flood System Conservation Strategy

CVFPP .....Central Valley Flood Protection Plan

Delta.....Sacramento-San Joaquin Delta

DWR .....California Department of Water Resources

FIP .....Floodplain Inundation Potential

FROA .....Floodplain Restoration Opportunities Analysis

RAMP .....Regional Advance Mitigation Planning

SPFC .....State Plan of Flood Control

State.....State of California

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PUBLIC DRAFT | January 2012

2012 Central Valley Flood Protection Plan

A Path for Improving Public Safety, Environmental Stewardship, and Long-Term Economic Stability

Volume V–Part 1
Attachments 9A through 9C

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

PUBLIC SAFETY ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

2012 Central Valley Flood Protection Plan

Public Draft, January 2012

Volume V – Part 1
Attachments 9A Through 9C

Table of Contents

Attachment 9A Regional Advance Mitigation Planning

Attachment 9B Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area

Attachment 9C Fish Passage Assessment

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Attachment 9A

Regional Advance Mitigation Planning

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2012 Central Valley Flood Protection Plan

Attachment 9A: Regional Advance Mitigation Planning

January 2012

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Table of Contents

1.0 Introduction 1-1
1.1 Background 1-1
1.2 Report Organization 1-2

2.0 Regional Advance Mitigation Planning 2-1

3.0 Acronyms and Abbreviations 3-1

List of Tables

Table 2-1. RAMP Timeline (Past, Present, and Future) 2-10

List of Figures

Figure 2-1. Hypothetical Use of RAMP-Sponsored Mitigation Sites During Federal Terrestrial Endangered Species Permitting 2-4

Figure 2-2. Hypothetical Use of RAMP-Sponsored Mitigation Sites During Federal Waters of United States Permitting 2-5

Figure 2-3. Hypothetical Use of RAMP-Sponsored Mitigation Sites During State Streambed Alteration Permitting (With or Without Species Impacts) 2-6

Figure 2-4. RAMP Pilot Area – June 2011 2-13

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1.0 Introduction

Sometimes the development of infrastructure can negatively impact habitats and species. Ways to better avoid, minimize, and mitigate these impacts for State Plan of Flood Control (SPFC) facilities is being developed under the Central Valley Flood Protection Plan's (CVFPP) Central Valley Flood System Conservation Strategy (Conservation Strategy). This attachment details the approach for Regional Advance Mitigation Planning (RAMP), which could support the Conservation Framework and the future Conservation Strategy. RAMP attempts to provide a method to achieve faster, less expensive, and better mitigation for unavoidable impacts associated with infrastructure projects proposed within the state.

1.1 Background

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, the California Department of Water Resources (DWR) has prepared a sustainable, integrated flood management plan called the CVFPP, for adoption by the Central Valley Flood Protection Board (Board). The 2012 CVFPP provides a systemwide approach to protecting lands currently protected from flooding by existing facilities of the SPFC, and will be updated every 5 years.

The State of California (State) and federal agencies recognize RAMP as a high-value decision-making process that should be able to identify the best offsite mitigation approach for the types of impacts expected from multiple agencies over multiple years. Several State and federal agencies are collaborating to develop RAMP in California. Participants include infrastructure agencies (DWR and California Department of Transportation [Caltrans]), and State and federal resource agencies including California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service, and U.S. Army Corps of Engineers' (USACE) regulatory office. The effort also receives support from The Nature Conservancy and Resources Legacy Fund. These nonprofits have secured several grants from private foundations to keep the RAMP effort moving forward, as well as helping extensively with science and analysis, outreach, policy development, and meeting support. RAMP also works with modeling researchers from University of California, Davis, to aid in development of planning tools.

1.2 Report Organization

Organization of this document is as follows:

- Section 1 introduces and describes the purpose of this report.
- Section 2 describes the RAMP approach and process.
- Section 3 lists acronyms and abbreviations used in this document.

2.0 Regional Advance Mitigation Planning

The State's public agencies spend billions of dollars each year on infrastructure projects to meet the State population's growing need for roads, bridges, levees, and other facilities. California hosts a rich array of valuable natural communities and ecosystems that provide habitat for rare and native plants and wildlife. These ecosystems and natural communities are also the source for Californians' drinking water and provide open space for healthy recreation. As California's population grows, it is imperative that this growth occurs in a manner that protects and enhances the State's natural resources.

The existing options for compensatory mitigation are helpful and practical approaches. But RAMP is an innovative approach that builds on existing conservation efforts and mitigation tools while also helping to solve some of the challenges associated with these tools, such as limited funding and protracted timelines. RAMP is investigating innovative ways to leverage multiple funding sources that allow for larger mitigation sites than could be accomplished if only existing funding options were used. RAMP intends to provide a more economical approach for mitigation of infrastructure project impacts on a landscape scale rather than by a project-by-project mitigation. While RAMP concepts have been implemented in some parts of the State (San Diego County, Orange County, and Elkhorn Slough in Monterey County), it is still considered a new approach, but is gaining widespread acceptance among agencies. RAMP requires a change by both infrastructure and regulatory agencies in their approach to the development of new mitigation areas and they will be asked to provide an investment in advance planning, which is intended to provide long-term ecological and financial benefits.

Although still in the development and testing phases, the basic RAMP concept is twofold. First, it establishes a regional framework for identifying existing and potential mitigation approaches in a geographically specific portion of the State that could support the needs of planned infrastructure projects and meet the needs of regulatory agencies. Second, it identifies which mitigation approaches could best create habitat in advance of potential unavoidable impacts of infrastructure projects. Working together, natural resource and infrastructure funding agencies can estimate mitigation needs early in the projects' timelines, avoiding permitting and regulatory delays and allowing public mitigation dollars to stretch further by securing and conserving valuable natural resources on a more

economically efficient scale and before related real estate values escalate. This strategy supports jobs and a vibrant economy – lower mitigation costs lowers overall project costs which frees up funds for additional projects; the certainty provided by RAMP allows infrastructure agencies to deliver on the pipeline of projects more consistently; and it supports jobs in the natural resources sector through restoration and management of natural lands.

Using an approach that emphasizes regional ecosystem needs and priorities, and drawing on the lessons learned from previous experience, DWR and others can explore various mitigation opportunities and make more informed mitigation decisions that hope to maximize conservation within a region while allowing timely construction of necessary infrastructure. DWR and Caltrans are leading development of the RAMP initiative using bond funding, but they will actively seek additional voluntary partners as the structure for long-term funding and governance is more clearly defined. Because this is a multi-agency effort supported by several funding sources, the geographic boundaries of any plan and the schedule for completing documents will be outside of the control of the DWR or Board staff working on the CVFPP effort. The draft work plan for the effort involves the following several general steps (see list below).

1. Develop support among infrastructure and regulatory agencies of a statewide region-based advanced mitigation approach and identify policy and funding issues with a timeline for resolving them (this will be described in a document currently entitled "Statewide Framework for RAMP in California," which is under internal review and will be widely available in the fall of 2012).

2. Develop geographically specific plans that (1) assess expected habitat mitigation demand (from multiple planned infrastructure projects), and (2) identify possible mitigation approaches in advance of any impacts (these will be described in documents currently entitled "Regional Assessment"). This advance planning should result in expedited permit reviews of infrastructure projects because all alternatives for mitigation would have already been evaluated at the regional level, eliminating the need to perform this analysis for a single project. There should also be a time savings for regulatory agency staff who would be making a decision on a few large sites versus several small sites.

3. Identify and describe a mitigation option that will be potentially pursued for the benefit of multiple infrastructure agencies (in documents entitled "Action Plan"). During development of the Action Plan, secure regulatory agency acceptance and approval of the RAMP mitigation approach and identify partners willing to sign cost-share

agreements to fund its implementation. While the contents of an Action Plan are still undefined, the RAMP Work Plan calls for the development of standardized outlines and budgets for their development over the first quarter of 2012.

4. Secure monetary support for the approved Action Plan and gain agreement on the financial reporting procedures to ensure transparent billings and transactions. Note that RAMP partners are anticipating that funding for implementation of the Action Plan would be independent of any line item from an individual infrastructure project's budget. Instead, funding for Action Plan implementation is based on a conservative estimate of a bundled multi-agency and multi-year projected "demand," as identified in both the Regional Assessment and the Action Plan. Ideally, funds would come from a "revolving fund" that has been established through legislation specifically for advance mitigation development.

5. Reevaluate mitigation approaches to continually provide sufficient and appropriate habitat to meet expected infrastructure project mitigation needs.

The RAMP Work Group
In 2008, several agencies came together to figure out a better way to mitigate for infrastructure projects that is faster, more effective, and yields larger scale conservation outcomes in California as compared to project-by-project mitigation. In 2009, leadership of the various agencies signed or supported a Memorandum of Understanding including: DWR, Caltrans, U.S. Environmental Protection Agency, USFWS, USACE, National Oceanic Atmospheric Administration (National Marine Fisheries Service), DFG, California Wildlife Conservation Board, Natural Resources Agency, and the California Business, Transportation & Housing Agency

RAMP does not supply permits for infrastructure projects; rather, its purpose is to provide a more efficient and cost-effective option for supplying mitigation within existing permitting processes. It can aid DWR and also its RAMP partners (see text box) in successfully completing the federal endangered species permitting process (see Figure 2-1), federal wetland permitting process (see Figure 2-2), and State lake and streambed alteration permitting process (see Figure 2-3). Infrastructure agencies will individually apply for their permits to perform actions. Within the application materials, they could reference an advance mitigation site created through RAMP. These sites may be authorized by the resources agencies using the same methodology as a private commercial mitigation bank and other agencies or authorized using alternative methods supported by these same agencies. RAMP will be successful if the advance mitigation sites are used expeditiously, indicating that RAMP is an effective planning method and provides a return on investment to infrastructure agencies. The success of RAMP's first Action Plan will allow more RAMP-sponsored mitigation to be developed in the region.

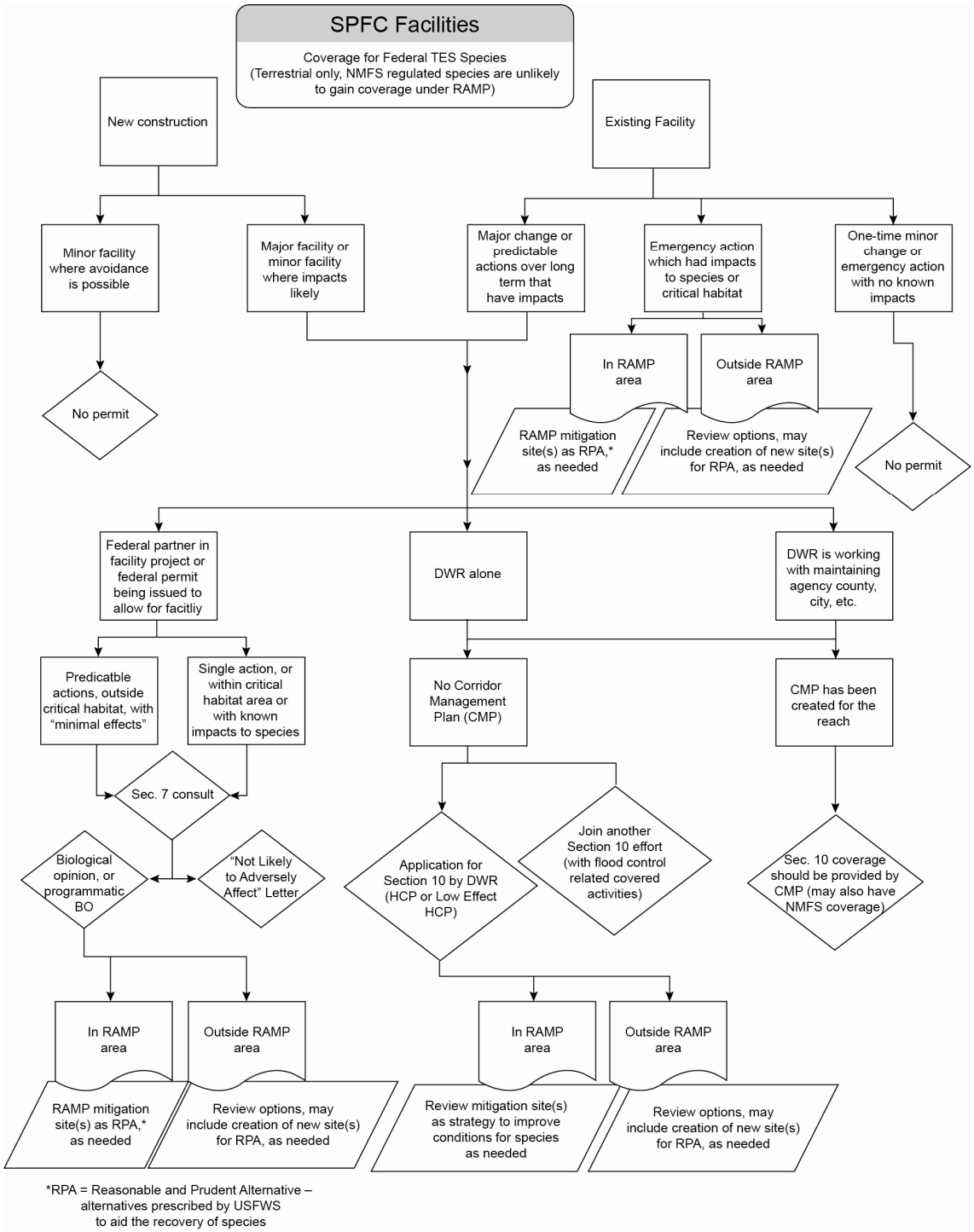

Figure 2-1. Hypothetical Use of RAMP-Sponsored Mitigation Sites During Federal Terrestrial Endangered Species Permitting

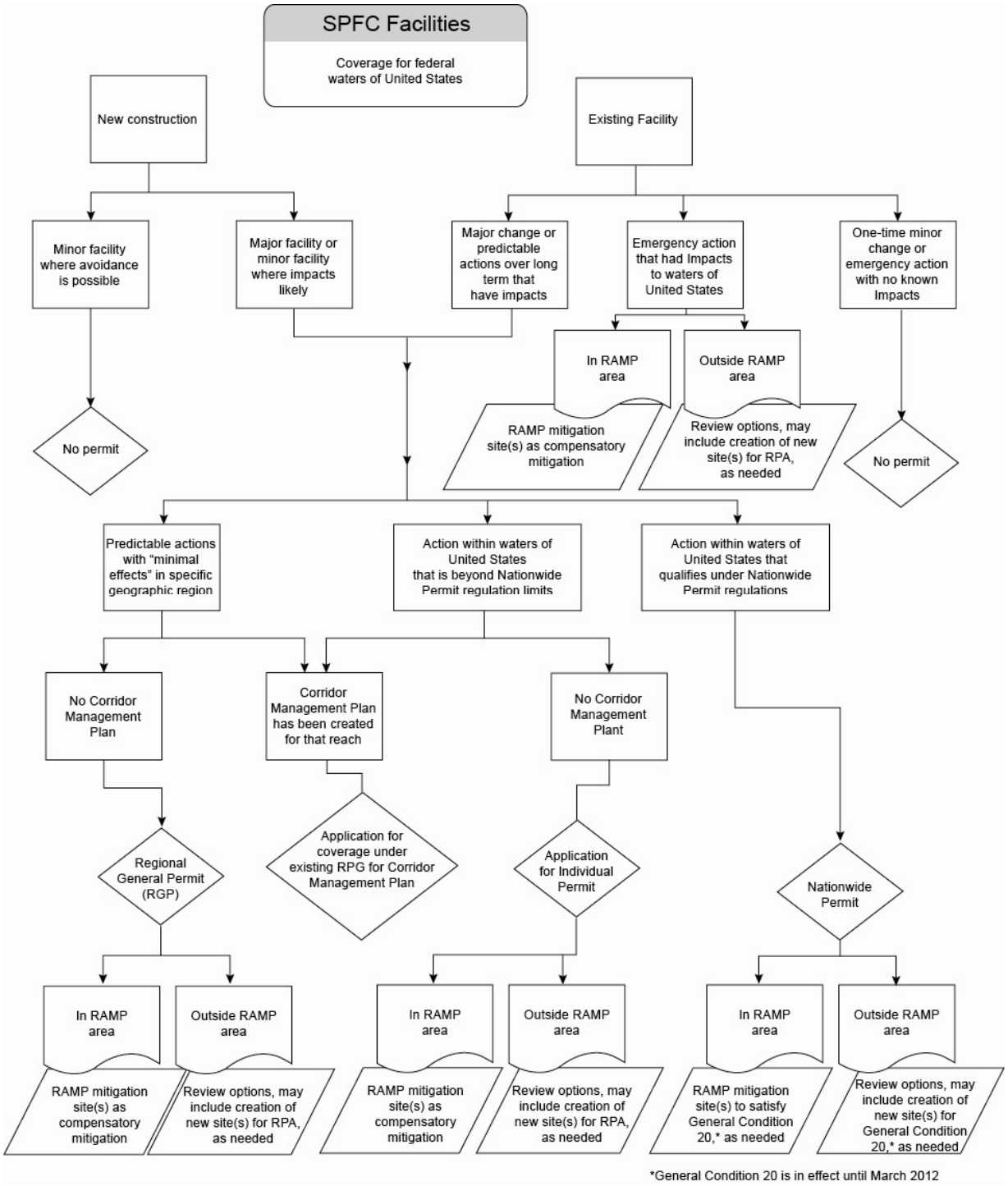

Figure 2-2. Hypothetical Use of RAMP-Sponsored Mitigation Sites During Federal Waters of United States Permitting

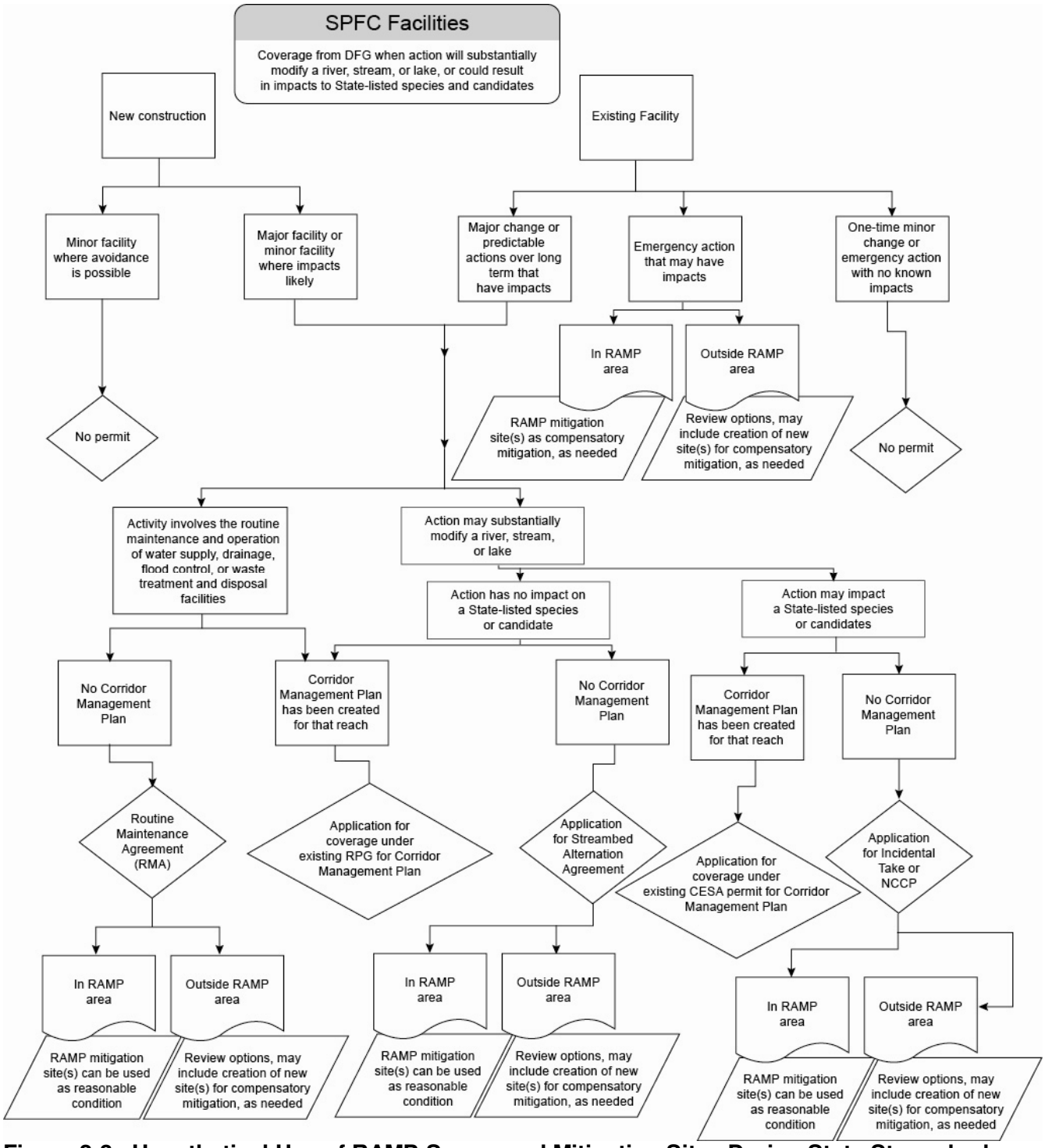

Figure 2-3. Hypothetical Use of RAMP-Sponsored Mitigation Sites During State Streambed Alteration Permitting (With or Without Species Impacts)

The Conservation Framework supports the premise that environmental considerations should be taken into account at all levels of flood management planning, as early as possible. In support of that goal, RAMP steers agencies away from (1) only planning mitigation on a project-by-project basis, usually near the end of a project's environmental review, and (2) any mitigation that occurs with insufficient consideration of regional or statewide conservation priorities. Permitting delays can occur when appropriate offsite mitigation sites cannot be easily identified and agreed on, and the cost of mitigation often increases between the time a project is planned and funded and the time mitigation land is acquired. As a result, infrastructure agencies may agree to pay "top dollar" to satisfy mitigation requirements through the quick purchase of credits to keep projects on schedule. Project-by-project mitigation, especially onsite mitigation, can overlook regional conservation needs and ecosystem-scale impacts to sensitive species and habitat, thereby missing critical opportunities for efficient, reliable, and biologically relevant mitigation. Additionally, the opportunity is lost for greater benefits to water and air quality and public health that regional planning would bring.

To address some of these concerns with project-by-project mitigation, the DFG and the USFWS have engaged in Habitat Conservation Plans (HCP) and Natural Community Conservation Plans. The HCP process has authority under Section 10(a)(1)(B) of the Federal Endangered Species Act, and the Natural Community Conservation Planning (NCCP) program is authorized by the Natural Community Conservation Planning Act of 1991, codified as Chapter 10, Division 3, of the California Fish and Game Code (2800 et. seq.). Often, an HCP and NCCP are prepared jointly for covered activities in a particular region. NCCP efforts take a broad-based ecosystem approach to planning for the protection and perpetuation of biological diversity. Thus, an HCP/NCCP can identify and provide for the regional protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity. Some HCPs/NCCPs analyze potential future impacts within a single county or can instead perform an analysis of multiple counties. The Central Valley has several such plans in operation or under development. Of these, DWR is currently participating in the multi-county *Bay-Delta Conservation Plan*, which is still in development. The challenges for using these plans for flood project mitigation needs include their incomplete coverage for the Central Valley, and the relatively long time frames (several years of negotiations) for completion.

RAMP can be integrated with and add benefits to conservation planning efforts such as HCPs/NCCPs, which are also attempting to address impacts in advance. Early engagement is already taking place with these planning efforts to identify areas where advance mitigation for impacts could contribute to the plans' goals and provide opportunities for cost sharing or

strategic leveraging of resources. Thus, early engagement should result in larger, more sustainable conservation. DWR and its current partners (see text box on page 2-3) in RAMP are evaluating potential opportunities to work with existing conservation plans to provide mitigation for infrastructure activities, and are exploring development of additional HCPs/NCCPs where none exist. Development or participation in HCPs/NCCPs gives permitting coverage to DWR for action involving the take of federal- or State-listed species. Some HCP/NCCP structures may provide local governance (such as a Joint Power Authority) for managing conservation areas, and allow DWR or its partners to be free of financial obligations relating to the success of any sites developed.

One mitigation approach that future RAMP documents will describe and review for feasibility is the prepurchase of mitigation credits held by private commercial mitigation and conservation banks. Such purchases should increase price predictability, which in turn gives infrastructure project budgets more certainty. Private commercial banks offer mitigation credits from a parcel of land that has been protected and has been rigorously reviewed by the regulatory agencies. Each credit is sold for a fixed price that covers the commercial banker's business expenses to date and allows them a profit. Regulatory agencies have approved and suggested purchases at banks when they are suitable in comparison to other mitigation approaches (after all avoidance and minimization measures have taken place). An advantage to DWR and Caltrans in purchasing credits from certified banks is that it allows the agency to release all further liabilities related to the success of the mitigation site. However, the credits can be more expensive than permitee-responsible (or on site) mitigation and have, on occasion, become a burden on a project's budget. In addition, while the coverage of private commercial banks is ever expanding, gaps exist in the Central Valley, and in some cases appropriate credits are not available for flood management projects. During the development of geographically specific plans (e.g., Regional Assessments), RAMP participants will review options to establish mutually beneficial arrangements with private commercial bankers. At this time there has not been sufficient outreach and discussion to solidify any arrangements.

Beyond private commercial banks, State agencies have established mitigation banks on State-owned lands (these are not commercial banks and are termed "single purpose" banks). For example, Caltrans has created banks that satisfy the mitigation needs of several transportation projects over several years; however, these banks currently do not meet DWR's needs for mitigating future flood activities because DWR is not a participant in any of the banks. RAMP will identify methods to create more State-owned mitigation banks, particularly banks that can be shared among more than one infrastructure agency. By leveraging mitigation funds for

multiple projects and directing mitigation to locations that meet conservation priorities, larger landscapes will be protected, rather than isolated islands of mitigation, furthering habitat connectivity, ecosystem function, and climate change adaptation.

One of the benefits of the RAMP effort has been to change the dynamics of building infrastructure from a negotiation-based process to a more collaborative process. Agencies and stakeholders are sharing ideas, goals, and methods with the RAMP Work Group (see text box on page 2-3). The RAMP Work Group in turn is using these ideas to reach the larger goal of mitigation that is faster, less expensive, and more effective than the status quo. The RAMP initiative does not replace any agency functions, programs, or interagency groups, such as the Interagency Flood Management Collaborative Program Management Group.

Since the RAMP effort was launched 4 years ago, much has been accomplished (see Table 2-1):

- State and federal agencies signed a Memorandum of Understanding (see text box on page 2-3) in 2009 committing to design a framework or program that would implement a RAMP and to participate in a pilot project, and they have been meeting regularly to work on the issues.

- Documents are being prepared that outline the RAMP goals and create a policy and financial framework for how a program could work, based on the pilot project, policy research, and other models.

- Legislation was introduced to establish RAMP in the State (but has yet to pass).

Table 2-1. RAMP Timeline (Past, Present, and Future)

2008	• Data gathered on DWR and Caltrans projects that potentially have impacts (demand analysis) • Pilot area identification process began and initial pilot area identified (CSV)
2009	• MOU signed between agencies (see text box on page 2-3) • Marxan analysis developed (a conservation planning tool) to find suitable mitigation sites in pilot area • "Advance mitigation" legislation developed by The Nature Conservancy
Q1 2010	• Next steps in RAMP discussed, including how to secure funding, create a governance structure, further define the "pilot area," and document RAMP as a program • Work began on a "Policy Paper" that described RAMP as a program and the obstacles to implementation
Q2 2010	• Contract signed with private consultants to develop three documents for RAMP (Statewide Framework, Regional Assessment (for the pilot area), and RAMP Manual) (DWR) • Contract signed with UC Davis for a Central Valley-wide analysis for suitable mitigation and also a wildlife corridor analysis (DWR) • Contract signed with UC Davis to include more transportation plans into "demand" analysis and perform an optimization analysis with results (Caltrans)
Q3 2010	• Efforts began to capture federal funds through SAMI (Caltrans)
Q4 2010	• Statewide Framework chapters developed by core group • Outreach occurred to Strategic Growth Council and also to other infrastructure agencies
Q1 2011	• Statewide Framework reviewed by geographic-specific staff of the signatory agencies to the MOU (DFG, DWR, Caltrans, etc.) – Caltrans met with MPOs and local transportation entities – DWR met with Regional Office staff and Regional Coordinators – DFG, USACE, and USFWS received feedback from Regional Office staff
Q2 2011	• Meetings began on CSV Regional Assessment (Pilot Project) with signatory agencies • Formal engagement occurred on CSV Regional Assessment with nonsignatories to the MOU (see text box on page 2-3)
Q3 2011	• Formally engage on Statewide Framework with nonsignatories to MOU (see text box on page 2-3)
Q4 2011	• Publish internal draft of the CSV Regional Assessment • Estimate costs for creating Action Plans and related documentation • Write MOU and/or Interagency Agreements to divide planning costs among interested parties (at a minimum between DWR and Caltrans and possibly other agencies that are not on the Statewide MOU but have local infrastructure projects) • Write Action Plan based on Regional Assessment • Create appropriate CEQA documentation and decide on State-preferred alternative for implementation based on Action Plan • Begin work on "Actions Needed" from Statewide Framework (e.g., make changes to agency policy, propose new funding structures)

Table 2-1. RAMP Timeline (Past, Present, and Future) (contd.)

2012	• DWR to submit BCP for first mitigation approach identified in Action Plan (will get $ in FY 13/14) • Caltrans to secure SAMI funding or write a BCP for first mitigation approach • Begin any negotiations on land (DWR has an 18-month timeline) • Begin any negotiations with regional plan partners under Natural Community Conservation Planning efforts or Habitat Conservation Plans • Begin any negotiations with private commercial mitigation bankers • Publish Statewide Framework, Regional Assessment, and RAMP Manual with lessons learned
2013	• Complete purchase of land and begin permitting work
2014	• Second Regional Assessment for new portion of the State

Key:
BCP = Budget Change Proposal
Caltrans = California Department of Transportation
CEQA = California Environmental Quality Act
CSV = Central Sacramento Valley (the pilot area's given name)
DFG = California Department of Fish and Game
DWR = California Department of Water Resources
FY = fiscal year
MOU = memorandum of understanding
MPO = Metropolitan Planning Organization, a legally defined entity that is tasked with transportation planning
Q = Quarter
RAMP = regional advance mitigation planning
SAMI = Statewide Advance Mitigation Initiative being performed by Caltrans
State = State of California
UC Davis = University of California, Davis
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service

The RAMP Work Group is currently developing a Statewide Framework document intended to convey to lawmakers and agency leaders the goals, benefits, and operational framework of a statewide RAMP initiative. The internal draft of the Statewide Framework has been completed, and a widely circulated version will be available in fall 2012. Outreach related to this document will be directed toward agency staff as well as several outside organizations (e.g., county staff, land trust organizations, nonprofits). The Statewide Framework will have a companion document, the RAMP Manual, which will serve as a comprehensive guidance document for planning and implementing regional advance mitigation throughout California. The manual will be developed to an internal draft in early 2012, and a circulating draft in fall 2012. Development of the RAMP Manual will draw from lessons learned during testing of the RAMP concept through a pilot project. The pilot project will include preparation of the first Regional Assessment (planned completion in spring 2012), which will provide the strategy for implementing advance mitigation in the pilot project region.

The RAMP Work Group has selected a region in the central Sacramento Valley (along the main-stem Sacramento River from approximately the Tehama County line south to Verona and along the Feather River and its tributaries to the east) for the pilot project (Figure 2-4). Outreach to DWR's Regional Offices and Regional Coordinators is in progress. Caltrans, DFG, and USFWS will perform similar outreach with their local offices. Outreach external to DWR, Caltrans, and the RAMP Work Group will take place in spring 2012. In fall 2012, an open forum will be held for nonprofits, county staff, private mitigation bankers, and other potentially affected parties to learn about RAMP, and to provide information on problems and opportunities within the region.

Working together, natural resource and infrastructure agencies can estimate mitigation needs early in the projects' timelines, avoiding delays from permitting and regulatory negotiations and gaining more value for public mitigation dollars by securing and conserving valuable natural resources on a more economically efficient scale. Having advance mitigation sites in strategic locations throughout the State should speed approvals when DWR seeks a decision on jeopardy of endangered species, expects impacts that result in the fill of wetlands, or expects disturbance to streambeds and/or their banks.

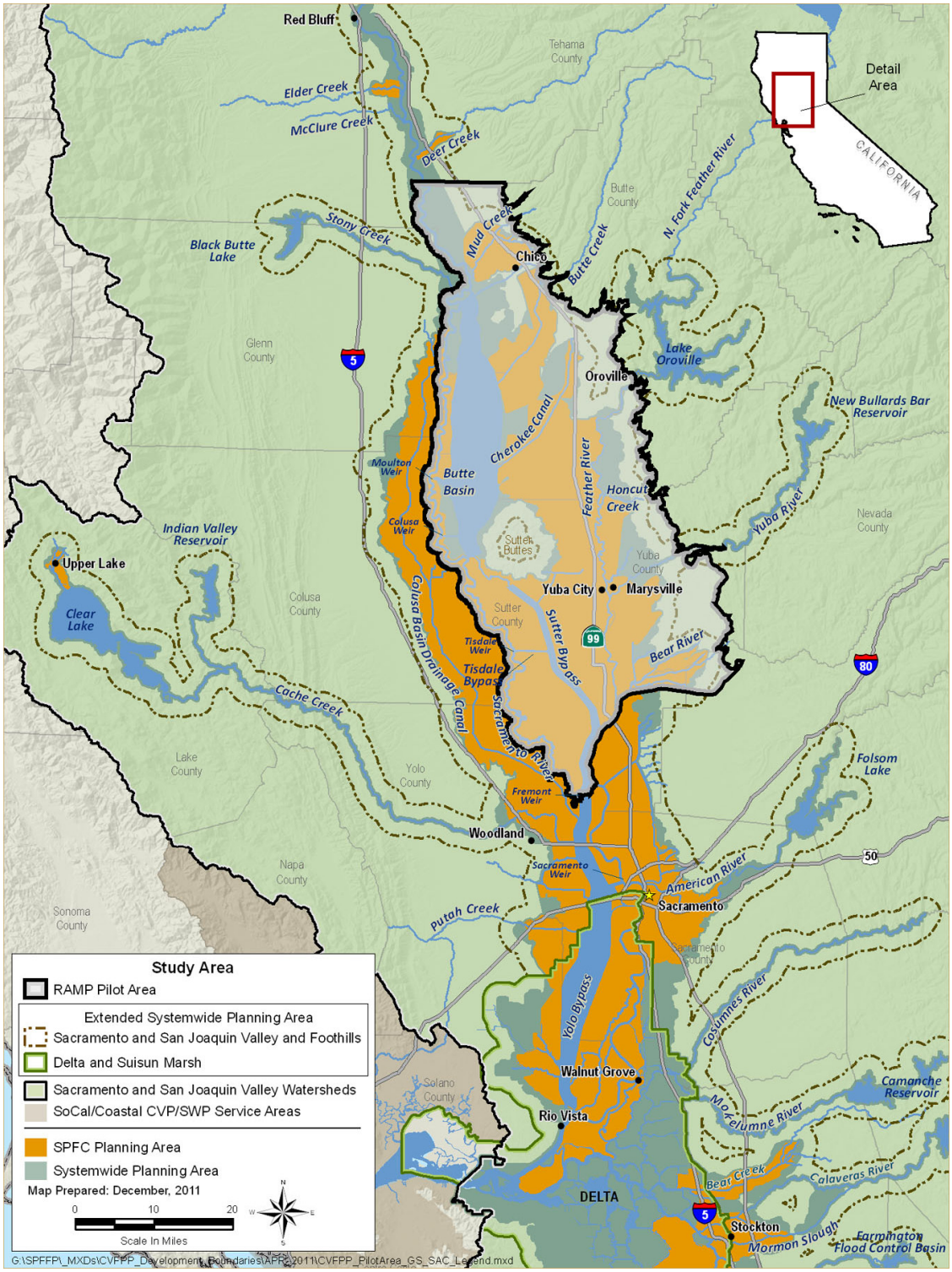

Figure 2-4. RAMP Pilot Area – June 2011

The RAMP Work Group (see text box on page 2-3) has identified numerous benefits that could result from implementing a RAMP program:

- Lower mitigation costs and simplified permitting for the infrastructure funding agency when offsite compensatory mitigation is required
- Fewer permitting or regulatory delays resulting from the need to find mitigation solutions
- Greater ecological and financial predictability
- Mitigation site planning, management, and monitoring efficiencies
- The ability to focus on large-scale conservation to benefit sensitive species through higher quality habitat, improved connectivity between habitat areas, and better long-term protection
- The ability to leverage and assist ongoing conservation efforts taking place at the local and state level
- Greater "co-benefits" to the environment and community, including cleaner water and air, open space and recreational opportunities, and improved public health

Where offsite mitigation is needed, RAMP potentially provides greater ecological and financial predictability and can better align project mitigation with regional conservation priorities. If cost savings are realized via RAMP, it could allow infrastructure bond funding to be used for even more flood protection measures and transportation projects, and result in a higher level of protection for State resources. More information about RAMP is available at https://rampcalifornia.water.ca.gov.

3.0 Acronyms and Abbreviations

Board ..... Central Valley Flood Protection Board

Caltrans..... California Department of Transportation

Conservation Strategy Central Valley Flood System Conservation Strategy

CVFPP ..... Central Valley Flood Protection Plan

DFG ..... Department of Fish and Game

DWR ..... California Department of Water Resources

HCP ..... Habitat Conservation Plan

NCCP..... Natural Community Conservation Planning

RAMP..... regional advance mitigation planning

SPFC ..... State Plan of Flood Control

State..... State of California

USACE..... U.S. Army Corps of Engineers

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

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

Attachment 9B

Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area

CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 9B: Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Table of Contents

1.0 Introduction 1-1
1.1 Purpose of Status and Trends Report 1-1
1.2 Background 1-1
1.3 CVFPP Planning Areas 1-2
1.4 2012 CVFPP Planning Goals 1-4
1.5 Scope of Status and Trends Assessment 1-4
1.6 Report Organization 1-5

2.0 Historical Conditions and Modifications of Central Valley Riparian and Riverine Ecosystems 2-1
2.1 Sacramento Valley Ecosystems 2-1
2.1.1 Pre-1850 Riparian and Riverine Ecosystems 2-1
2.1.2 Historical Modifications of the Riparian and Riverine Ecosystems 2-5
2.2 San Joaquin Valley Ecosystems 2-9
2.2.1 Pre-1850 Riparian and Riverine Ecosystems 2-9
2.2.2 Historical Modifications of the Riparian and Riverine Ecosystems 2-11

3.0 Basis for Evaluation of Status, Trends, and Stressors 3-1
3.1 Scope of Status, Trends, and Stressor Evaluation 3-1
3.2 Hydrologic Processes 3-1
3.2.1 Floodplain Inundation Flow 3-3
3.2.2 Bankfull Flow 3-3
3.2.3 Base Flow 3-4
3.3 Geomorphic Processes 3-4
3.4 Ecosystem Responses 3-6
3.4.1 In-Channel Responses 3-6
3.4.2 Floodplain Responses 3-9
3.5 Primary Stressors 3-11
3.5.1 Levees and Bank Revetment 3-11
3.5.2 Reservoirs 3-13
3.5.3 Diversions 3-17
3.5.4 Invasive Species 3-18
3.5.5 Fish Passage Barriers 3-19

4.0 Status, Trends, and Stressor Assessment 4-1
4.1 Status and Trends Metrics 4-1
4.1.1 Hydrologic Processes 4-1
4.1.2 Channel and Floodplain Dynamics 4-13
4.1.3 Riparian and Riverine Habitats 4-21
4.2 Stressor Metrics 4-48
4.2.1 Levees and Bank Revetment 4-48
4.2.2 Reservoirs 4-51
4.2.3 Diversions 4-59
4.2.4 Invasive Species 4-60
4.2.5 Fish Passage Barriers 4-68

5.0 Recommendations and Conclusions 5-1
5.1 Data Gaps and Analysis Needs 5-1
5.1.1 Hydrologic Processes 5-1
5.1.2 Channel and Floodplain Dynamics 5-2
5.1.3 Riverine and Riparian Habitats 5-3
5.1.4 Levees and Bank Revetment 5-4
5.1.5 Reservoirs 5-5
5.1.6 Diversions 5-5
5.1.7 Invasive Species 5-5
5.1.8 Fish Passage Barriers 5-6
5.2 Development of Conceptual Models 5-6
5.3 Conclusions 5-9

6.0 References 6-1

7.0 Abbreviations and Acronyms 7-1

List of Tables

Table 2-1. Major Human Activities that Affected the Hydrology of the Sacramento River, 1849–2010 2-6

Table 2-2. Major Human Activities That Affected the Hydrology of the San Joaquin River, 1849–2010 2-12

Table 3-1. Effects of Different Categories of Flows on Geomorphic and Ecological Processes and Species 3-2

Table 4-1. Periods of Record for Hydrologic Process Metrics 4-2

Table 4-2. Probable Historical Distribution of Key Riparian-Associated Species 4-41

List of Figures

Figure 1-1. Central Valley Flood Protection Plan Planning Areas 1-3

Figure 1-2. Relationships Among Hydrologic and Geomorphic Processes, Habitats, and Representative Species of Sacramento and San Joaquin Valley Streams 1-5

Figure 2-1. Extent of “Overflowed Lands” (Tule Marshes) (Shaded Area) in the Sacramento Valley in 1873 2-2

Figure 2-2. Extent of “Overflowed Lands” (Tule Marshes) (Shaded Area) in the San Joaquin Valley in 1873 2-4

Figure 4-1. Monthly Median Flows in the Sacramento River at Bend Bridge (USGS Gage 11377100) 4-3

Figure 4-2. Monthly Median Flows in the San Joaquin River at Friant (USGS Gage 11251000) 4-3

Figure 4-3. Median Spring Flow in the Sacramento River at Bend Bridge (USGS Gage 11377100) 4-5

Figure 4-4. Median Spring Flow in the San Joaquin River at Friant (USGS Gage 11251000) 4-5

Figure 4-5. Mean Annual Discharge, Frequency, and Duration of Floodplain Inundation Flows and Bankfull Flows in the Sacramento River at Bend Bridge (USGS Gage 11377100) 4-8

Figure 4-6. Mean Annual Discharge, Frequency, and Duration of Floodplain Inundation Flows and Bankfull Flows in the San Joaquin River at Friant (USGS Gage 11251000) 4-9

Figure 4-7. Base-Flow Discharge in the Sacramento River at Bend Bridge (USGS Gage 11377100) 4-12

Figure 4-8. Base-Flow Discharge in the San Joaquin River at Friant (USGS Gage 11251000) 4-13

Figure 4-9. Change in Total River Length over Time for the Middle Sacramento River (RM 143 to RM 244) 4-15

Figure 4-10. Calculation Method of Area of Floodplain Reworked 4-16

Figure 4-11. Area of Floodplain Reworked over Time for the Middle Sacramento River (RM 143 to RM 244) 4-17

Figure 4-12. Floodplain Age Mapped Along the Middle Sacramento River (RM 145 to RM 243) 4-19

Figure 4-13. Area of Newly Created Floodplain by Year Along the Middle Sacramento River (RM 217 to RM 243) 4-21

Figure 4-14. Percent Natural Bank Length and SRA Cover by Reach 4-24

Figure 4-15. LWM Cover Class Distribution of Riparian Scrub and Forest by Reach 4-25

Figure 4-16. Riparian and Wetland Habitat in the Central Valley 4-27

Figure 4-17. Riparian and Wetland Habitat in the Central Valley: Red Bluff to Colusa 4-28

Figure 4-18. Riparian and Wetland Habitat in the Central Valley: Colusa to Verona 4-29

Figure 4-19. Riparian and Wetland Habitat in the Central Valley: Verona to Rio Vista 4-30

Figure 4-20. Riparian and Wetland Habitat in the Central Valley: Delta 4-31

Figure 4-21. Riparian and Wetland Habitat in the Central Valley: Paradise Cut to Merced River 4-32

Figure 4-22. Riparian and Wetland Habitat in the Central Valley: Merced River to Friant Dam 4-33

Figure 4-23. CNDDB Occurrences: Bank Swallow 4-37

Figure 4-24. CNDDB Occurrences: Valley Elderberry Longhorn Beetle 4-38

Figure 4-25. CNDDB Occurrences: Least Bell's Vireo, Riparian Woodrat, Riparian Brush Rabbit, and Yellow-Breasted Chat 4-39

Figure 4-26. Chinook Salmon Historic and Current Distribution in the Central Valley 4-43

Figure 4-27. Central Valley Steelhead Historic and Current Distribution in the Central Valley 4-44

Figure 4-28. Winter-Run Chinook Salmon Escapement in the Central Valley 4-46

Figure 4-29. Spring-Run Chinook Salmon Escapement in the Central Valley 4-46

Figure 4-30. Fall-Run Chinook Salmon Escapement in the Central Valley 4-47

Figure 4-31. Late Fall-Run Chinook Salmon Escapement in the Sacramento River System 4-47

Figure 4-32. Central Valley Steelhead Adult Return Estimates in the Upper Sacramento River System 4-49

Figure 4-33. Levees in the Central Valley 4-52

Figure 4-34. Bank Revetment in the Sacramento Valley 4-53

Figure 4-35A. Meander Potential Along the Sacramento River (RM 170 to RM 243) 4-55

Figure 4-35B. Meander Potential Along the Sacramento River (RM 103 to RM 170) 4-57

Figure 4-36. Diversions in the Central Valley 4-62

Figure 4-37. Invasive Plant Species in Riparian and Riverine Habitat in the Central Valley 4-63

Figure 4-38. Giant Reed Distribution in the Central Valley 4-66

Figure 4-39. Red Sesbania Distribution in the Central Valley 4-67

Figure 4-40. Fish Passage Barriers in the Central Valley 4-69

Figure 5-1. Conceptual Model Diagram Example for Central Valley Swainson's Hawk Conservation 5-8

1.0 Introduction

This section states the purpose of this attachment, gives background information (including a description of planning areas and goals), discusses the scope of the status and trends assessment, and provides an overview of the report organization.

1.1 Purpose of Status and Trends Report

The purpose of this status and trends report is to summarize the current status and historical trends of riparian and riverine ecosystems in the Systemwide Planning Area for the Central Valley Flood Protection Plan (CVFPP). This area includes lands that are subject to flooding under the current facilities and operation of the Sacramento-San Joaquin River Flood Management System. The lands that currently receive protection from the State Plan of Flood Control (SPFC) are entirely within the SPA.

The summary of status and trends in this report is intended to document the need for and support of the development of the Conservation Framework. The Conservation Framework will be a component of the 2012 CVFPP and the Central Valley Flood System Conservation Strategy (CVFSCS). It will describe how environmental stewardship would be an integral part of CVFPP actions to improve integrated flood management in lands currently protected by facilities of the SPFC flood management system in the SPA. The CVFSCS will identify opportunities in the SPA to promote natural dynamic hydrologic and geomorphic processes; increase and improve the quantity, diversity, and connectivity of habitats; and promote the recovery and stability of native species' populations.

This interim report, developed to support the 2012 CVFPP, will be followed by a more complete report to be prepared at a later date, in concert with the CVFSCS, during development of the 2017 CVFPP.

1.2 Background

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, the California Department of Water Resources (DWR) has prepared a sustainable, integrated flood management plan called the CVFPP, for adoption by the Central Valley Flood Protection Board (Board). The 2012 CVFPP provides a systemwide approach to

protecting lands currently protected from flooding by existing facilities of the SPFC, and will be updated every 5 years.

As part of development of the CVFPP, a series of technical analyses were conducted to evaluate hydrologic, hydraulic, geotechnical, economic, ecosystem, and related conditions within the flood management system and to support formulation of system improvements. These analyses were conducted in the Sacramento River Basin, San Joaquin River Basin, and Sacramento-San Joaquin Delta (Delta).

As a supplement to the CVFPP, this status and trends report is intended to provide SPFC planners and engineers with relevant ecological background on Sacramento Valley and San Joaquin Valley riparian and riverine ecosystems, including an overview of the hydrologic and geomorphic processes that contribute to the structure and function of these ecosystems. It focuses on stressors specifically related to operations and maintenance of the SPFC so that flood system planners and engineers can understand the ecological consequences of previous flood management decisions and consider the potential ecological consequences of management actions considered as part of the 2012 CVFPP.

1.3 CVFPP Planning Areas

For planning and analysis purposes, and consistent with legislative direction, two geographical planning areas were important for CVFPP development (Figure 1-1):

- **SPFC Planning Area –** This area is defined by the lands currently receiving flood protection from facilities of the SPFC (see *State Plan of Flood Control Descriptive Document* (DWR, 2010)). The State of California's (State) flood management responsibility is limited to this area.

- **Systemwide Planning Area –** This area includes the lands that are subject to flooding under the current facilities and operation of the Sacramento-San Joaquin River Flood Management System (California Water Code Section 9611). The SPFC Planning Area is completely contained within the Systemwide Planning Area which includes the Sacramento River Basin, San Joaquin River Basin, and Delta regions.

Planning and development for the CVFPP occurs differently in these planning areas. The CVFPP focused on SPFC facilities; therefore, evaluations and analyses were conducted at a greater level of detail within the SPFC Planning Area than in the Systemwide Planning Area.

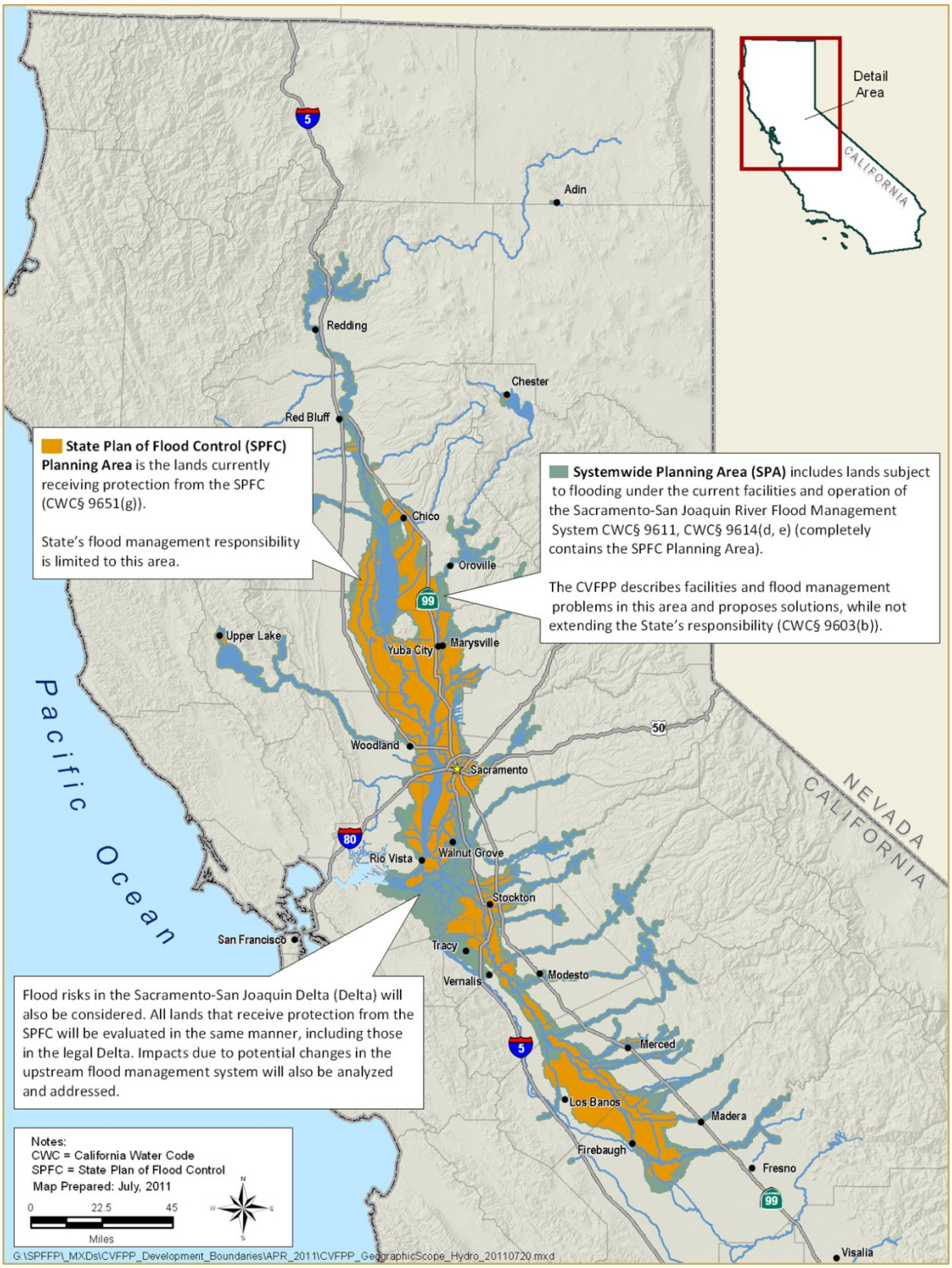


Figure 1-1. Central Valley Flood Protection Plan Planning Areas

This status and trends report focuses on the Systemwide Planning Area.

1.4 2012 CVFPP Planning Goals

To help direct CVFPP development to meet legislative requirements and address identified flood-management-related problems and opportunities, a primary and four supporting goals were developed:

- **Primary Goal**: Improve Flood Risk Management
- Supporting Goals:
  - Improve Operations and Maintenance
  - Promote Ecosystem Functions
  - Improve Institutional Support
  - Promote Multi-Benefit Projects

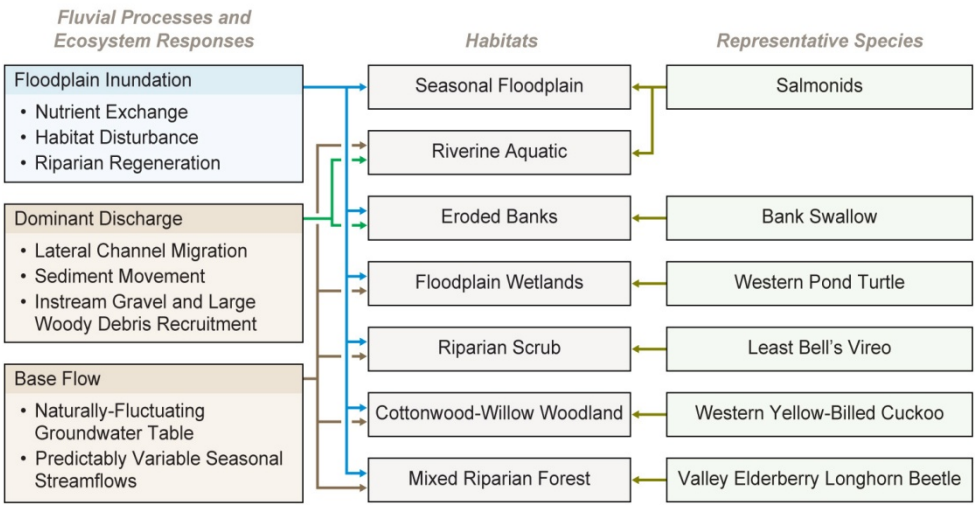
This attachment provides the important background necessary for achieving the goal of promoting ecosystem functions.

1.5 Scope of Status and Trends Assessment

This report is not intended to be an exhaustive description of the SPA's riparian and riverine ecosystems. Rather, it focuses on describing key relationships among the Sacramento Valley's and San Joaquin Valley's river flows, geomorphic processes, and ecosystem responses that are relevant for understanding how these ecosystems function and how key stressors have modified these ecosystems historically and continue to modify them today. It also identifies key data gaps regarding stressors and current status and trends. Documenting these relationships is an important initial step in the development of a CVFSCS.

This report examines only those hydrologic and geomorphic processes that are most strongly linked to ecosystem functions, and it focuses on representative habitats and species that are most indicative of Sacramento Valley and San Joaquin Valley riparian and riverine ecosystems. Similarly, the report assesses the effects of only a limited number of stressors that are thought to have had the greatest effect on hydrologic and geomorphic processes and related riparian and riverine habitats. These stressors are strongly linked to the operations and maintenance of the SPFC because these stressors are most likely to be mitigated through potential

modifications to the SPFC adopted as part of the CVFPP. As stated above, it is intended to provide a foundation for a more detailed assessment conducted during development of the CVFSCS. Processes and related habitats, stressors on these processes and habitats, and interrelationships among processes, habitats, and stressors discussed in this ecological status and trends report are shown on Figure 1-2.



Source: Prepared by AECOM in 2011

Figure 1-2. Relationships Among Hydrologic and Geomorphic Processes, Habitats, and Representative Species of Sacramento and San Joaquin Valley Streams

1.6 Report Organization

Organization of this document is as follows:

- Section 1 introduces and describes the purpose of this report.
- Section 2 describes the ecological history of the Sacramento Valley's and San Joaquin Valley's riparian and riverine ecosystems, how these ecosystems historically functioned, and early stressors on these ecosystems that have contributed to their current status and observed trends.
- Section 3 builds from the relationships illustrated on Figure 1-2 and describes the ecological relevance of the hydrologic and geomorphic processes emphasized in this report and the mechanisms by which these processes interact with each other and affect the ecosystem functions of Sacramento Valley and San Joaquin Valley riparian and riverine habitats. Additionally, it describes the mechanisms by which specific

stressors negatively affect hydrologic, geomorphic, and ecosystem processes.

- Section 4 assesses the status and trends of Sacramento Valley and San Joaquin Valley hydrologic processes, geomorphic processes, and related habitats through a series of metrics calculated from readily available data described in detail in Section 4. Each metric is described in a concise summary that identifies the rationale for selecting that metric to illustrate a particular process or habitat status, trend, or stressor; describes how the metric was developed and analyzed; and identifies the primary conclusion that can be drawn from each metric. The assessment relies heavily on graphical representations of each metric (e.g., charts or maps).

- Section 5 summarizes data gaps documented during the analysis of status, trends, and stressor metrics and highlights the potential for conceptual ecological models as a planning tool for the CVFSCS. Key data gaps need to be documented and the utility of conceptual ecological models needs to be highlighted because this report is intended to serve as the framework for a future, more comprehensive report developed as part of the CVFSCS.

- Section 6 contains references for the sources cited in this document.

- Section 7 lists abbreviations and acronyms used in this document.

2.0 Historical Conditions and Modifications of Central Valley Riparian and Riverine Ecosystems

This section describes the historical conditions of the Sacramento Valley and San Joaquin Valley riparian and riverine ecosystems before the Gold Rush and the subsequent modification of these ecosystems associated with settlement and development. The description of historical conditions and modifications provides a framework for understanding the origins of conditions observed today.

2.1 Sacramento Valley Ecosystems

2.1.1 Pre-1850 Riparian and Riverine Ecosystems

The Sacramento River is more than 400 miles long and drains a watershed of more than 27,000 square miles. Inflow to the Delta in an average water year is approximately 21.3 million acre-feet (URS Corporation, 2007). The Sacramento River is mainly a rainfall river, with discharges that before the construction of major dams on average peaked in February to April (see Section 4). High flow variability and limited channel capacities resulted in frequent flooding of the lowland basins that cover most of the Sacramento Valley floor: the Butte, Marysville, Colusa, Sutter, American, Yolo, and Sacramento basins (Singer et al., 2008). Before the construction of major dams, the Sacramento River carried large amounts of sediment that was deposited along broad natural levees that bordered the river channel during overbank flows (James and Singer, 2008). At flood stages, the river flowed into its flood basins through openings in the natural levees and deposited large amounts of silt. In these flood basins, known as “tulares,” large expanses of freshwater marsh were dominated by common tule (*Schenoplectus acutus*) (Figure 2-1).

In the Sacramento Valley, the Sacramento River and its major tributary, the Feather River, are affected by valley tectonics and geology (Singer et al., 2008). Upstream from Red Bluff, the Sacramento River descends to the Sacramento Valley floor mostly between bedrock bluffs. In this reach, there is little opportunity for the river to meander or to overflow onto adjacent floodplains. Downstream from Red Bluff, the Sacramento River is a broadly meandering, alluvial river until it reaches the city of Colusa.

Source: Alexander et al., 1874

Figure 2-1. Extent of "Overflowed Lands" (Tule Marshes) (Shaded Area) in the Sacramento Valley in 1873

There, it encounters a buried geologic formation known as the Colusa Dome.

The presence of the Colusa Dome has resulted in the surface expression of a Modesto Formation outcrop, an erosion-resistant Pleistocene alluvial geologic formation commonly encountered in the Sacramento and San Joaquin valleys (Singer and Dunne, 2001). At this point, the river is deflected east, where it passes between the Colusa Dome and the Sutter Buttes, causing a sequestration of water and sediment in the reach upstream from this deflection point and a decrease in downstream channel capacity of approximately 70 percent (Singer et al., 2008).

Another major geologic control is formed by the Pleistocene alluvial fan of Cache Creek, a westside tributary. This obstacle causes the river to run eastward to the confluence with the Feather River at Verona. Because backwaters would be created here historically during floodflows, the Knights Landing Ridge Cut was dug through the Cache Creek fan in 1915 to bring floodflows to the Yolo Bypass.

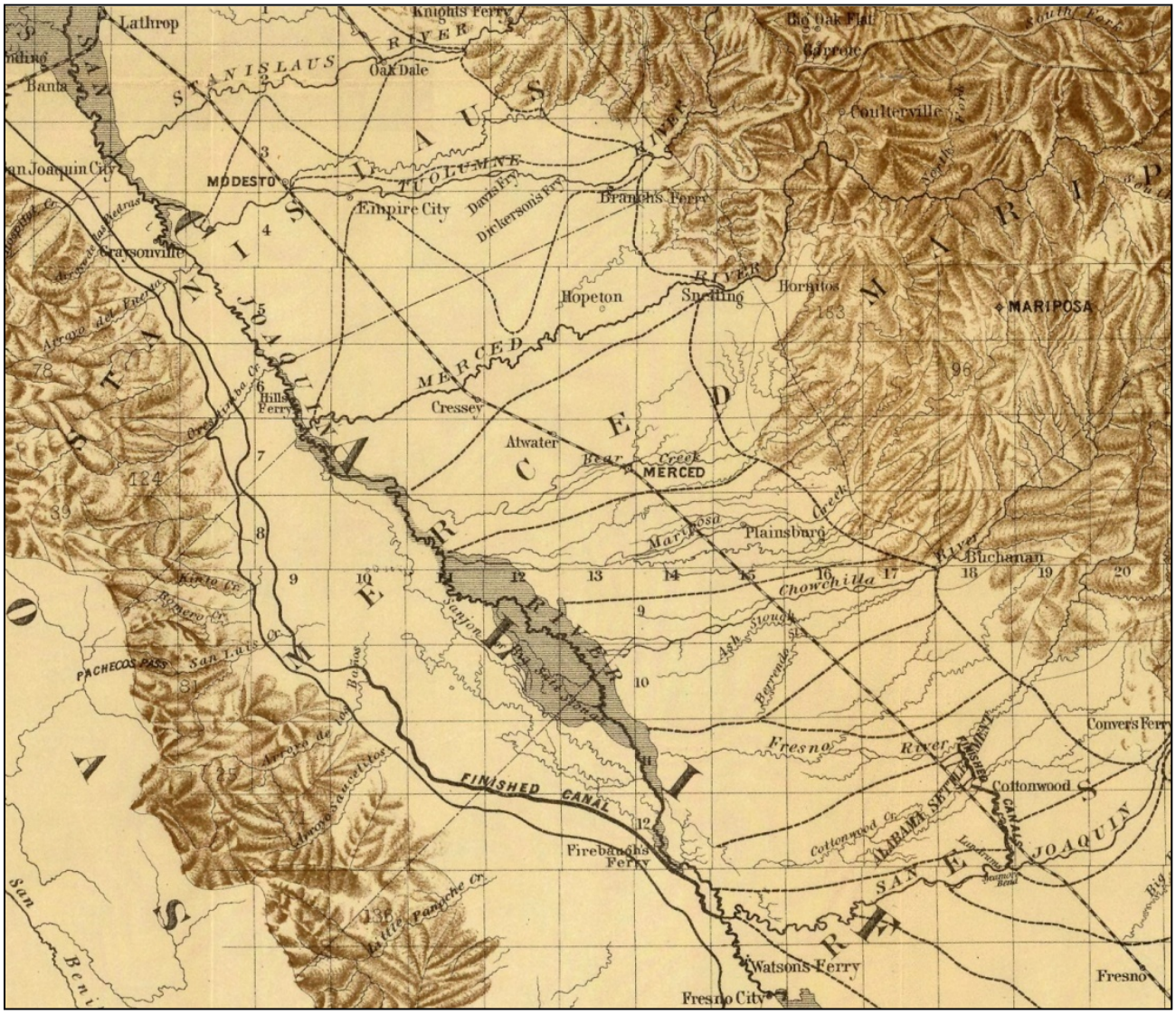
The land surface of the basins in the Sacramento Valley outside the natural levees has historically subsided and is lower in elevation than the floodplains directly along the river corridor (Singer et al., 2008). In some reaches, such as at the south side of the river between Knights Landing and Verona, at the current site of the Fremont Weir, the river frequently broke through the natural levees and deposited “alluvial splays” within the subsided basins.

The pre-1850 vegetation of the Sacramento Valley reflected the valley’s geomorphology. The subsided basins of the valley floor where the rivers deposited silts and clay during flood stage supported extensive tule marshes. The total area of tule marshes and other associated wetlands and open water was estimated by The Bay Institute (1998) by digitizing maps developed by Hall (1887, cited in The Bay Institute, 1998) and Alexander et al. (1874) (Figures 2-1 and 2-2). The total extent of wetlands in 1873 was estimated at approximately 300,000 acres in the Sacramento Valley (The Bay Institute, 1998).

The historical acreage of marshes and other types of wetlands in the riparian zone of the Sacramento Valley was estimated at 87,000 acres, the remainder of the 300,000 acres of wetland was mostly tule marsh in the basins (The Bay Institute, 1998). Riparian forest that occupied the natural levees and adjacent alluvial lands (e.g., splays) along the Sacramento River in the Sacramento Valley has been estimated at 364,000 acres (The Bay Institute, 1998). Because the disturbance regime along the channel and floodplain of the river was highly dynamic, with ongoing meandering

processes forming point bars at the inside of bends and eroding steep banks at the outside of bends, the riparian habitat was diverse, with a mosaic of patches of different riparian habitat types (see Section 3). At its upland edges, the riparian forest graded into grassland and valley oak woodland.

The grasslands and woodlands associated with the riparian zone occupied approximately 186,000 acres of the Sacramento Valley (The Bay Institute, 1998).



Source: Alexander et al., 1874

Figure 2-2. Extent of "Overflowed Lands" (Tule Marshes) (Shaded Area) in the San Joaquin Valley in 1873

Historically, aquatic habitat in the Sacramento River and its tributaries was more diverse and variable than it is under current conditions. Periodically flooded basins provided seasonal rearing habitat for many native fish species, including salmonids (Sommer et al., 2001, 2003). Riparian forest canopies provided inputs of organic material, including large woody material (LWM), which provided abundant instream structure, shade, and reduced water temperatures, important habitat components for migrating salmonids and other native fish species. Salmonid fish species had access to their spawning grounds in the foothills and mountains and were historically much more abundant than today (Moyle, 2002). Historically, the dead Chinook salmon (*Oncorhynchus tshawytscha*) provided an estimated nutrient input of 20 million to 80 million pounds of organic matter per year for the entire Central Valley ecosystem (Moyle and Yoshiyama, 1992, cited in The Bay Institute, 1998). The abundant salmon fed numerous wildlife species, including the now extinct California grizzly bear (*Ursus arctos horribilis*).

Riparian and marsh vegetation of Sacramento Valley floodplains and flooded basins also supported abundant wildlife. The high diversity of riparian forest most likely supported a diverse assemblage of breeding birds. The tule marshes supported large numbers of waterfowl, and other species, such as beaver (*Castor canadensis*), and tule elk (*Cervus canadensis* ssp. *nannodes*) (The Bay Institute, 1998).

2.1.2 Historical Modifications of the Riparian and Riverine Ecosystems

In the 1850s, American and European settlers of the Sacramento Valley drained and cultivated the fertile flood basins and dug irrigation canals and ditches to provide their fields with water diverted from the Sacramento River and its tributaries. Floods in the early 1850s led the communities to build protective levees (James and Singer, 2008).

The Sacramento River spilled into its natural flood basins at relatively low flood stages. The construction of levees resulted in increased flood stages and velocities and more serious flooding when floods did occur. To counter the increased flooding severity, levees were built along longer stretches of the river and tributaries and were incrementally increased in height (James and Singer, 2008). Competing levee districts often knowingly exacerbated flooding in neighboring lands by building higher levees on their lands that forced flooding onto adjacent lands. These “levee wars” lasted until 1876, when building dams and levees that endangered others was outlawed in California (James and Singer, 2008).

At the same time, hydraulic mining became increasingly common in the northern Sierra Nevada. This practice produced large amounts of sediment

that was delivered in torrents to the Sacramento Valley, starting in the early 1860s. It caused increased flooding along rivers of the Sacramento Valley (i.e., the lower Yuba, Feather, Bear, American, and Sacramento rivers) because it raised channel beds, and decreased channel gradients and flood conveyance capacity (James and Singer, 2008). Hydraulic mining on tributaries to navigable rivers was halted by the Sawyer Decision in 1884, but storage and remobilization of sediment continue to this day (James and Singer, 2008). Sediment delivery from the mountains to the valley was stopped by major dams built from 1928 to 1967 (Table 2-1).

Table 2-1. Major Human Activities that Affected the Hydrology of the Sacramento River, 1849–2010

Year	Activity
1849	Gold Rush started
1852	Hydraulic mining started
1884	Federal injunction banned the use of hydraulic mining unless sediment was controlled (*Woodruff v. North Bloomfield et al.*)
1895	(Old) Folsom Dam constructed
1902	Sutter Butte Canal Company started construction of large facilities near Gridley
1912	Construction of Goodwin Dam completed on Stanislaus River
1914	Sacramento River Flood Control Project levees constructed for improved flood control and navigation, and to minimize flooding related to increased elevation of riverbed caused by mining debris
1916	Sacramento Weir constructed (releases to Sacramento Bypass started)
1924	(Old) Bullards Bar Dam completed on Yuba River
1924	Fremont Weir constructed (releases to Yolo Bypass started)
1933	Colusa Weir constructed (releases to Colusa and Sutter basins started)
1944	Construction of Shasta Dam completed on Sacramento River
1950	Construction of Keswick Dam completed on Sacramento River downstream from Shasta Dam
1955	Construction of Nimbus Dam and power plant completed on American River
1956	Construction of Folsom Dam completed on American River
1960	Sacramento Ship Channel constructed
1963	Construction of Whiskeytown Dam completed on Clear Creek (tributary to Sacramento River)
1963	Construction of Lewiston Dam completed on Trinity River, and Clear Creek Tunnel, which transfers water from Trinity River to Whiskeytown Lake in the Sacramento River watershed, completed
1964	Construction of Trinity Dam completed on Trinity River
1967	Construction of Oroville Dam completed on Feather River
1969	Construction of New Bullards Bar Dam completed on Yuba River

Sources: Reclamation, 1997, pp. II-7 through II-14; James and Singer, 2008, p. 132

In the late 19th century, the state and federal governments' flood control strategy in the Sacramento Valley focused on a single-channel system, with tall, narrowly spaced levees, to encourage bed scour that would remove mining debris and improve opportunities for navigation. After the California Debris Commission was formed in 1893, state-federal cooperation on flood control started, and a systemwide review of the flood control system was initiated. After major floods in 1907 and 1909, the California Legislature and U.S. Congress adopted the Jackson Plan, which proposed a system of flood bypasses and weirs, widening of the Sacramento River channel near Rio Vista, and many miles of levees. The levee system incorporated existing levees and the construction of new levees. About 200 miles of levees along the main river channels below Colusa were narrowly spaced to promote bed scour, 300 miles of levees were located along tributaries and sloughs, and a setback reach was incorporated upstream from Chico Landing. Because federal funding was not immediately available, construction of the Sacramento River Flood Control Project did not start until 1918. The Sacramento River Flood Control Project is a system of levees, weirs, flood relief structures, and bypasses that was designed to route floodflows from the Sacramento River into a system of bypasses, while additional flood control is provided by major dams. By 1944, 90 percent of the project was completed. Major flood control was also provided by Shasta Dam, and additional flood protection was provided with the closure of Oroville Dam in 1968. Five major weirs were constructed between 1916 and 1933 that allowed the river to overflow into bypasses at specific flood stages or overflow into the Butte Basin designated floodways to make their way into the bypass system. These bypasses incorporated to some degree the historical flood basins described above.

In addition to providing flood control, major dams were constructed to manage irrigation water and generate electricity. Multipurpose dams provide flood storage, but were not economically justified for the purpose of flood control alone. The Sacramento River Flood Control Project should, therefore, be considered within the context of the larger water management system of the federal Central Valley Project and the State Water Project. Reservoir operations include consideration of flood management and the supply of water to agricultural, industrial, and municipal water users in the Central Valley, the Delta, Bay Area (Contra Costa, Santa Clara and Napa counties), and Southern California. Reservoir operations also are adjusted for environmental purposes; for example, to maintain prescribed levels of fresh water in the Delta for the benefit of native fish species.

The conversion of tule marshes and other wetlands, grasslands, oak woodlands, and riparian habitats to agricultural lands on much of the valley floor has resulted in changes in water demand. Water diverted from the

rivers has been supplemented with groundwater, and groundwater pumping has led to a drop in groundwater levels that locally may affect riparian vegetation. The need for irrigation water in summer and fall also has led to reservoir operations that cause higher base flows during summer and fall than occurred before European settlement. This has resulted in higher than historical groundwater levels during this period (see Section 4).

The riparian and riverine ecosystems of the Sacramento River and its tributaries have been affected by the major changes in land use and the resulting need for flood control, and water management. The primary change is that the area of natural habitat has been greatly reduced. Based on 1993 California Department of Fish and Game (DFG) geographic information system (GIS) data, The Bay Institute (1998) concluded that less than 5 percent of the historically mapped wetlands in the Central Valley remain. Most remaining wetlands today are located on federal and state wildlife areas and on private duck clubs that are managed as waterfowl habitat. They are not directly connected to the river and typically are flooded from October to spring. Katibah (1984) estimated that 102,000 acres of riparian forest remained in the Central Valley, or about 11 percent of the pre-1850 area. He also estimated that of this area, 49,000 acres were in “disturbed and/or degraded” condition. The Bay Institute (1998) concluded, based on the 1993 DFG GIS data, that approximately 56,000 acres of riparian forest remains, or approximately 6 percent of the pre-1850 acreage. Much of this riparian habitat is highly fragmented or occurs as narrow strips along waterways. Habitat quality has been further degraded as the result of invasive plant species occurring in riparian habitats, such as saltcedar (*Tamarix* spp.) and giant reed (*Arundo donax*). These species have become especially abundant in stream reaches where geomorphic processes have been disturbed by sand and gravel mining and other disturbances.

The riverine (aquatic) habitat of today is also modified greatly from the pre-1850 condition. The channels have in many areas been straightened, and 150 miles of bank of the Sacramento River have been lined with riprap (The Bay Institute, 1998). In summer, the water tends to be deeper and of more uniform depth than it was before 1850, when aquatic habitats were much more diverse. Major dams on the main stem of the Sacramento River, the Feather River, and other Sacramento River tributaries has led to a substantially modified hydraulic regime with greatly reduced winter peak flows and increased summer flows that convey irrigation water to downstream diversions. The sediment supply has been altered, first by hydraulic mining and subsequently by dam construction. The reduction of riparian forest acreage has led to the reduced recruitment of woody material to the river and the reduced inputs of organic material into the water. The reduction in riparian tree acreage along streambanks has also led to a

reduction in shade and changes in temperature regimes. Bypasses still provide seasonal habitat for native fish species (Sommer et al., 2003); however, the frequency and duration of inundation may be reduced compared to conditions before 1850. Many unscreened diversions along the rivers cause fish mortality, and because of blockage by dams, most potential spawning habitat for salmonids is no longer accessible (The Bay Institute, 1998). Salmon populations, conservatively estimated at 1 million to 2 million spawners in the Central Valley before European settlement, declined to small fractions of these previous numbers as the result of overfishing, blockage and damage of streams by mining, and modifications of flows by dams and water diversions (Yoshiyama et al., 1998). Other native fish species have also been impacted by these stressors, which are described in more detail in Sections 3 and 4.

Although no baseline data are available, the reduction in overall riparian habitat area has no doubt reduced the abundance of wildlife species supported by riparian habitat. For example, the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), a state-listed endangered species and a federal candidate for listing under the Endangered Species Act, breeds in large patches of well-developed, riparian habitat patches that were more abundant historically than today along the Sacramento River (Greco, 2008). California population size at the end of the 19th century was estimated at15,000 breeding pairs (Hughes, 1999, cited in 66 Federal Register 38614, July 25, 2001). Recently, the Sacramento River population of this species has declined from 96 pairs in 1973 to 40 pairs in 2000 (Greco, 2008). A survey conducted in 2010 estimated 38 existing territories that each could be occupied by a pair or individual bird (Dettling and Howell, 2011). To what extent the decline is attributable to loss of Sacramento River riparian habitat is unknown. However, this decline underscores the importance of conserving this riparian habitat-dependent species.

2.2 San Joaquin Valley Ecosystems

2.2.1 Pre-1850 Riparian and Riverine Ecosystems

The San Joaquin River is 330 miles long and drains an area of 15,558 square miles, or 58 percent of the size of the Sacramento River watershed. Inflow to the Delta in an average water year is approximately 2.8 million acre-feet, or 13 percent of the Sacramento River inflow (URS Corporation, 2007). The San Joaquin River is mainly a snowmelt river, with discharges that peak on average in May and June (see Section 4).

The San Joaquin River is inset between terraces as it descends with a low sinuosity into the San Joaquin Valley and down to Gravelly Ford. Historically, the river was flanked by at least two terraces at 40 feet and 20 feet above the current riverbed (Jones & Stokes Associates, 1998a). A diversity of riparian vegetation types representing different successional stages was supported by the river in this reach before Friant Dam was constructed, including riverwash (bare gravel and sand), riparian scrub, cottonwood-willow riparian forest, mixed riparian forest, riparian forest dominated by valley oak (*Quercus lobata*), and substantial areas of herbaceous wetlands (Jones & Stokes Associates, 1998b, 2002).

At Gravelly Ford, the alluvial fan of the San Joaquin River meets the valley floor. The valley slope increases here, resulting in increased river sinuosity until, near the city of Mendota, the river reaches the confluence with the Kings River North (current James Bypass), which drained the former Tulare Lake. At this confluence, the San Joaquin River bends north and extends along the main axis of the San Joaquin Valley. Before Friant Dam was constructed, vegetation in this reach was characterized by extensive wetlands, riparian scrub, and riparian forest (Jones & Stokes Associates, 1998b, 2002).

After the San Joaquin River moves north, sinuosity declines as the slope of the river decreases. The river historically formed a single channel (Jones & Stokes Associates, 1998a) with diverse riparian habitat. This single-channel reach ended approximately 20 river miles to 25 river miles downstream from the confluence with the Kings River North, at the edge of a historical basin, where the river branched into multiple channels and where large expanses of marshes were supported (Figure 2-2) (see also The Bay Institute, 1998, Appendix A, Map G6). The interconnected channels of the basin historically stored and conveyed floodflows that were collected in Mud, Salt, and Sand sloughs, which join the San Joaquin River above the confluence with the Merced River. The alluvial fan of the Merced River functions as grade control for the San Joaquin River (Jones & Stokes Associates, 1998a). Historically, floodflows backed up upstream from the confluence with the Merced River, and extensive tule marshes were located in this reach (Figure 2-2).

The width of the riparian zone and stretches of marsh varied between the confluence with the Merced and Stanislaus rivers. Downstream from the confluence with the Stanislaus River, the San Joaquin River spread into a broad delta covered with tule marshes (Figure 2-2).

The major tributaries of the San Joaquin River, including the Merced, Tuolumne, and Stanislaus rivers, supported their own riparian zones. The remaining remnant of primary riparian forest at Caswell Memorial State

Park on the Stanislaus River provides a glimpse into the historical riparian forest conditions, with massive valley oak trees growing on natural levees along the river meanders. These riparian forests gradually became oak woodlands and grasslands on higher ground. The Mokelumne, Cosumnes, and Calaveras rivers drain into the San Joaquin River in the Delta, each supporting abundant riparian habitat along its banks (The Bay Institute, 1998, Appendix A, Map G6).

The historical extent of the riparian zone in the San Joaquin Valley was approximately 329,000 acres, about half the extent in the Sacramento Valley (The Bay Institute, 1998). In the San Joaquin Valley, riparian zones were generally present in narrower bands than in the Sacramento Valley. The riparian zone was heterogeneous with patches of forest and woodland in drier spots, surrounded by tule marshes (The Bay Institute, 1998).

The pre-1850 San Joaquin River and its major tributaries supported abundant runs of spring- and fall-run Chinook salmon (Cain, 1997). As described for the Sacramento River, the dead salmon historically provided substantial nutrient input to the San Joaquin River ecosystem and fed numerous wildlife species. As in the Sacramento Valley, the high diversity of riparian forest most likely supported a diverse assemblage of breeding birds. The tule marshes supported large numbers of waterfowl.

2.2.2 Historical Modifications of the Riparian and Riverine Ecosystems

Major modifications to the San Joaquin River and its tributaries include the construction of diversion facilities for irrigation, including Friant Dam, which also has a flood management function; construction of flood control levees and channelization (including straightening) of the river; encroachment of agriculture and urban land uses into the floodplain; and aggregate mining in the upper reaches of the San Joaquin River and its tributaries. Table 2-2 lists major modifications that have led to changes in San Joaquin River hydrology.

Table 2-2. Major Human Activities That Affected the Hydrology of the San Joaquin River, 1849–2010

Year	Activity
1849	Gold Rush started
1871	Mendota Dam (Weir) constructed
1872	Miller & Lux Canal constructed along west side of San Joaquin Valley to convey water from San Joaquin River
1912	Goodwin Dam completed on Stanislaus River
1916	Newer Mendota Dam constructed on San Joaquin River with a movable section to allow navigation
1919	Exchequer Dam and Power Plant constructed by Merced Irrigation District
1923	O'Shaugnessy Dam constructed on Tuolumne River (Hetch Hetchy Reservoir created)
1923	Don Pedro Reservoir constructed on Tuolumne River
1924	Melones Dam constructed on Stanislaus River
1929	Construction of Pardee Dam completed on Mokelumne River
1940	Water diversions started in Contra Costa Canal
1944	Construction of Friant Dam completed on San Joaquin River
1951	Construction of Delta Cross Canal, Delta-Mendota Canal, and Tracy Pumping Plant completed
1958	Construction of Tulloch Dam completed on Stanislaus River
1963	New Hogan Dam completed on Calaveras River
1963	Construction of Camanche Dam completed on Mokelumne River
1959-1966	Implementation of the Lower San Joaquin River Flood Control System, including construction of bypass system, above Merced River
1967	Construction of San Luis Canal and Dam completed
1967	Construction of New Exchequer Dam completed on Merced River
1967	Construction of State Water Project Delta pumps and California Aqueduct completed
1970	Construction of New Don Pedro Dam completed on Tuolumne River
1978	Construction of New Melones Dam completed on Stanislaus River
1992	Central Valley Project Improvement Act enacted
1998	Los Vaqueros Reservoir completed

Sources: Reclamation, 1997, pp.II-7 – II-14; James and Singer, 2008, p. 132

The first major changes to the San Joaquin River were facilities built for irrigation, including the Miller & Lux Canal, a major canal built on the west side of the San Joaquin Valley that was completed in 1872 (Table 2-2). Frequently, temporary dams were placed in the river to divert irrigation water. These dams usually failed during floodflows in winter. One of the major examples is Sack Dam, which was originally built from sand bags, but is now a permanent structure, and which diverts water into the Arroyo Canal. A diversion dam at Mendota was first built in 1871 and has been replaced several times since then. The Mendota Pool behind this dam is a major diversion point for irrigation water. The most important changes to the hydrology of the San Joaquin River occurred when Friant Dam was completed in 1944 and when the Delta-Mendota Canal was completed in 1951 (Table 2-2).

Friant Dam intercepts all San Joaquin River water except floodflows and flows needed to maintain water rights downstream from the dam to Gravelly Ford. Almost all water released from Friant Dam is routed into two major irrigation canals. The result is that the reach between Gravelly Ford and the Mendota Pool has been dry during a large part of the year. In some cases, this reach can be dry continuously for several years. The Delta-Mendota Canal brings high-quality Delta water to the Mendota Pool. Some of the water is taken out of Mendota Pool for irrigation, and some of it moves down the river where it is diverted into numerous canals, such as the Arroyo Canal. Near the Sand Slough Control Structure, the flow has become so small that the river passes through a culvert.

The system of sloughs that enter the river upstream from the confluence with the Merced River captures agricultural return water and carries it back into the river. The quality of this water is poor. Groundwater in this reach of the river also appears to be of relatively poor quality because it has high levels of boron and salt (Jones & Stokes Associates, 1998a).

Although local levees have existed along the San Joaquin River since the 19th century, the San Joaquin River Flood Control Project levees were constructed between 1956 and 1972 by the state and federal Lower San Joaquin River and Tributaries Project from the Delta upstream to the Merced River. Additional modifications were completed in the 1980s. In the upper reaches from the Delta to Mossdale in the Stockton Area, the levees are frequently narrowly spaced. Below Mossdale, near the Stanislaus River, they become more set back and often are on just one side of the river. Between the Stanislaus River and Merced River, levees are discontinuous, allowing some overflow during high waters. In this reach, Paradise Cut Bypass carries floodwaters directly to Old River and Delta channels.

Immediately upstream from the Merced River to the beginning of the bypass system near the Sand Slough Control Structure, project levees alternate between being located on only the east side or on both sides of the San Joaquin River. Upstream from this point, between the San Joaquin Flood Control Structure and Fresno Slough, about 45 miles of the San Joaquin River have no SPFC levees or facilities. This reach differs from the downstream reaches in that it is not a single channel, but rather an anabranching river system with Salt Slough, Sand Slough, Mariposa Slough, and the San Joaquin River in parallel channels.

The Chowchilla, Eastside, and Mariposa bypass system intercepts flows from Bear Creek, Owens Creek, Chowchilla River, Ash Slough, Berenda Slough, and the Fresno River in addition to two-thirds of the San Joaquin River's higher flows. Initially, the U.S. Army Corps of Engineers (USACE) recommended that approximately 118,000 acres of grassland floodplain between Friant Dam and the Merced River be retained as flood detention basins, in lieu of flood protection works (Reclamation Board, 1966). Instead, between 1956 and 1966, the state designed and constructed the Eastside Bypass system from the Merced River upstream to the head of the Chowchilla Bypass, isolating about 240,000 acres of floodplain from the San Joaquin River (Mussetter Engineering and Jones & Stokes Associates 2002).

In some areas, the soil may not be suitable for farming – for example, in the reach upstream from the confluence with the Merced River, where a claypan subsoil makes cultivation difficult. Here, higher ground is used as pastureland, and lower areas have been converted to state wildlife management areas, federal national wildlife refuges (e.g., the San Luis National Wildlife Refuge Complex), or private duck clubs (e.g., many acres of private wetlands in the Grasslands Irrigation District). These wetland areas provide important wintering habitat for waterfowl that migrate along the Pacific Flyway.

Flow regulation by Friant Dam has had a dramatic effect on riparian habitats. Without scouring flows, natural succession has progressed uninterrupted in most areas, and early successional stages of riparian vegetation, such as riverwash, riparian scrub, and cottonwood-willow forest, have declined in cover, while the extent of mixed riparian forest has increased (Jones & Stokes Associates, 1998b, 2002). In some reaches – for example, downstream from Mendota Dam – riparian forest flourishes directly along the channel because of continual high base flows. Downstream from Sack Dam, riparian vegetation completely covers the riverbed because floodflows bypass these areas, but they remain wet throughout the summer because of leakage through the dam or agricultural runoff (Jones & Stokes Associates, 1998a).

As described for the Sacramento River, the reduction in overall riparian habitat area has no doubt reduced the abundance of wildlife species supported by riparian habitat. A number of neotropical migrant songbirds breed in riparian scrub, such as the least Bell's vireo (*Vireo bellii pusillus*), which is state- and federally listed as endangered, but riparian scrub habitat for these species has been greatly reduced along the San Joaquin River (Jones & Stokes Associates, 1998b, 2002).

The dry sections of the San Joaquin River form a major obstacle to migration by salmonids. As the result of a legal settlement, the U.S. Department of Interior, Bureau of Reclamation (Reclamation), is restoring a self-sustaining Chinook salmon population to the San Joaquin River between the Merced River and Friant Dam. The Merced, Tuolumne, and Stanislaus rivers each have remnant Chinook salmon runs that spawn below the major dams on these rivers (on the Merced River, salmon are also reared in a hatchery). On each of these rivers, active riparian and riverine habitat restoration projects have been implemented to improve Chinook salmon habitat, including the isolation of instream gravel pits from the river channel. A whole community of native fish, including hitch (*Lavinia exilicauda*), California roach (*Lavinia symmetricus*), hardhead (*Mylopharodon conocephalus*) and others that were present in the 19th century in the San Joaquin River at Friant have been replaced by largely nonnative species such as largemouth bass (*Micropterus salmoides*) and common carp (*Cyprinus carpio*) (Moyle 2002, Table 9). The largest change in fish community composition occurred after the construction of Friant Dam.

The operation of Friant Dam has prevented the regeneration of willows and cottonwoods. Typically, these species germinate in June on bare sand or gravel bars that under natural conditions typically would be deposited by a moderate-sized flood (e.g., 10-year flood) in western rivers (Stromberg et al., 1991; Scott et al., 1997; Shafroth et al., 1998). After seed of these species is dispersed by wind in spring and early summer, they may germinate, but the abrupt termination of almost all flow releases in spring or early summer causes these seedlings to die. Early age classes of willows (e.g., black willow (*Salix gooddingii*) and Fremont cottonwood (*Populus fremontii*) are therefore almost absent from much of the San Joaquin River. A pilot project initiated by the Friant Water Users Authority and the Natural Resources Defense Council in 1999 used water purchased by the CALFED Bay-Delta Program to extend releases from Friant Dam into summer and fall. This project demonstrated that black willow can be established if a gradually declining hydrograph is provided, allowing growing roots to reach the declining groundwater.

The San Joaquin River has been greatly modified by sand and gravel mining, especially in the vicinity of Fresno. Although mining does not occur in the bed of the river, the berms that separate the mining pits from the river frequently are captured by the river at high flows. Sediment transport is affected by these mining pits because the flows may capture coarse sediment, but sand may also "waste" out of these mine pits and be deposited downstream. Sand and gravel mining also occurs along the Merced, Tuolumne, Stanislaus, and Calaveras rivers. To the salmonids that migrate up these rivers, the mining pits become a major potential source of mortality because the warm water in the pits provides ideal habitat for largemouth bass and other nonnative predatory fish that feed on juvenile salmonids.

Although invasive riparian plant species, such as giant reed, are present throughout the riparian habitat along the San Joaquin River, the density of invasive plants is highest in disturbed areas, such as mining pits. Near Fresno, the mining pits have relatively recently become infested by red sesbania (*Sesbania punicea*), and this area is now a seed source for downstream parts of the San Joaquin River and the Delta (Hunter and Platenkamp, 2003). The spread of giant reed, red sesbania, and Chinese tallow (*Triadica sibifera*) reduces habitat area for native plant species, creates lower quality habitat for native wildlife species than native vegetation, and causes flood management problems by increasing the hydraulic roughness of the channel.

3.0 Basis for Evaluation of Status, Trends, and Stressors

3.1 Scope of Status, Trends, and Stressor Evaluation

This section summarizes hydrologic and geomorphic fluvial processes, ecosystem responses to these processes, and stressors that have modified these processes and resulted in adverse effects on Sacramento Valley and San Joaquin Valley riparian and riverine ecosystems. It provides the basis for the description of specific metrics that are indicators of the processes, stressors, and ecosystem responses presented in Section 4.

This section does not provide a comprehensive account of fluvial processes and stressors. Instead, it presents an overview of hydrologic and geomorphic processes that are capable of producing substantial ecosystem responses in the Sacramento and San Joaquin rivers and their tributaries. Much of the information below describes how these processes interact in a hypothetical "typical" river system. Although the resulting characterization may not accurately reflect actual interactions in the Sacramento and San Joaquin rivers today, it provides a conceptual framework for understanding how these processes interact and for evaluating the extent to which they have been modified from historical conditions.

Similarly, the discussion focuses on stressors that have most affected hydrologic and geomorphic fluvial processes and ecosystem responses in the Sacramento Valley's and San Joaquin Valley's rivers and that are affected by the operations and maintenance of the SPFC. Other stressors, such as historical hydraulic mining, urban and agricultural development, and global climate change, are acknowledged as past and likely future stressors, but they are not discussed in this report because they are not reasonably caused by or could be affected by the operations and maintenance of the SPFC.

3.2 Hydrologic Processes

This discussion provides an overview of three ecologically significant categories of flows: floodplain inundation, bankfull, and base flows. The emphasis on these three flows does not imply that other flows (e.g., flows

greater than base flow but less than bankfull) are ecologically insignificant. However, these three flows are generally regarded as more ecologically meaningful than other flows (Poff et al., 1997). Table 3-1 summarizes the effects of the three flow categories on geomorphic processes, ecosystem processes, and species in the riverine and riparian ecosystems. These effects are discussed in more detail below.

Table 3-1. Effects of Different Categories of Flows on Geomorphic and Ecological Processes and Species

	Floodplain Inundation Flow	Bankfull Flow	Base Flow
Geomorphic processes	Causes major changes in channel morphology (scouring, erosion, channel cutoffs, new side channels)	Causes ongoing scouring and erosion of banks, formation of point bars, lateral channel migration, and mosaic of different-aged floodplain surfaces	Causes deposition in channel
	Mobilizes coarse to fine sediments	Mobilizes moderate to fine sediments	Mobilizes fine sediments only
Ecosystem processes	Increases large woody material in river	Increases large woody material in river	Provides perennial flow for fish, birds, and other species and maintains vegetation growth
	Increases dissolved oxygen in water	Increases dissolved oxygen in water	Reduces dissolved oxygen in water
	Increases aquatic structural diversity and exposes gravels for spawning	Increases aquatic structural diversity and exposes gravels for spawning	Decreases aquatic structural diversity
	Enables establishment of early successional vegetation (willows and cottonwoods)	Creates mosaic of riparian vegetation (pioneer to mature) with time	Allows mature vegetation to outcompete early successional species if base flow is prolonged
	Provides nutrients, sediment, and plant seeds to floodplain from upstream	Provides nutrients, sediment, and plant seeds to riverbank from upstream	No major effect
	Increases primary aquatic productivity	No major effect	Allows accumulation of organic materials, as well as contaminants
Species	Provides floodplain habitat to outmigrating salmonids and spawning splittail and increases early successional habitat for plants and animals, potential to strand or isolate fish species	Provides instream fish habitat to channel and maintains diversity of early to late successional habitat for plants and animals	Provides summer channel habitat for fish; causes silts to cover spawning gravels; and facilitates invasion of less-flood-tolerant species, including nonriparian and nonnative species

Source: Prepared by DWR and AECOM in 2011.

3.2.1 Floodplain Inundation Flow

Floodplain inundation occurs when river flows exceed channel capacity, and water overflows onto adjacent land. Typically, floodplain inundation is associated with storms occurring more frequently than once every 2 years (Leopold et al., 1964), although the actual frequency of floodplain inundation is affected by watershed characteristics, channel morphology, and channel incision, in particular, along a given river reach. In the Sacramento and San Joaquin valleys, floodplain inundation can occur at any time during the rainy season roughly from October 1 through May 31. It lasts for a variable duration, from hours to days or weeks, and exhibits a variable rate of flow, depending on precipitation and snowmelt patterns, and reservoir storage capacity.

During floodplain inundation, a variety of physical processes occur. The magnitude of ecosystem responses to these events depends on flow timing, frequency, magnitude, and duration. Changes in channel dynamics and channel morphology resulting from scouring, erosion, and sediment deposition are typically associated with floodplain inundation (see Section 3.3). Additionally, because the energy of floodplain inundation flow is dissipated over a large area (i.e., the floodplain rather than the channel), floodplain inundation flows have a reduced capacity to carry suspended sediments and other debris. Sediments and debris typically are deposited on the floodplain. Floodplain vegetation, which increases hydraulic roughness and further slows flow velocity, can increase the amount of sediment and organic matter that settles on the floodplain during a floodplain inundation flow. The ecological implications of this interaction between the river and its floodplain are described in more detail in Section 3.4.2.

3.2.2 Bankfull Flow

The flow that occurs, on average, once every 1.5 years to 2 years is often referred to as the bankfull flow (Leopold et al., 1964), even though a 1.5- to 2-year recurrence interval flow may not represent an actual bankfull condition in many stream reaches. A bankfull flow event can occur at any time during the rainy season. It lasts for a variable duration, from hours to days or weeks, and exhibits a variable rate of flow, depending on precipitation and snowmelt patterns, and reservoir storage capacity.

Because a bankfull flow is often the maximum flow that can be contained within the active river channel, these flows are responsible for most of the force on the channel and bed (Allan and Castillo, 2007). This force has the ability to mobilize most medium and fine gravels, as well as organic and inorganic sediments. It also creates meandering stream patterns through

erosion on the outside bends of meanders and deposition on the inside bends of meanders, and creates point bars, undercut banks, and other instream features that increase riverine habitat complexity (Leopold et al., 1964).

Many of these same processes occur with floodplain inundation flows, and the effects of floodplain inundation flows may be slightly greater in magnitude (e.g., mobilization of coarser sediments as bedload – i.e., sediment moving along the stream bed – or creation of chute cutoffs instead of progressive bend meanders), but the cumulative effect of bankfull flows is greater because this flow occurs with greater regularity (TNC, 2007). Although many of these processes have been empirically observed occurring with flows much less than the assumed bankfull flow in parts of the Sacramento River (TNC, 2007 and references cited therein), the bankfull flow likely has the most pronounced effect because it exerts a greater amount of force on the channel than the lower velocity flows. Geomorphic processes related to bankfull flows are described in more detail in Section 3.3.

3.2.3 Base Flow

Base flows are typically the annual minimum flows that occur in summer and fall. Historically, base flow conditions were likely observed on the Sacramento and San Joaquin rivers from approximately July through October, following the cessation of snowmelt runoff and before the onset of the rainy season (see Section 4.1). Although local groundwater contributions from perched aquifers and agricultural water discharge can be important drivers of base flows on some tributaries (e.g., Fleckenstein et al., 2004), base flows in the mainstem rivers were primarily sustained by groundwater discharge into tributaries of these streams in the Sierra Nevada, Cascade Range, and Coast Ranges. With the current system of reservoirs and water diversions in the Sacramento and San Joaquin valleys, base flows are elevated above historical conditions on the Sacramento River and its tributaries and greatly reduced on major portions of the San Joaquin River and its tributaries (see Section 4).

3.3 Geomorphic Processes

The fundamental geomorphic processes of alluvial floodplain rivers are channel migration, channel cutoff, channel anabranching, bed mobility, and fine and coarse sediment transport. All these processes influence floodplain formation and other floodplain dynamics. The SPA extends along the Sacramento River up to Shasta Dam, however this document focuses on leveed reaches of the Sacramento River.

The following brief description focuses on channel dynamics typically observed on the middle reach of the Sacramento River (River Miles (RM) 143 to 243), between Red Bluff and Colusa. The middle reach is emphasized for two reasons. First, it is the only segment of a major river in the Sacramento and San Joaquin valleys where channel dynamics are still regularly observed. Second, channel dynamics observed on the middle Sacramento River are also likely representative of other meandering alluvial river systems in the Sacramento and San Joaquin valleys. This does not imply that there are not potentially significant differences in channel dynamics between the middle Sacramento River and other rivers in the Sacramento Valley. However, the types of channel dynamics observed on this reach are likely to be broadly representative of these processes on other rivers in the Sacramento Valley.

The middle Sacramento River meanders within a belt of recent alluvium and outcrops of weathered Pleistocene-aged alluvium characterized by claypans and duripans that are resistant to erosion (Helley and Harwood, 1985). The region is tectonically active, with many landscape features formed as a consequence of east-west compression progressing up the valley (Harwood and Helley, 1987). The channel bed of the middle Sacramento River is composed of gravel and sand.

This reach of the river is characterized by an actively meandering channel with point bars on the inside of meander bends and active floodplain and older terraces on the outside of meander bends. The river channel migrates across this floodplain to the limits of the meander belt, constrained only by outcrops of erosion-resistant geologic formations or artificial bank protection. In these actively meandering reaches, a characteristic chronosequence of floodplain surfaces results, with younger surfaces closest to the river and oldest surfaces furthest from the river. Over time, meandering channels naturally tend to maintain roughly constant dimensions as erosion of outside bends is balanced by deposition on point bars, a state known as dynamic equilibrium.

Meander migration is one of the primary processes driving riparian ecosystem functions on large, single-channel alluvial rivers (Hughes, 1997). When not constrained by natural or artificial erosion-resistant banks, large alluvial meandering rivers have a tendency to migrate laterally (Johannesson and Parker, 1989). For example, in bank erosion studies conducted on the Sacramento River, annual migration rates have been observed to vary between 0 meters and 39 meters per year (Larsen et al., 2006a). Channel migration of meandering rivers has been shown to establish and maintain riparian habitats, oxbow lakes, and riverbank ecosystems (Hupp and Osterkamp, 1996; Scott et al., 1996; Ward et al., 2001). These habitat linkages are described in more detail in Section 3.4.

As meander bends grow, they may become unstable and form cutoffs. Three basic types of cutoffs may be observed on meandering alluvial rivers: chute cutoffs, partial cutoffs, and neck cutoffs. Chute cutoffs and partial cutoffs are regularly observed on the middle Sacramento River (Hooke, 1984, 1995a, 1995b; Fares and Herbertson, 1990), although chute cutoffs are more common (Micheli and Larsen, 2011).

Chute cutoffs are a type of channel avulsion that occurs when overbank flows are sufficient to concentrate shear stresses to a degree capable of carving a new channel across the floodplain (Hooke, 1984, 1995a, 1995b). If a floodplain "chute" erodes a secondary channel linking approximately the upstream and downstream inflection points of a bend, the chute may grow, short circuit the former meander path, and become the primary channel (Gay et al., 1998). The abandoned former channel, depending on the degree of remnant hydrologic connection to the river, may function as a slough or, eventually, as an oxbow lake, providing important wetland habitat for a variety of species. In contrast, partial cutoffs tend to develop into side channels, separated from the main river flow by an instream island, rather than offstream wetland features.

Although not currently observed on the middle Sacramento River, neck cutoffs, which result when the sinuosity of a bend increases and the radius of curvature in the bend decreases until the bend essentially doubles back on itself through progressive migration, may have historically occurred (Robertson, 1987). The occurrence of neck cutoffs before European settlement or under a different climatic regime cannot be ruled out, particularly in the lower section of the middle Sacramento River and other low-gradient reaches of other rivers in the Sacramento and San Joaquin valleys.

3.4 Ecosystem Responses

This section discusses the ecosystem responses to floodplain inundation flows, bankfull flows, and base flows and their associated geomorphic processes. Major in-channel and floodplain responses are discussed separately.

3.4.1 In-Channel Responses

Fluvial hydrologic and geomorphic processes in river channels are associated with flows up to and including the bankfull flow and the geomorphic process of channel meandering. These processes are particularly important for salmonids and aquatic habitat quality, the recruitment and succession of riparian vegetation, and riparian wildlife.

High flows transport significant amounts of fine sediments and, by extension, most of the nutrients, contaminants, and organic matter that accumulate on the riverbed, resulting in improved water quality. During low-velocity flow conditions, fine sediments, organic material, inorganic compounds, pollutants, and similar materials accumulate on the stream bed because the stream lacks sufficient force to suspend these materials and transport them. Organic materials that accumulate on the channel bottom are decomposed by microorganisms, resulting in the consumption of available dissolved oxygen (DO) through increased biological oxygen demand (BOD). The result can be a nutrient-rich, low-DO sludge, which is a poor-quality habitat for most aquatic organisms (TNC, 2007).

The reduction in siltation associated with flushing flows increases benthic algal production, which provides a source of primary production in streams (TNC, 2003) that benefits aquatic organisms. The flushing associated with higher flows can also significantly improve gravel quality for incubating salmonid eggs, salmonid larvae, and salmonid fry by reducing gravel embeddedness (Kondolf, 2000). High water velocities associated with bankfull flows not only flush the fine sediments and accumulated organic matter, resulting in improved water quality and chemistry of the sediments, but they also create broken surface water, which increases the diffusion of atmospheric oxygen into the water column, resulting in increased concentrations of DO.

The recruitment of LWM is also tied to elevated flows and associated geomorphic processes of channel meander and erosion. As meander bends migrate during higher flows, banks are undercut and mature trees fall into the channel, becoming LWM. Although the term “debris” has negative connotations associated with navigation hazards and potential impacts with bridges and other infrastructure during floods, the importance of LWM for salmonids is becoming increasingly recognized (Harmon et al., 1986; Maser and Sedell, 1994), and the continual recruitment of LWM is important to maintain salmonid habitat as existing LWM is transported downriver by floodflows.

In addition to higher flows, base flows contribute to salmonid habitat quality. As discussed in Section 3.2.3, base flows help to maintain perennial water flows and thereby contribute to the suitability of spawning habitat for spring- and fall-run Chinook salmon. Spring- and fall-run Chinook salmon begin spawning in the Sacramento and San Joaquin valleys before the onset of winter rains (TNC, 2007 and references cited therein). Therefore, important Chinook salmon spawning habitat attributes, such as water depth, flow velocity, and water temperature, are closely tied to base flows. In rivers without adequate base flows (e.g., the Cosumnes River and upper San Joaquin River), Chinook salmon numbers have been

drastically reduced, in part, because a lack of adequate base flows has resulted in a lack of suitable spawning habitat.

Ongoing channel meandering and associated high flows are also important for the formation and sustainability of riparian habitats. Point bars formed on the inside of meander bends are common locations for recruitment of willow and cottonwood, which establish on newly deposited surfaces in response to specific combinations of flow events (Mahoney and Rood, 1998). Channel meandering creates point bar depositional surfaces of different ages, each of which supports riparian vegetation of a different age class (Greco et al., 2007). As channel migration continues, older depositional surfaces shift from cottonwood and willow dominance to dominance by other species less tolerant of flooding and disturbance, resulting in greater vegetation community structure and increased overall species diversity (Ward and Stanford, 1995). Because riparian forest ecosystems mature relatively rapidly (e.g., within 100 to 300 years), they can transition to upland ecosystems without periodic disturbance related to channel meandering, sediment deposition, and point bar formation (Sands and Howe, 1977; Johnson et al., 1976; Fremier, 2003).

Base flows also affect the establishment and sustainability of riparian vegetation. Most riparian plants require a source of soil moisture to maintain growth and vigor during summer, and conceptual models for riparian recruitment have described zones of successful riparian vegetation establishment in relation to base flow elevations (Mahoney and Rood, 1998). Adequate soil moisture is typically provided by shallow groundwater tied to base flows in adjacent rivers and streams. Similarly, riparian wetlands may require shallow groundwater created by river base flows to maintain perennial inundation and habitat functions associated with perennial wetlands. On rivers lacking sufficient summer base flows, such as many portions of the San Joaquin River, riparian vegetation can be replaced entirely by upland vegetation and invasive plants that are more tolerant of low soil moisture.

This diversity of riparian habitat patches created by meandering rivers and high flows, and sustained by adequate summer base flows, is critically important for a variety of wildlife and supports high levels of biodiversity (Ward et al., 2001). For example, many bird species, such as yellow-breasted chat (*Icteria virens*), prefer early seral stages of riparian habitat subject to regular disturbance (from high-water events, meander migration, and channel abandonment) for foraging and nesting (RHJV, 2004). Bank swallows (*Riparia riparia*), a species listed by the State as threatened, also depend on periodic disturbance, in the form of eroding banks, for nesting substrate (Morken and Kondolf, 2003; RHJV, 2004). These sites must be

periodically disturbed through high flows and channel meander migration to maintain their suitability for bank swallow nesting (Garrison, 1999).

3.4.2 Floodplain Responses

Many of the processes described previously as occurring in the river channel also occur in adjacent floodplains during higher river flows (i.e., flows above the bankfull stage). As with in-channel processes, these floodplain processes are important for riparian habitats and riparian-associated wildlife, as well as salmonids and other native fish species.

Floodplains are created primarily by lateral accretion of point bars and vertical accretion from suspended sediments in overbank flows (Wolman and Leopold, 1957). Lateral point bar accretion and overbank deposition are readily observed along most meandering and wandering channels carrying a mixed load of gravel, sand, and silt/clay. This results in a characteristic floodplain stratigraphy of channel deposits (gravel and/or sand) overlain by point bar deposits of sand and perhaps gravel, which in turn are overlain by overbank deposits (sand and silt/clay).

Historically, overbank flows were commonly observed in the Sacramento and San Joaquin valleys during winter and spring in response to spring snowmelt, rain-on-snow events, and prolonged periods of heavy rainfall that are characteristic of the region (Kondolf et al., 2000). Floodplain inundation caused by overbank flows can result in widespread disturbances to existing riparian vegetation through scouring and removal of existing vegetation. Floodplain inundation may also result in death of plants from physiological stress related to prolonged inundation, root suffocation from the deposition of fine sediment, and similar factors (TNC, 2007). These disturbances remove existing vegetation and may create suitable conditions for the germination and recruitment of early successional vegetation, leading to increased habitat diversity and increased wildlife diversity, as described in Section 3.4.1.

Cottonwood and willow require moist, bare, mineral soil during periods of seed release. In the Sacramento and San Joaquin valleys, this period of seed release roughly lasts from mid-March through July (see TNC, 2007 and studies referenced therein) and may vary widely by species and geographic location within years and according to annual temperature and precipitation patterns among years. Flows leading to successful recruitment of cottonwoods and willows have been estimated to occur every 5 years to 10 years on meandering alluvial rivers, similar to those found in the Sacramento and San Joaquin valleys, although recruitment events may occur much less frequently on rivers constrained by geology, bank revetment, or levees (see TNC, 2007 and references cited therein).

The geomorphic process of gradual channel meander migration, coupled with overbank flows, may also result in the formation of side channels, sloughs, and oxbow lakes through the cutoff of meander bends and gradual separation of the flow in these habitats from the mainstem of the river (see Section 3.3). The formation and sustainability of off-channel habitats is important for species such as western pond turtle (*Actinemys marmorata*) that prefer slow-moving water, and in many river reaches, these off-channel habitats provide substantial opportunities for recruitment of cottonwood and willows, particularly when in-channel recruitment zones (e.g., point bars) are lacking (TNC, 2007).

Aside from effects on the successional processes of riparian vegetation through disturbance, vegetation recruitment, and the formation of off-channel habitats, overbank flows increase the amount and quality of rearing habitat for Chinook salmon. Studies have shown that juvenile Chinook salmon that have been reared on seasonal floodplains are much larger than salmon that have been reared in river channels (Sommer et al., 2001, 2003). The mechanisms by which seasonal floodplains positively affect salmonid rearing include increased primary production and food availability (Junk et al., 1989, cited in TNC, 2007), lack of predation from nonnative fish that are generally not found on seasonal floodplains, and improved habitat quality relative to river channels (lower velocity flows, greater structural diversity) (Sommer et al., 2001, 2003). Larger juvenile salmon are assumed to have a greater probability of successful outmigration to the Pacific Ocean.

Three main races of Chinook salmon–fall/late fall run, winter run, and spring run–are found in the Sacramento River, and the San Joaquin River supports or historically supported runs of fall/late fall run and spring-run fish. These races historically made extensive use of seasonal floodplains during winter and spring outmigration. Today, substantial areas of seasonal floodplain in the Delta and its vicinity are still found in the Yolo Bypass and along the lower Cosumnes River (Sommer et al., 2001, 2003). The timing, duration, and frequency of floodplain flows that are optimal for salmon rearing have been variously estimated (Williams et al., 2009; USACE, 2002). However, the general consensus from these and other studies (TNC, 2007) is that frequent floodplain inundation (i.e., inundation approximately every 2 years to 4 years on average) of some duration during periods of salmon outmigration from January through May has a positive effect on outmigration success.

3.5 Primary Stressors

3.5.1 Levees and Bank Revetment

Flood control levees confine floodflows, controlling the width, depth, gradient, and velocity of flows that without levees would spread out on the floodplain. Levees tend to increase the sediment-carrying capacity of the stream, which leads to degradation of the channel thalweg (i.e., the line defining the lowest points along the riverbed) and widening of the channel. Many levees were originally constructed to aid in the movement of sediment resulting from hydraulic gold mining to clear the channel for navigation purposes (see Section 2).

Bank revetment (i.e., the hardening of streambanks by riprap or other material to prevent erosion) generally causes the riverbanks to become narrower and deeper. Bank protection may also increase the incidence of riverbend cutoffs, thus reducing the overall length and sinuosity of the river.

Effects on Geomorphic Processes

River channel migration results in bank retreat, which can cause conflicts with adjacent land uses and infrastructure. Efforts to protect against bank retreat often involve lining the riverbank with riprap or large rocks. Likewise, efforts to protect communities and other landscapes from flood risk can involve levee construction. In selected areas of the Sacramento River, as in many places throughout the world, riprap and levees have virtually halted natural river processes such as river channel meander migration and meander cutoffs that create and maintain the complexity of aquatic and riparian ecosystems (Naiman et al., 1993; Lytle and Poff, 2004). In addition, most alluvial reaches of the middle Sacramento River have narrowed during the last century, largely in response to bank stabilization measures (Fischer, 1994).

Riprap and other bank armor solutions are almost always considered only with respect to local channel bank protection and not to downstream consequences. Such site-by-site planning solutions often lead to more problems in both the near and long term, especially in dynamic landscapes, such as riparian corridors. For example, changing bank erosion rates at one site, either by removing vegetation or by hardening the banks, can alter the migration pattern as far as three or four bends downstream (Larsen, 1995). These channel alterations can occur over relatively short periods (less than 5 years) and may affect the timing and location of avulsion events. Clearly, planning and management of infrastructure at a site should consider long-term consequences (e.g., periods greater than 50 years). These consequences may include infrastructure impacts on upstream conditions,

as well as downstream effects on river channel and adjacent floodplain conditions.

Effects on Habitat

The ecosystem benefits of altering channel dynamics (by removing constrictions to channel migration) often can be greater than those associated with changing the flow regime. Larsen (2007) conducted a simulation study comparing removal of revetment to changes in flow regime at three bends in the Sacramento River at Woodson Bridge, Hamilton City, and Ord Ferry. The gain in floodplain area from removing revetment in three individual bends was larger in magnitude (but of a similar order of magnitude) than the effects of changing the flow regime over the entire reach.

Two important aspects of habitat for salmonids and other native fish species are affected by channel migration: shaded riverine aquatic (SRA) cover and LWM.

SRA cover is defined as the overhanging vegetation, in-water cover, and natural banks of the nearshore aquatic area occurring at the interface between a river and adjacent woody riparian habitat (USFWS, 1992). Vegetation in this terrestrial-aquatic transition zone provides plant and animal materials that are used by aquatic and aquatic-dependent species (e.g., birds). Near-shore LWM is part of the in-water cover component of SRA cover, although LWM may also occur away from the shore in the river channel.

LWM is also critically important to aquatic species, contributing to habitat creation (e.g., habitat complexity and refuge habitat) and serving a role in storing sediment and organic matter. LWM is important to salmon populations in the Sacramento River. Bank protection with riprap drastically reduces LWM production and also reduces LWM retention along armored banks. According to the U.S. Fish and Wildlife Service (USFWS) (2004), a substantial reduction of LWM has occurred in the Sacramento River as a result of the Sacramento River Bank Protection Project. Alternative approaches to flood protection that can generate LWM resources are the construction of setback levees, adjacent levees that retain waterside growth, and constructing waterside planting benches in urban or other constrained areas. Levee setbacks have been constructed to provide flood protection and can at the same time provide ecosystem benefits, including LWM (Larsen et al., 2006b).

3.5.2 Reservoirs

Storage reservoirs created by large multipurpose dams are located on the Sacramento and San Joaquin rivers and on most of their major tributaries. The dams have major effects on the hydrology and geomorphic processes of the downstream river reaches, and because of those effects, they also have greatly affected the habitats of plants and fish and wildlife species supported by the riparian and riverine ecosystems.

The hydraulic effect depends on the watershed area above the reservoir, the storage capacity of the reservoir, the operational criteria, and the nature of the river downstream from the dam. The larger the watershed above the dam and the smaller the reservoir storage, the less effect the dam has on the streamflow. The dam's operational criteria also affect streamflow. Larger, multipurpose reservoirs affect the magnitude, timing, and frequency of channel-forming flows and consequently have a large effect on the river downstream.

Effects on Hydrology

The most important effects of dams on the hydrology of downstream river reaches are decreases in flow peak frequency, magnitude, and duration, and increases in the frequency, magnitude, and duration of low flows (Singer, 2007).

In the Sacramento River, the reduction in median winter and spring flows is accompanied by increased summer and fall flows, some of which originate from diversions from the Trinity River. However, downstream from Friant Dam, on the San Joaquin River, median flows in both winter and summer are reduced because the water captured by Friant Dam is diverted into two major canals for irrigation during summer. Downstream from Mendota Pool, where the Delta-Mendota Canal enters the San Joaquin River, median summer flows used for irrigation are generally higher than in winter. The hydrologic effect of dams therefore depends on interactions of dam operations and the operation of diversion facilities.

The major dams were designed primarily to reduce the largest winter flood peaks and store spring snowmelt runoff (Singer, 2007). A useful index of the effect of dams on downstream hydrology is the impoundment runoff index (IRI), which is the ratio of reservoir capacity to median annual flood runoff volume (Singer, 2007). There are two major ways of operating dams for flood control. Dams with a high IRI (e.g., Shasta, Whiskeytown, and Oroville dams) are likely to cut off flood peaks and store them for subsequent release for irrigation and hydropower generation. Dams with a low IRI (e.g., New Bullards Bar, Camp Far West, and Folsom dams) do not have storage capacity adequate to completely cut off flood peaks, and must instead release high flows early and longer, i.e., lengthen the rising and

falling limbs of the hydrograph (Singer, 2007). IRIs have not been published for dams in the San Joaquin River watershed.

Effects on Geomorphic Processes

Channel-forming flows are mostly responsible for bank erosion, bed degradation, meandering, and sediment transport. These flows generally are winter and spring high-flow events. There is usually a threshold flow in each river reach where bed and banks begin to erode and sediment begins to move. As flow increases above this threshold, the flow velocity and geomorphic effects also increase until a bankfull stage is reached.

Bankfull discharge is considered to be the geomorphic flow that is the most responsible for shaping the channel form and function. In a natural, undammed river, it is defined as the flow that occurs on average approximately every 2 years (2-year event). A bankfull discharge normally fills the channel but does not inundate the floodplain. Post-dam bankfull discharge is also considered to be the flow with an approximate 2-year recurrence interval, but it may have a much smaller discharge and not fill the channel, particularly in watersheds with large multipurpose dams.

Bankfull discharges meet the following two criteria for shaping channel cross sections: the flows are strong enough to erode banks and to transport and deposit sediment, and the flows occur often enough to overcome the effects of larger flows.

Floodflows above bankfull discharge affect the river somewhat differently than the bankfull discharge. Flows that move out of the channel do not erode or deposit sediment in the channel. Velocities in the channel generally do not increase and sometimes decrease because of backwater effects. Many dams decrease the number of floodflows and may, in wet years, increase the number of bankfull discharges.

The installation of a dam on a river disrupts the frequency of an established bankfull discharge.

Sediment transport is also affected by the dams. Unlike most hydraulic parameters that are affected mostly by storage capacity of dams in the watershed, the effect of dams on sediment is controlled more by the location of the dam in the watershed.

Dams trap sediment from the watershed upstream by allowing sediment to settle and become trapped in the reservoir area. The trap efficiency of large dams like Oroville may be higher than 95 percent, only releasing the very fine silts and clays to the river below. All of the bedload of a stream is generally trapped by a dam.

The effect of dams on the downstream channel is a combination of the watershed area above the dam, the flow release, and sediment trap efficiency. The pre-dam and post-dam frequency of bankfull discharge is a useful indicator of the change in the river's ability to move the sediment in the channel below the dam.

A normal, undammed river system is typically in dynamic equilibrium. The river may incise its channel for a number of years, then fill with sediment to reestablish a stable grade. Sediment carried by a stream may conveniently be divided into bedload (moving by saltation, which is to move by bouncing along the bottom of the river) and suspended sediment moving in the water column.

Dams may change this dynamic equilibrium by trapping bedload that would normally replenish bedload washed downstream; larger dams also trap most of the suspended sediment. In addition, larger dams change the magnitude and frequency of flows, affecting sediment transport in the stream below. The river downstream from a dam is sediment starved, resulting in a gradual removal of the finer fractions of sediment in the channel (TNC, 2007). Over time, the channel degrades and becomes entrenched. Riffles become coarser and armored with a surface layer with particles too large for most flows to move. The channel, riffles, islands, and other depositional features become static. Riffles, used by spawning salmonids and other species, become impermeable and too coarse for the species that would use them. In addition, degradation of the channel bed may also cause headcuts to prograde up tributary channels below the dam, and degradation of the bed in these tributaries.

Suspended sediment concentrations are reduced by dams. Suspended sediment is particularly important to floodplain development. During large floods, the sediment is deposited on the floodplain, over the long term replacing the soils lost through bank erosion. Sediment transport in the Sacramento River is driven by the natural characteristics of the river and its watershed and by the engineered features used to manage the river. The sources and degree of sediment transport vary between the upper (above Red Bluff) and lower (below Red Bluff) reaches of the watershed.

Above Red Bluff, the Sacramento River is mostly an incised, narrow bedrock stream and is characterized by conveyor-belt-like bedload sediment transport. This transport generally occurs during winter storm events, with sediment loads generated by western tributaries. Minimal sediment storage is available because large alluvial floodplains are not present. Cottonwood Creek produces the greatest amount of sediment; Dibble, Blue Tent, Reeds, and Red Bank tributaries also supply sediment (Jones et al., 1972). During summer, releases from upstream dams (e.g.,

Shasta, Keswick, and Whiskeytown dams) dominate streamflow but provide minimal sediment loads, capturing more than 90 percent of all upper watershed sediment (K. Buer, pers. comm., 2011). In wet water years, water levels in the reservoirs may rise to the point where flood releases occur, producing a scenario whereby sediment concentrations may vary as much as three orders of magnitude for a single flow rate.

Below Red Bluff, the Sacramento River has point bars and a widened river corridor, and alluvial floodplains are located adjacent to the river, providing for large amounts of sediment storage and a disruption of the conveyor-belt-like sediment transport of the upper reach. Most of the sediment in the lower reach is produced through bank erosion that occurs when flood releases from upstream dams maintain bankfull conditions for extended periods. Westside tributaries, such as Elder and Thomes creeks, also provide significant amounts of sediment (USACE, 1981). Deposition of this sediment on the Sacramento River floodplain naturally replenishes sediment lost because of bank erosion in the lower Sacramento River. Since the early 1960s, however, the use of bank protection has reduced the amount of sediment locally generated by bank erosion (DWR, 1994). In addition, below Hamilton City, constructed and natural levees constrain the floodplain and reduce sediment deposition on the floodplain during moderate flow events.

Apart from the interruption of sediment transport, geomorphic processes are also affected by the modification of the flow regime. Channels become more stable and narrow when high flows are reduced. The rate that point bars, secondary channels, oxbows, and changes in channel planform (e.g., meander migration) are formed is reduced when the frequency and magnitude of high flows are reduced (Poff et al., 1997; Friedman et al., 1998). The effects of these reductions in flood frequency, magnitude, and duration are difficult to analyze because of the confounding effects that land-use changes and bank revetment have on channel dynamics.

Effects on Habitat

As was described above, reservoirs may be associated with downstream channel narrowing. Channel narrowing is generally accompanied by an increase in vegetation cover along the channel. This vegetation gradually undergoes succession to mature riparian forest because of a lack of scouring flows and channel migration that would “reset” the successional process to an earlier stage (Friedman et al., 1998). This phenomenon was observed on the San Joaquin River after the completion of Friant Dam when “river wash” (exposed sand and gravel) and early successional riparian communities (e.g., riparian scrub) gradually disappeared in favor of mixed riparian and valley oak riparian forest (Jones & Stokes Associates, 1998b, 2002).

At Friant Dam and other dams with a high IRI, an abrupt drop in dam releases in spring causes the regeneration success of woody riparian species, such as Fremont cottonwood and black willow, to be reduced. Mahoney and Rood (1998) postulated that river stage decline during the period of seed release for cottonwoods had to remain within limits dictated by the root growth rate of the seedlings, which needs to keep up with the decline of the water table and saturated soil zone. This relationship was later confirmed by Stella et al. (2010) with a controlled declining water table in a laboratory setting for three riparian plants species that occur in the San Joaquin Valley. This study showed that the simulated groundwater declines had to be less than 2 inches per day to allow seedling survival.

3.5.3 Diversions

Effects on Hydrology

Before the development of large-scale water supply dams in the mid-20th century, miners and settlers constructed smaller dams to impound and divert water for mining, irrigation, and grazing in the mid- and late 19th century. Many of these structures still exist or have been replaced by larger, more modern structures. Various agricultural and municipal water districts have also constructed water diversions that pump water directly out of the Sacramento and San Joaquin rivers and their tributaries. An inventory of water diversions estimated that 722 such diversions are present along the Sacramento River and in the San Joaquin River Basin (Herren and Kawasaki, 2001). Many large diversions (greater than 250 inches in diameter) exist on the Sacramento and San Joaquin rivers and their tributaries (Moyle and White, 2002). Forty-four diversions located in the SPFC are controlled by the DWR.

In the Sacramento River, the overall effect of these diversions is difficult to estimate for any one diversion. Cumulatively, their effects are likely substantial but difficult to quantify (TNC, 2007). Aside from their effects as fish passage barriers, discussed separately below, the most serious effect of these diversions is likely not the reduction in flow tied to the amount of water withdrawn but rather the artificially elevated summer base flows routed through the rivers to facilitate these water diversions (see Section 4). Although there are few quantitative estimates of the total number of fish killed at these diversions (Moyle and White, 2002), these diversions are undoubtedly a stressor on salmonids, and the installation of screens to prevent entrainment at these diversions has been considered a major conservation action for these species (Moyle and White, 2002).

Artificially elevated and constant, sustained releases of water to facilitate water diversions likely promote nonnative fish populations over native fish (Marchetti and Moyle, 2001) and inhibit the establishment of woody

riparian species (TNC, 2007). Fish species that are native to the Sacramento River system evolved with historically variable flows characteristic of Mediterranean ecosystems, whereas nonnative species (e.g., nonnative predatory species introduced from the eastern United States) evolved and thrive in less variable flow conditions (Marchetti and Moyle, 2001). Maintaining relatively constant summer base flows to maintain water supply for agriculture diversions, therefore, is more likely to promote nonnative fish assemblages over native assemblages. Similarly, flow variability is a driver of early successional riparian vegetation germination and recruitment. Certain rates of water recession in spring and summer are required to keep pace with the root growth of newly germinated Fremont cottonwood seedlings (Mahoney and Rood, 1998; TNC, 2007). Elevated summer base flows may contribute to reduced elongation of roots and thus increased susceptibility to scour in winter floods, and may cause direct “drowning” mortality of newly germinated seedlings through prolonged inundation during the summer months (TNC, 2007).

In the upper San Joaquin River, the nearly complete diversion of water from the river channel has drastically reduced salmonid populations and effectively halted riparian forest succession. With little or no water in the channel, suitable spawning habitat for salmonids is absent in the upper San Joaquin River. Because water supply is cut off in spring or early summer, willows and Fremont cottonwood seedlings that may have germinated earlier in the spring are killed. As a result, early age classes of willows and Fremont cottonwood are almost absent from the San Joaquin River (see Section 2). Reclamation is implementing the San Joaquin River Restoration Program to restore a salmon run to the San Joaquin River upstream from the Merced River by releasing addition flows from Millerton Reservoir and by building infrastructure improvements to facilitate salmon migration.

3.5.4 Invasive Species

Effects on Geomorphic Processes

Invasive species can alter hydrology and sedimentation rates in riparian and aquatic systems (Cal-IPC, 2011a). Dense stands of invasive species can alter channel morphology by retaining sediments and increasing the hydraulic roughness of the channel that restricts flows and reduces flood conveyance (Bossard et al., 2000). For example, saltcedar traps and stabilizes alluvial sediments, which results in the narrowing of stream channels and more frequent flooding (Bossard et al., 2000). Species with shallow root systems, such as giant reed and red sesbania, promote bank undercutting, collapse, and erosion (Bossard et al., 2000; Cal-IPC, 2011b).

Effects on Habitats and Native Species

Invasive plants can alter the structure of the vegetation they invade and thereby significantly degrade wildlife habitat quality and ecosystem health (Cal-IPC, 2011a). They may outcompete native species, suppress native species recruitment, and provide food and cover for undesirable nonnative animals (Bossard et al., 2000). Aquatic invasive plants can degrade aquatic habitat by reducing areas of open water used by waterfowl for resting, shading out algae in the water column that serve as the basis of the aquatic food web, and displacing native aquatic plants used for food or shelter by wildlife species (Bossard et al., 2000). Invasive terrestrial plants can also reduce groundwater availability by transpiring large amounts of water, making less water available for native riparian vegetation (Bossard et al., 2000).

Invasive plants can threaten the integrity of native riparian plant communities by outcompeting native plant species, hybridizing with native plant species, reducing habitat quality and food supply for wildlife, and interfering with wildlife management (Bossard et al., 2000; Cal-IPC, 2011a). Nationally, invasive species are the second-greatest threat to endangered species, after habitat destruction (Cal-IPC, 2011a). Invasive aquatic plants often form dense mats that kill fish by lowering pH, DO, and light levels and increasing carbon dioxide and turbidity (Bossard et al., 2000). Some invasive plants hybridize with natives that could, in time, effectively eliminate native genotypes of some species (Bossard et al., 2000).

3.5.5 Fish Passage Barriers

This section is based on an advance administrative draft of the technical memorandum “Fish and Flood Management” (DWR, 2011b).

Effects on Species Abundance and Distribution

Fish passage barriers, such as dams, weirs, and water diversions for agricultural and municipal uses, have greatly reduced the amount of salmonid habitat and can result in the direct mortality of fish at diversions. The effects of passage barriers on salmonids differ by species and race as described below.

Most races and species of salmonids have been adversely affected by the construction of dams and similar passage barriers. However, spring-run Chinook salmon and steelhead (*Oncorhynchus mykiss*) have likely been the most seriously affected, in terms of direct habitat loss, by the construction of passage barriers. These fish historically spawned in tributaries of the Sacramento and San Joaquin rivers in the Sierra Nevada and Cascade Range. The vast majority of historical spring-run Chinook habitat in the Sacramento River and all historical spring-run habitat in the San Joaquin

River is now blocked by passage barriers, collectively reducing spring-run spawning and rearing habitat by 80 percent to 90 percent (DWR, 2005). Currently, the only viable, naturally reproducing populations of spring-run Chinook are found in Deer, Mill, and Butte creeks (NMFS, 2009).

Spring-run Chinook salmon have also been subject to hybridization because their habitat overlaps with that of fall-run fish below passage barriers. Historically, the two races would have been spatially segregated, with spring-run fish spawning further into the mountains and fall-run fish spawning on the valley floor and lower foothills. With construction of Shasta Dam and other passage barriers on the Sacramento Valley's and San Joaquin Valley's major rivers, the two races now use the same segments of these rivers for spawning. The larger, more vigorous fall-run fish typically outcompete spring-run fish for redd sites, or construct their redds on top of spring-run redds, and extensive hybridization between fall-run and spring-run fish has been detrimental to the gene pool of the spring-run fish (Yoshiyama et al., 1998).

Steelhead spawning habitat loss from construction of passage barriers has been estimated at 80 percent (Lindley et al., 2006). Currently, spawning and rearing habitat for wild steelhead exists in Mill and Deer creeks, tributaries of the Sacramento River, and the Yuba River (Moyle, 2002). Incidental occurrences of steelhead have also been recorded in Cow, Battle, Clear, and Cottonwood creeks. Opportunities exist for restoration in these creeks, as well as in the Big Chico, Antelope, and Butte creeks and in the Yuba River. The distribution in the San Joaquin River system is limited to a small sport fishery in the Tuolumne River (DWR, 2005). Steelhead are found in other parts of the Sacramento River watershed, but the presence of hatchery fish makes identifying the origin of the fish difficult (e.g., fish originating from the Eel River in the American and Mokelumne rivers) (Moyle, 2002).

To some extent, steelhead may have initially benefited from construction of Shasta Dam and other Sacramento Valley and San Joaquin Valley dams (TNC, 2007). Persistent releases of cool water and, at least initially, readily available spawning gravels below dams may have mitigated extensive losses in the extent of total spawning habitat above the dams by providing suitable steelhead spawning and rearing habitat where it did not previously exist, at least during the first decade following construction of the dams. However, bed coarsening has, over time, reduced habitat suitability.

Additionally, unlike Chinook juveniles, which spend up to several months in their natal rivers before migrating to the ocean and forming schools, juvenile steelhead spend up to 3 years in their natal streams and vigorously defend their territories from other juvenile steelhead. Historically, juveniles

hatched in tributaries above present-day reservoirs could disperse throughout their natal streams in search of suitable and available rearing habitat. With construction of dams, available rearing habitat has been greatly reduced, and temperatures in some areas are too high. Competition for rearing habitat has been tied to numerous adverse effects on individual fish and steelhead populations (Keeley, 2001), and competition for suitable sites among 1- and 2-year-old fish is now likely to be at least as limiting on steelhead populations as the lack of spawning habitat (TNC, 2007).

The construction of passage barriers has also been a stressor on winter-run Chinook. Adult winter-run Chinook migrate into the Sacramento River during winter and spring. Historically, these fish held for several months in deeper pools to reach sexual maturity and then spawned during summer in cool-water reaches of streams in the upper watershed of the Sacramento River (e.g., McCloud River, Pit River, upper Sacramento River) and Battle Creek (Yoshiyama et al., 1998). Construction of Shasta Dam has nearly completely eliminated historical holding and spawning grounds for winter-run fish.

Although historical spawning areas have been eliminated, winter-run Chinook have adapted to holding and spawning in cool-water releases from Shasta Dam on the upper portion of the lower Sacramento River. Under current conditions, the total amount of suitable spawning habitat for winter-run fish may actually be equal to or greater than the amount of spawning habitat that was historically available (TNC, 2007). The exact causes of declines in winter-run populations are not known, but it is hypothesized that spawning habitat reduction related to the construction of passage barriers is not one of the primary stressors on winter-run fish (TNC, 2007). This hypothesis does not imply that passage barriers, such as Shasta Dam, have not affected winter-run Chinook. However, the reservoirs impounded by passage barriers and related modifications to river flows and geomorphic processes below reservoirs are likely more significant stressors on winter-run fish (TNC, 2007).

As described for winter-run fish, passage barriers are a stressor on fall- and late fall-run Chinook but may not be a significant stressor compared to other stressors described previously (TNC, 2007). Relative to other salmonids, fall- and late fall-run fish historically spawned much lower in the Sacramento and San Joaquin rivers, generally at elevations below 500 feet to 1,000 feet, as far south as Kings River and as far north as the upper Sacramento, McCloud, and Pit rivers (DWR, 2005; Yoshiyama et al, 2001). Because of their larger size, fall- and late fall-run Chinook are capable of spawning in a wider range of gravel sizes. Therefore, although their historical spawning ranges have likely been reduced, the relative amount of habitat reduction caused by construction of passage barriers is likely less

than for other salmonids, particularly steelhead and spring-run Chinook. Current distribution of fall- and late fall-run Chinook on the Sacramento River encompasses all historic habitat on lower foothill and Central Valley streams and spawning occurs upstream as far as Keswick Dam. On the San Joaquin River, distribution reaches up to the Merced River.

Aside from dams and similar passage barriers that have directly blocked historical holding, spawning, and rearing areas for salmonids in the Sacramento and San Joaquin valleys, partial passage barriers, such as intakes for water diversions, are an additional stressor on salmonids. Diversions are discussed further in Section 3.5.3.

4.0 Status, Trends, and Stressor Assessment

4.1 Status and Trends Metrics

4.1.1 Hydrologic Processes

Description of Metrics

Hydrology metrics were calculated with the Indicators of Hydrologic Alteration (IHA) software (Version 7.1.0.10), developed by The Nature Conservancy. IHA was used to query historic flow records to identify event-based metrics. The average annual peak discharge (in cubic feet per second (cfs)), average annual frequency, and average annual duration were determined for small floods (conforming to floodplain inundation flows), high pulse flows (conforming approximately to bankfull flows), and extreme low flows (conforming to base flows).

In addition, the median yearly, spring, and monthly flows were calculated. The median yearly flow is the median daily average flow for each year, the median spring flow is the median daily average flow occurring between March 1 and June 30, and the median monthly flow is the median daily average flow for each month.

The hydrologic metrics were calculated at two gages maintained by the U.S. Geological Survey with long-term flow records: Sacramento River above Bend Bridge and San Joaquin River at Friant. These gages were selected because they most clearly represent the effects of changes in flow related to reservoir construction (i.e., they represent the furthest upstream gaging stations on the Sacramento and San Joaquin rivers) and because they both have continuous observations of average daily flows dating from 1891 and 1908, respectively. All metrics were calculated separately for the pre-reservoir and post-reservoir flow periods. On the Sacramento River, a third period representing the period following the construction of Shasta Dam and before the import of Trinity River water from Whiskeytown Reservoir, was also calculated. The specific periods of record analyzed are shown in Table 4-1.

Approximately 12 additional flow gages with long-term average daily flow observations were identified on the Sacramento and San Joaquin rivers and their tributaries; however, because of time constraints, flow metrics were

not prepared for these gaging stations. Similar analyses may be completed for these gages as part of the development of the 2017 CVFSCS.

Although the approach used here supports an initial analysis of more general patterns, this analysis has important limitations. In particular, median flows cannot be used to evaluate effects occurring on a finer time scale, such as individual daily flow effects on salmonids. Effects of specific flow management events, such as introduction of the Central Valley Project Improvement Act mandated flows in 1992 and the flow management resulting from several Biological Opinions were also not assessed.

Table 4-1. Periods of Record for Hydrologic Process Metrics

Period of Record	Sacramento River	San Joaquin River
Pre-reservoir period	1901[1]–1944	1908–1941
Post-reservoir period	1945–1964	1942–2010
Period following initiation of Trinity River imports	1964–2010	NA

Source: Prepared by AECOM in 2011 for this report.

Note:
[1] The record was truncated because Excel does not recognize dates before 1901.

Key:
NA = not applicable

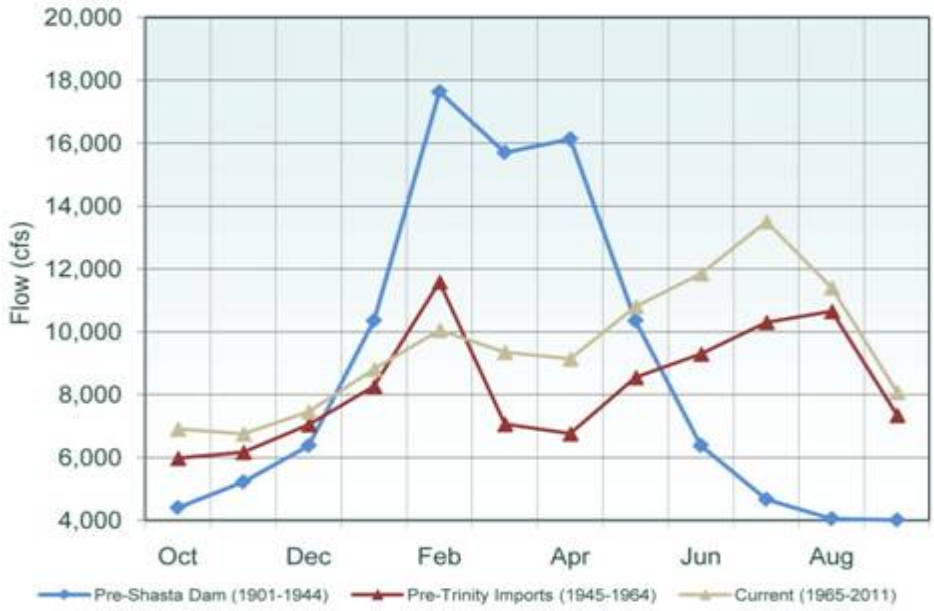
Median Flows

Timing and variability of median flows from pre-reservoir and post-reservoir periods were compared to assess changes in the hydrologic habitat parameters of native species. The life cycles and physiology of native plant, fish, and wildlife species are adapted to the hydrologic regime that predates reservoirs on the major rivers. Major changes in hydrologic habitat parameters would reduce habitat suitability for native species.

Methodology and Rationale The median yearly, spring, and monthly flows (in cfs) for the pre-reservoir and post-reservoir periods were determined as a means to compare changes in the pattern of flows, compare the timing of peak and low flows, and visualize overall flow variability under historical conditions and with operation of reservoirs. They provide a concise overview of overall hydrologic conditions while conveying information about the typical timing and intensity of the annual high and low flows and information about flow variability.

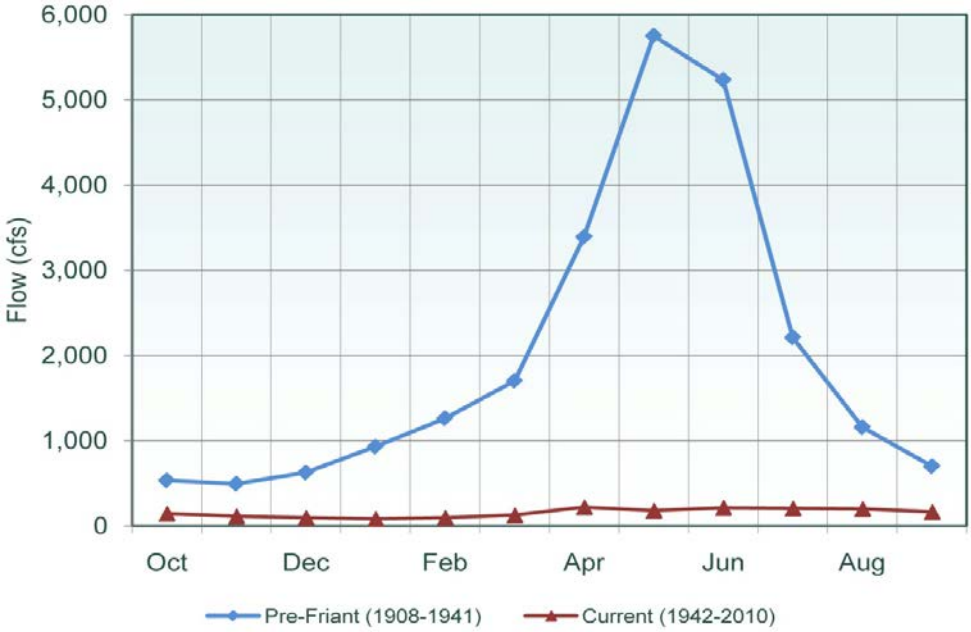
Metric Summary Monthly median flows in the Sacramento and San Joaquin rivers are shown on Figures 4-1 and 4-2, respectively. Before Shasta Dam was completed and the Trinity River imports to the Sacramento River were initiated, peak median flows occurred in the

February-through-April period. After Shasta Dam was completed in 1944, peak flows occurred in February and then again in July and August. After imports from the Trinity River were introduced, median summer flows in the Sacramento River increased by 2,000 cfs to 3,000 cfs (Figure 4-1).



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-1. Monthly Median Flows in the Sacramento River at Bend Bridge (USGS Gage 11377100)



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-2. Monthly Median Flows in the San Joaquin River at Friant (USGS Gage 11251000)

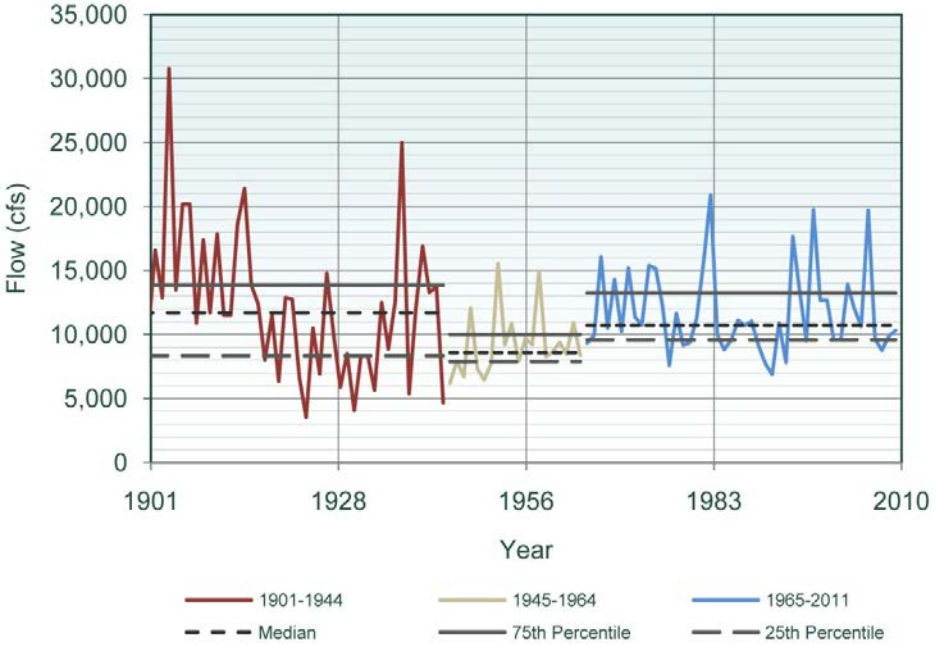
Recently, Trinity River imports have changed as a result of the Trinity River Mainstem Fishery Restoration Final EIS/EIR Record of Decision in 2000 (U.S. Department of Interior 2000).

Before completion of Friant Dam, monthly median flows in the San Joaquin River peaked in the May-to-June period (Figure 4-2). After Friant Dam was completed in 1941, flows in the San Joaquin River were much reduced because the vast majority of water is conveyed through the Friant-Kern and Madera canals (Figure 4-2).

The floodflows in spring are the most ecologically and geomorphologically relevant floodflows. Median spring flows for the Sacramento and San Joaquin rivers are shown on Figures 4-3 and 4-4. Sacramento River flows had much greater year-to-year variability before Shasta Dam was completed in 1944 than after completion of the dam. After flows from the Trinity River were added in 1965, annual variability increased, but not to the pre-Shasta level (Figure 4-3).

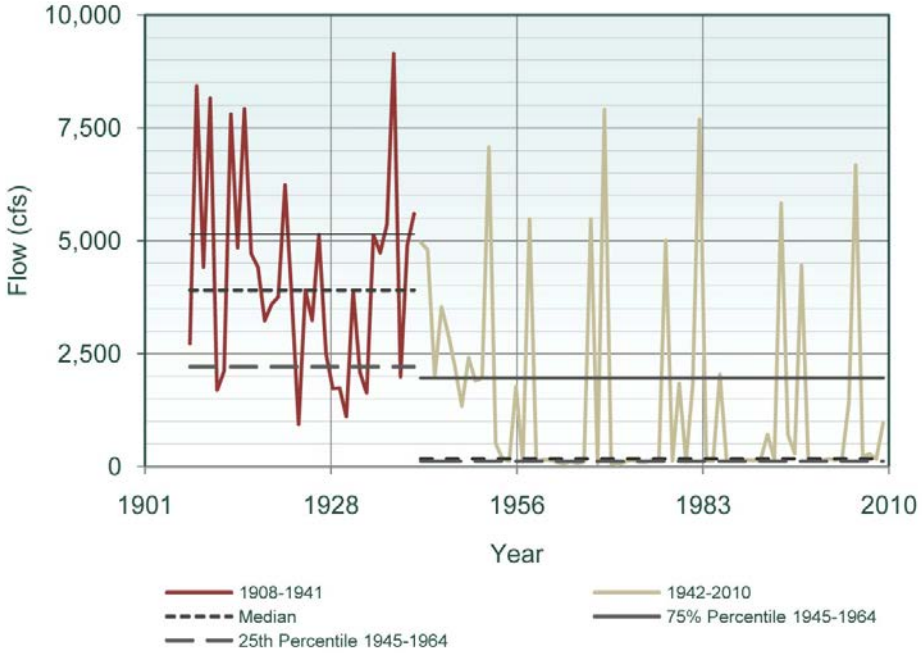
San Joaquin River flows decreased greatly below Friant Dam after the dam was completed, although large flood events (e.g., greater than 4,500 cfs) are not affected because they cannot be contained by the dam (Figure 4-4).

As discussed in Section 3, before the construction of major dams, the timing of flow events in the Sacramento and San Joaquin valleys had a consistent seasonal cycle, with maximum flows in spring and minimum flows in summer. In an environment with highly variable rainfall and streamflow regimes, these flows typically varied within years (from month to month) and between years, and species such as salmonids, various species of riparian trees and shrubs, and, by extension, wildlife that depend on riparian vegetation exhibited life histories that exploited these variable streamflow patterns. Natural communities were likely more diverse before the dams were built than after because the variability of streamflows and higher frequency of high, scouring flows created a diverse physical habitat.



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-3. Median Spring Flow in the Sacramento River at Bend Bridge (USGS Gage 11377100)



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-4. Median Spring Flow in the San Joaquin River at Friant (USGS Gage 11251000)

Floodplain Inundation Flow Discharge, Frequency, and Duration

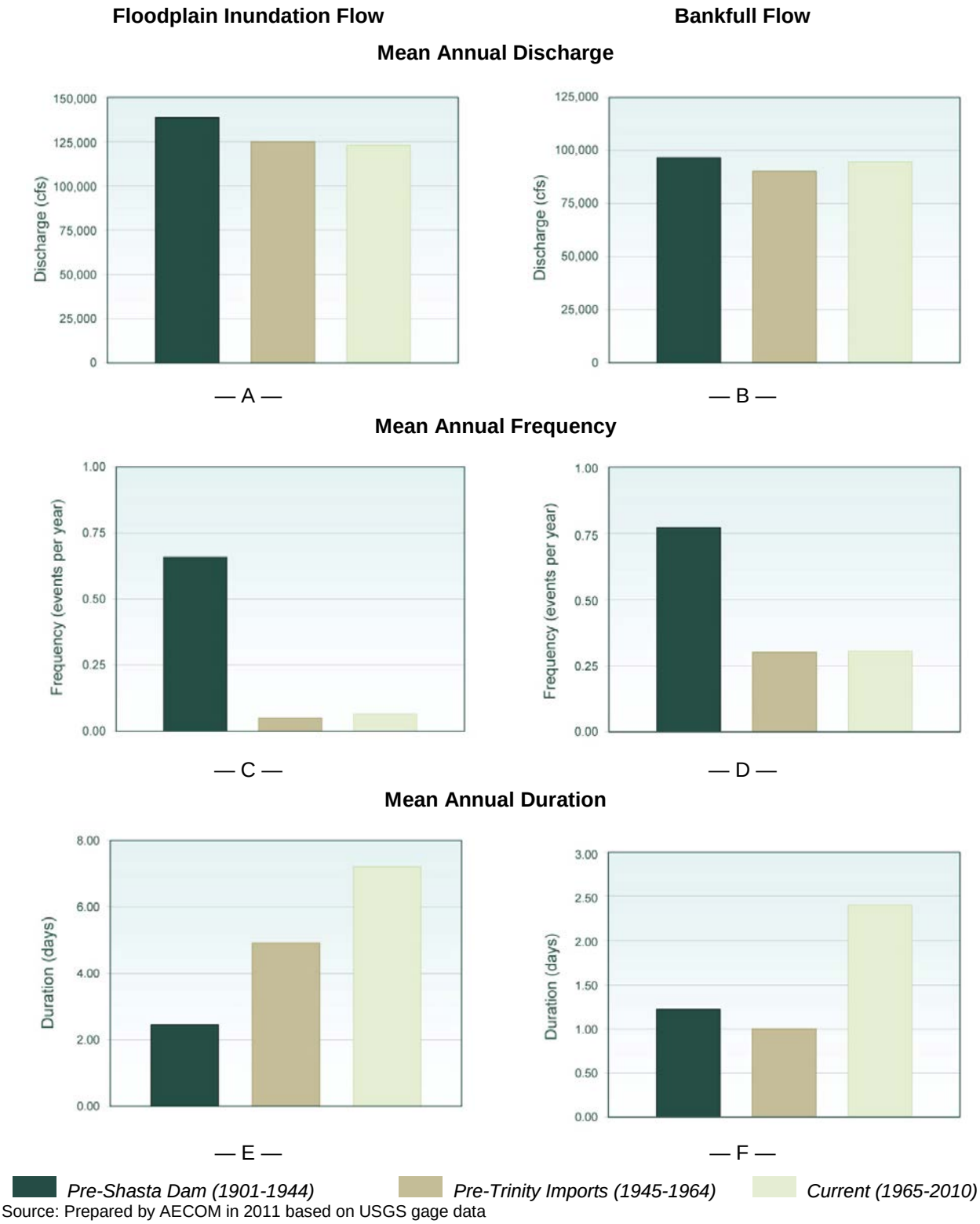
Floodplain inundation flows provide native fish species access to floodplain habitat, where rates of predation by nonnative fish are lower and food production are higher than in the channel (Sommer et al., 2001, 2003). Floodplain inundation particularly benefits outmigrating salmonids and spawning Sacramento splittail (*Pogonichthys macrolepidotus*). Floodplain inundation also provides nutrients and seeds of riparian species to the floodplain and provides water to floodplain habitats. The discharge, frequency, and duration of floodplain inundation flows were assessed because a reduction in these parameters resulting from a change in reservoir operations would represent a reduction in benefits to native species and habitats.

Methodology and Rationale IHA was used to compute the average annual peak discharge, frequency, and duration of small floods before and after reservoir construction at the two long-term flow gages identified above. In IHA, a small flood is defined as a flow event with a peak flow greater than a pre-dam 2-year return interval flow rate and less than or equal to the pre-dam 10-year return interval flow rate. These small flood ranges were selected because these flows represent a range of floods (i.e., a 2- to 10-year recurrence interval) that inundated floodplains before the dams were constructed and that are thought to be positively related to a variety of ecosystem functions, such as the regeneration of riparian habitat and the provision of salmonid rearing habitat (see Section 3.4.2). Larger floods with a recurrence interval of greater than 10 years may also have ecosystem benefits, but they do not occur regularly enough to have the ecosystem benefit of more frequent floods.

For each year in which a small flood event occurred, IHA computed the maximum event-peak discharge. The average of these maximum peaks was then computed and plotted in Microsoft Excel to convey the change, before and after dam construction, on small flood event peak discharges. In addition, IHA records the number and median duration of small flood events per year. The number and average duration of the events were then computed and plotted on an annual basis in Microsoft Excel. These plots are shown on Figures 4-5 and 4-6.

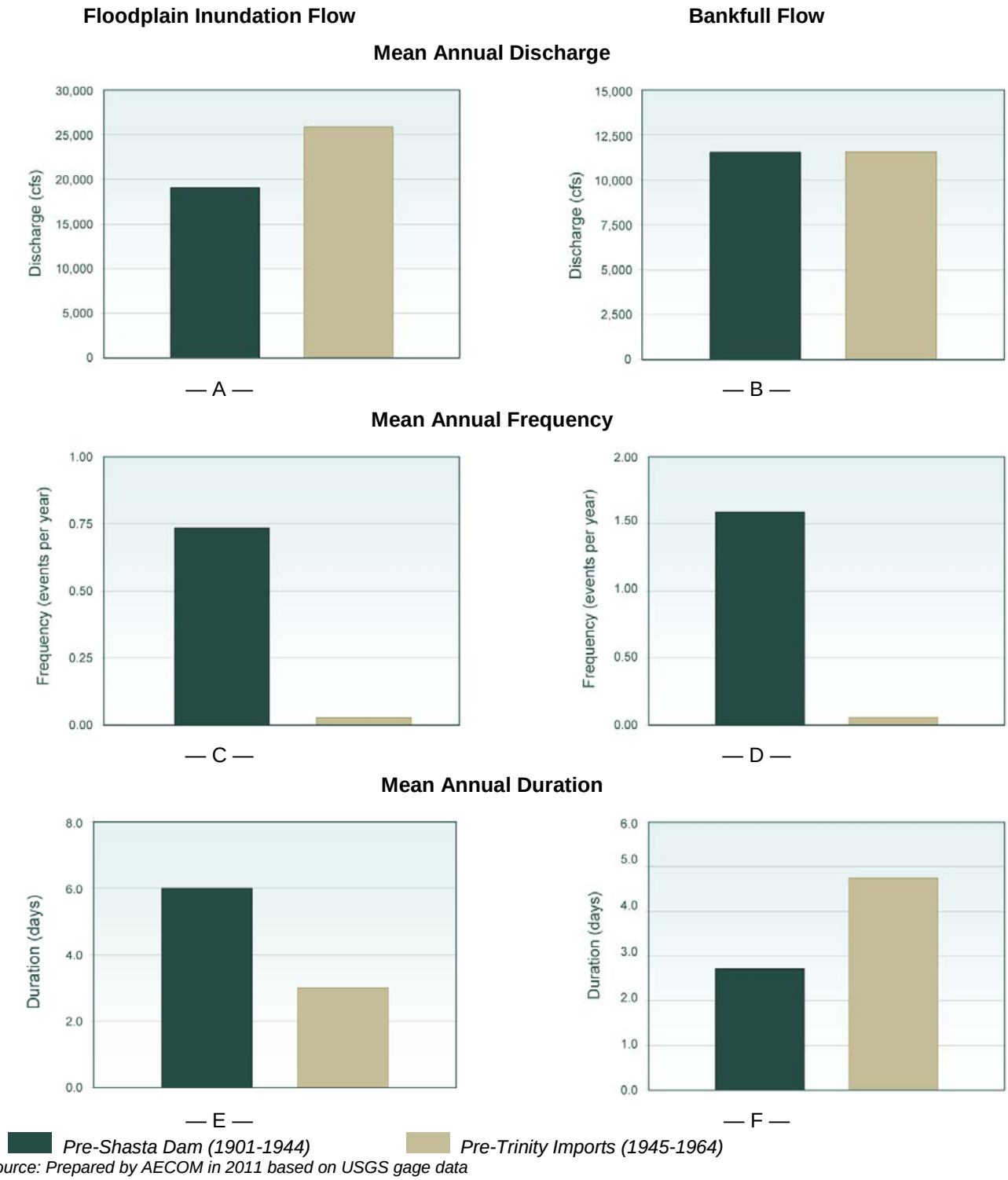
Metric Summary The average annual peak discharge of small floods on the Sacramento River downstream from Shasta Dam declined by 10 percent for the period from construction of Shasta Dam to before the Trinity imports began in 1965. Since the Trinity imports began, the average annual peak discharge remains similar (Figure 4-5A). Although peak discharges have not changed significantly, the average annual frequency has been reduced from 0.66 event per year to 0.07 event per year (Figure 4-5C). This suggests that although Shasta Dam has reduced the frequency of

small floods on the Sacramento River, the dam does not have the capacity (or is not operated) to significantly reduce the peak of small flood events when they do occur. The average duration of these events increased by 100 percent during the pre-Trinity imports period (from 2.5 to 5 days) and again by 47 percent following the Trinity imports (from 5 days to 7.3 days), for a total increase of 193 percent since before Shasta Dam was constructed (Figure 4-5E). This increase in duration reflects typical flood control operations, where flood event peaks are stored and subsequently released at lower flow rates following the event peak.



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-5. Mean Annual Discharge, Frequency, and Duration of Floodplain Inundation Flows and Bankfull Flows in the Sacramento River at Bend Bridge (USGS Gage 11377100)



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-6. Mean Annual Discharge, Frequency, and Duration of Floodplain Inundation Flows and Bankfull Flows in the San Joaquin River at Friant (USGS Gage 11251000)

The average annual peak discharge for small floods on the San Joaquin River downstream from Friant Dam increased by 36 percent after Friant Dam was built in 1942 (Figure 4-6A). However, only two small flood events are recorded at the Friant gage since 1942. Peaks of 14,900 cfs and 36,800 cfs were recorded for these two events, where the 36,800 cfs peak is greater than any small flood event recorded during either period. This suggests that Friant Dam was likely at or near capacity before the second event peak and that the dam may be optimized for small flood events as opposed to large flood events, allowing for upper end (i.e., with a 10-year return interval) peak discharges to be released. Given that the frequency of small flood events has been reduced from 0.74 event per year to 0.03 event per year (Figure 4-6D), it is clear that Friant Dam is operated to capture and is successful at capturing small flood events. The duration of small floods has also been reduced, from 6 days to 3 days (Figure 4-6E), suggesting that the dam is operated not only to capture all small flood events but to release those events at extreme low-flow rates. This is confirmed by the increase in average yearly duration of extreme low-flow events from 29.4 days to a very long 352.3 days.

Small flood events (i.e., with a 2- to 10-year return interval) are both geomorphologically and ecologically important because of the overbank flooding that occurs during these events. Shasta and Friant dams have significantly reduced overbank flooding, as is evident from 90 percent and 96 percent reductions in small flood frequency on the Sacramento and San Joaquin rivers, respectively, and have reduced the frequency of inundation of floodplain habitats and species.

Bankfull Flow Discharge, Frequency, and Duration

Bankfull flows drive meandering and other related geomorphic processes (e.g., erosion and deposition of sediment) in the major rivers. LWM, which provides important habitat for native fish and invertebrate species, is generated by the erosive processes caused by these flows because they cause trees to fall into the channel. The discharge, frequency, and duration of bankfull flow were assessed because a reduction in these hydrologic parameters resulting from a change in reservoir operations would represent a reduction in the geomorphic process that generates LWM and maintains habitat diversity.

Methodology and Rationale IHA also was used to compute the discharge, frequency, and duration of high pulse flows. In IHA, a high pulse flow is defined as a flow event greater than a pre-dam 1.5-year return interval flow rate and less than or equal to the pre-dam 2-year return interval flow rate. A 1.5- to 2-year recurrence interval flow is roughly equivalent to the hypothetical bankfull flow, and although dynamic channel processes have been observed on the Sacramento River at discharges much

less than the presumed bankfull discharge, the bankfull discharge, because of its regularity and force, is assumed to be responsible for most of the force in the bed and channel. Thus, the bankfull discharge is strongly linked to sediment mobilization and transport and with the creation and maintenance of meandering streams, eroded banks, and point bar deposition. These physical changes to the stream can be positively associated with a variety of ecosystem functions (see Section 3.4.1).

As for small flood metrics, high pulse-flow metrics were computed and plotted using IHA and Microsoft Excel, as described in the following section.

Metric Summary The high pulse flow (or bankfull flow) was defined as a particular range of discharges observed before dam construction, and the pre-dam and post-dam median peak flows were selected to be the same and, therefore, do not differ (Figures 4-5B and 4-6B). The high pulse flow in the San Joaquin River was about 12 percent of the high pulse flow in the Sacramento River.

The frequency of these pre-dam bankfull flows is much reduced by the dams (Figures 4-5D and 4-6D), especially by Friant Dam. These flows are responsible for most of the channel migration, so the extent of channel migration was severely reduced with construction of the dams, especially on the San Joaquin River (Jones & Stokes Associates 1998b, 2002). However, on the Sacramento River, the effects of an increase in land conversion to agricultural land uses and an increase in bank revetment that have also occurred since Shasta Dam was built have confounded the effect of the hydrologic changes on geomorphology and plant community diversity.

The duration of the high pulse flows increased after the construction of dams on the Sacramento and San Joaquin rivers (Figures 4-5F and 4-6F). The reason is that the dams are operated to keep flows at the bankfull level and to keep them from spilling onto the floodplain.

Extreme Low-Flow Discharge

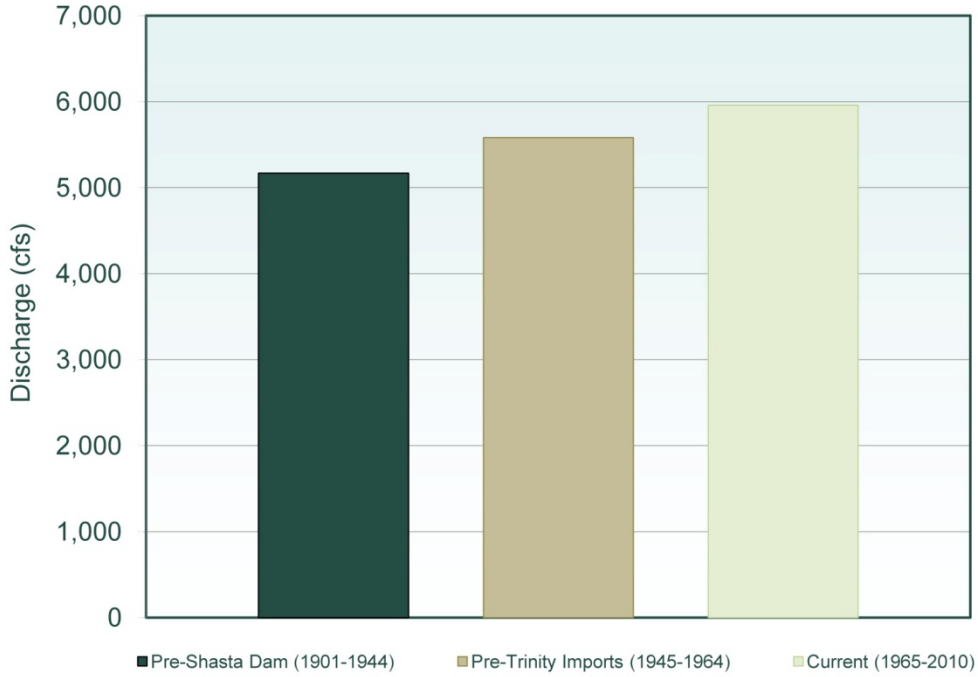
Low flows maintain riparian vegetation through summer by preventing desiccation. However, if summer low flows are too high, they may cause the drowning of seedlings of riparian trees and shrubs. The discharge of low flows was assessed to determine whether changes in summer low flows resulting from a change in reservoir operations could result in the desiccation or drowning of riparian vegetation.

Methodology and Rationale Extreme low-flow events were defined as events with a peak discharge less than or equal to the maximum of the

minimum 90-day running-average flows of each water year. The flow record for each gage was queried using IHA for the minimum 90-day flow for each year, and Microsoft Excel was used to determine the maximum of these 90-day-duration minimums. IHA and Microsoft Excel were then used to compute the average annual discharge of extreme low-flow events.

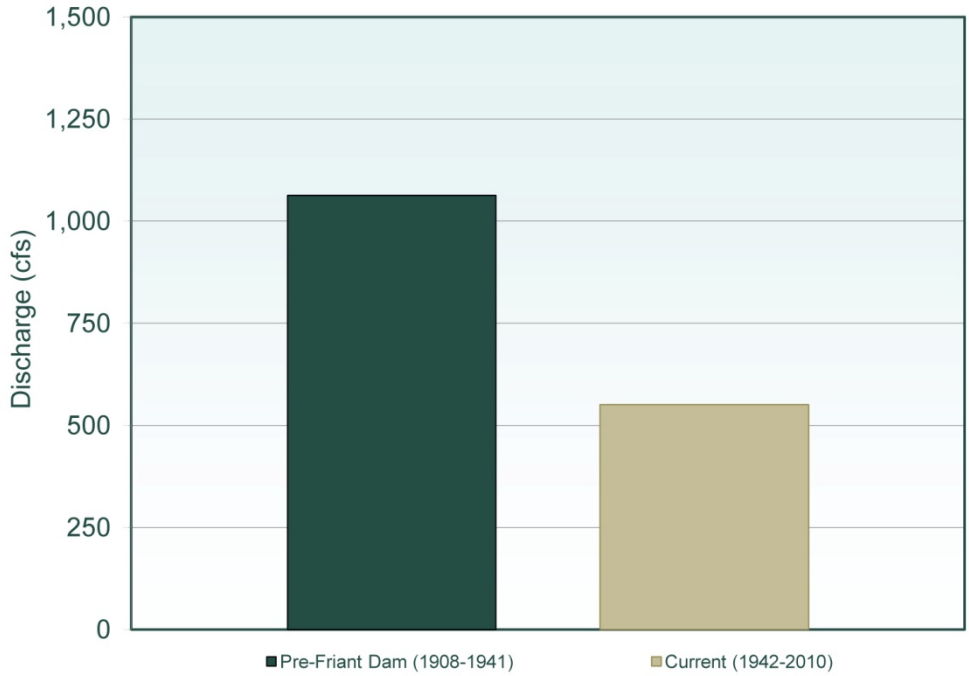
A 90-day minimum flow was chosen to represent low flows because a flow of this duration is most likely to represent the average annual base flow. As described in Section 3.2.3, base flows are positively linked to the sustainability of riparian vegetation and riparian wetlands and the suitability of salmonid spawning habitat. Modified base flows may also be a primary factor limiting the recruitment of early successional riparian vegetation in the Sacramento River (see Section 3.5.3).

Metric Summary The low flow of the Sacramento River was increased after Shasta Dam was completed to provide irrigation water during summer (Figure 4-7, see also Figure 4-1). These flows are high enough to "drown" seedlings of riparian tree and shrub species. In the San Joaquin River, low flows after Friant Dam was completed were much lower than the flows before dam construction (Figure 4-8, see also Figure 4-2). Low flows in the San Joaquin River are so low that riparian seedlings cannot survive the summer in the reach between Gravelly Ford and Mendota Dam.



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-7. Base-Flow Discharge in the Sacramento River at Bend Bridge (USGS Gage 11377100)



Source: Prepared by AECOM in 2011 based on USGS gage data

Figure 4-8. Base-Flow Discharge in the San Joaquin River at Friant (USGS Gage 11251000)

4.1.2 Channel and Floodplain Dynamics

Description of Metrics

The metrics chosen to represent the status and trends of channel and floodplain dynamics are total river length, floodplain reworked (i.e., area that the channel moved through), and floodplain age. These metrics were computed previously for the middle reach of the Sacramento River (from RM 143 to 244) (Larsen, 2010). Because of time constraints associated with preparing this information for inclusion in the 2012 CVFPP, these metrics were included from this previous report but were not calculated for other reaches of the Sacramento River, tributaries to the Sacramento River, or the San Joaquin River system. It is anticipated that these metrics will be calculated for other rivers in the Sacramento and San Joaquin valleys as part of the 2017 CVFPP.

Total River Length

Total river length represents the amount of riverine and channel margin habitat available to native species. Changes in total river length were assessed to determine whether habitat for native species had changed as a result of a change in river planform.

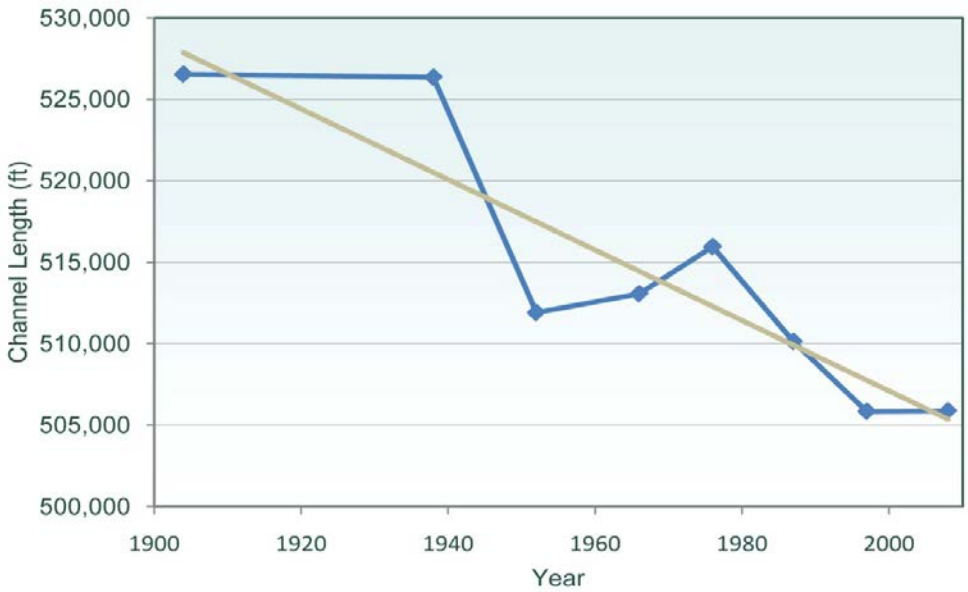
Methodology and Rationale Total river length was calculated as the distance along the Sacramento River channel centerline from the Red Bluff Diversion Dam (RM 244) to the Colusa Bridge (RM 143). The total river length was calculated in GIS by measuring the centerline length of the river channel for eight periods between 1904 and 2007. Historic river centerlines were created by GIS analyses of aerial photographs and historic centerlines. Because the river tended to be located in different locations through time, a common start and end point was chosen for analysis. Channel segments that extended past these points were trimmed, resulting in a measure of river length reflective of sinuosity between a common starting and ending point.

The total length of river between a starting location and an ending location is a clear and obvious measure of the size of the river. For ecosystem processes related to the areal extent of a river channel, such as salmonid rearing habitat or floodplain interaction, and area of riparian habitat, a greater total length of river (given fixed end locations) will provide more area and therefore more ecosystem functions and processes. Total river length is by definition a large-scale metric that assesses the overall health of the river. This indicator was previously used as a metric of river health on the Willamette River in Oregon (IMST, 2002).

A longer, and therefore more sinuous, river provides an ecosystem with greater habitat values (e.g., Brookes, 1987; James and Henderson, 2005). In alluvial river settings, a sinuous river has more cut banks and point bars than a straight river. It is also likely to be a more active river in terms of riverine processes of meander migration and erosion and sediment deposition, although such processes may be constrained by the presence of riprap on the riverbank. Because sinuous rivers have a greater complexity of habitats and ecological processes associated with them (e.g., Boano et al., 2006), they are more supportive of native species (e.g., bank swallows, salmon) and communities (e.g., cottonwood forests) (e.g., Jungwirth et al., 1993; Brunke and Gonser, 1997).

Metric Summary From 1904 through 2007, the geometric complexity and meander migration dynamics of the middle Sacramento River have decreased (Figure 4-9), which has implications for the riparian ecosystem. The river channel length has tended to decrease, suggesting that the river length lost to cutoff and other processes has not been replaced by an increase in length related to channel migration over that period. In addition, other metrics representing the channel complexity and dynamics have also decreased in a manner similar to the channel length (Larsen, 2010; Micheli and Larsen, 2011). For example, the formation of high-sinuosity bends susceptible to future cutoff has declined; the river sinuosity, the average entrance and exit angle magnitudes, and the average migration rate have all tended to decrease with time. The entrance angle represents the upstream

curvature of a bend and can be correlated with a tendency to cut off the bend (Micheli and Larsen, 2011). Cutoffs can produce oxbow lakes on the Sacramento River, which are important habitats (Morken and Kondolf,



Source: Larsen, 2010

Figure 4-9. Change in Total River Length over Time for the Middle Sacramento River (RM 143 to RM 244)

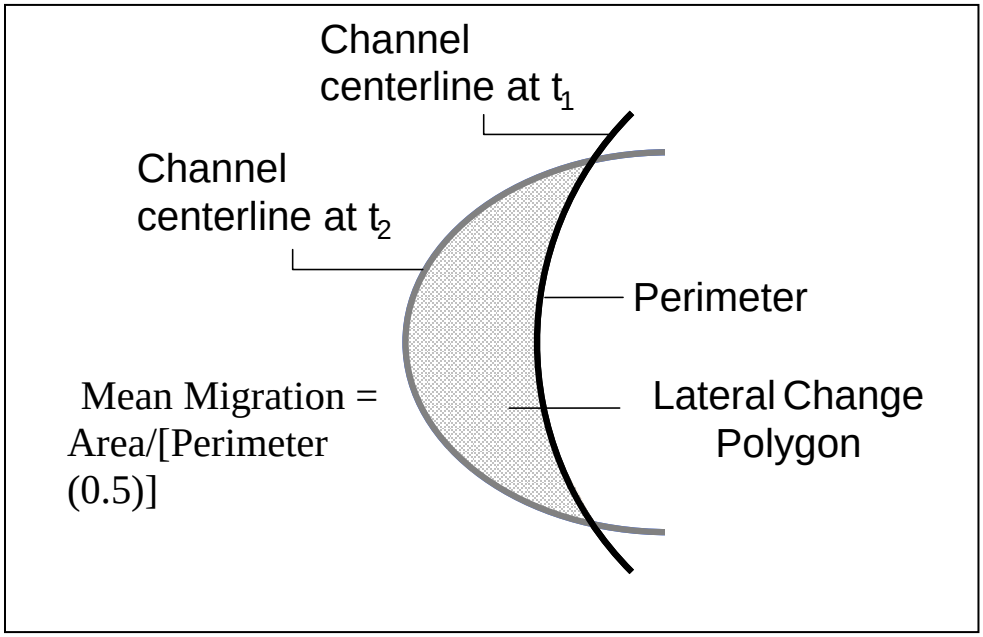
2003). The exit angle is similar but is measured at the downstream inflection point.

Floodplain Reworked

Methodology and Rationale The area of floodplain reworked per year was calculated in GIS by measuring the area of the "lateral change polygon" that is formed when two channel centerlines from two different periods are intersected. A time series of river centerlines was created as described above under "Total River Length." The resultant area between two river centerlines was divided by the number of years in the time interval between the two periods (Figure 4-10). The area of floodplain reworked measured in this way is an estimate of "new floodplain created" (Larsen et al., 2006b). A related metric is floodplain age (Fremier, 2003), which is described in more detail below.

For ecosystem functions and processes related to the areal extent of river channel or of riparian habitat area, the reworking of land and creation of new floodplain are critical (Malanson, 1993; Naiman et al., 2005; Greco et al., 2007). For example, Fremont cottonwood development depends on point bars that are created. As cottonwoods mature, they depend on the

time-sequence of land reworked or floodplain creation. Other riparian species also require heterogeneity of floodplain age, which is produced by land being reworked (van Coller et al., 2000; Dixon et al., 2002; Steiger et al., 2005). The "per year" measurement of land reworked is a metric of the rate that such land is being produced.



Source: Prepared by Dr. Eric Larsen in 2011

Figure 4-10. Calculation Method of Area of Floodplain Reworked

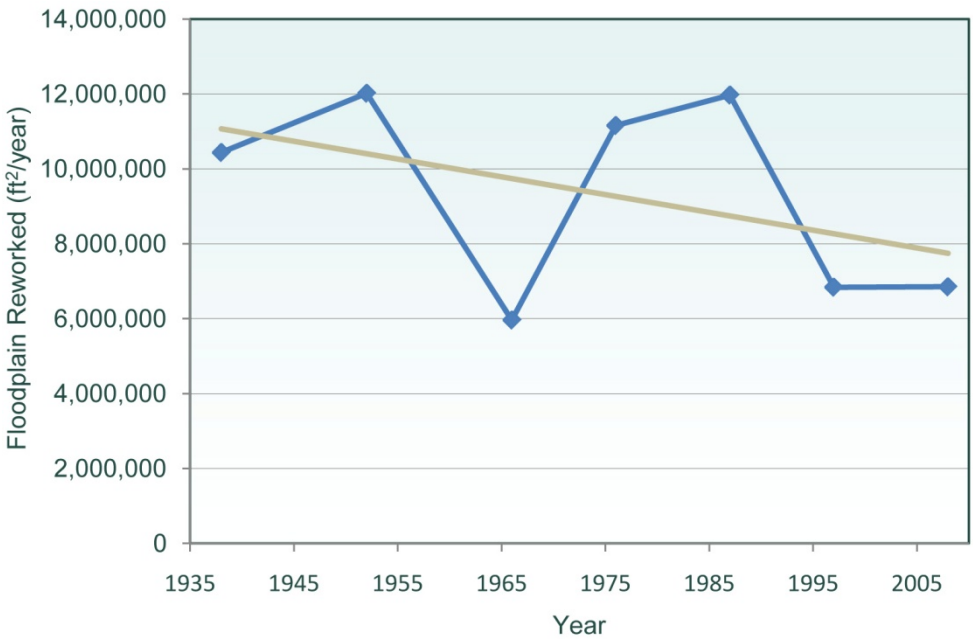
Metric Summary The floodplain area reworked generally shows a decreasing trend over time, although there are large fluctuations (Figure 4-11). As described below, the reasons for these fluctuations are complex.

Some of the reasons can be better understood by separating the area of floodplain reworked into separate components, such as progressive migration, partial cutoff, and chute cutoff (Micheli and Larsen, 2011).

Changes in the indicator values indicate that some of the changes in the river have causes and conditions that conflict with each other. An example of these complicated relationships is the rate of floodplain area reworked. The changes in area reworked on the middle Sacramento River are the result of multiple (sometimes conflicting) causes. For example, the rate of area reworked has decreased with the use of bank protection, but it also has increased with replacement of native riparian vegetation with agriculture (Micheli et al., 2004).

Floodplain Age

Methodology and Rationale Floodplain age is defined as the time elapsed since a specific area changed from aquatic to terrestrial (e.g., river channel to point bar). This metric was measured using the same digitized time series of channel centerlines used to compute total river length and floodplain reworked. Algorithms were developed in GIS to interpolate channel positions between years because the source aerial photographs used to derive channel centerlines were taken, on average, 10 years to 15 years apart. The resultant geospatial data depict the estimated age of the



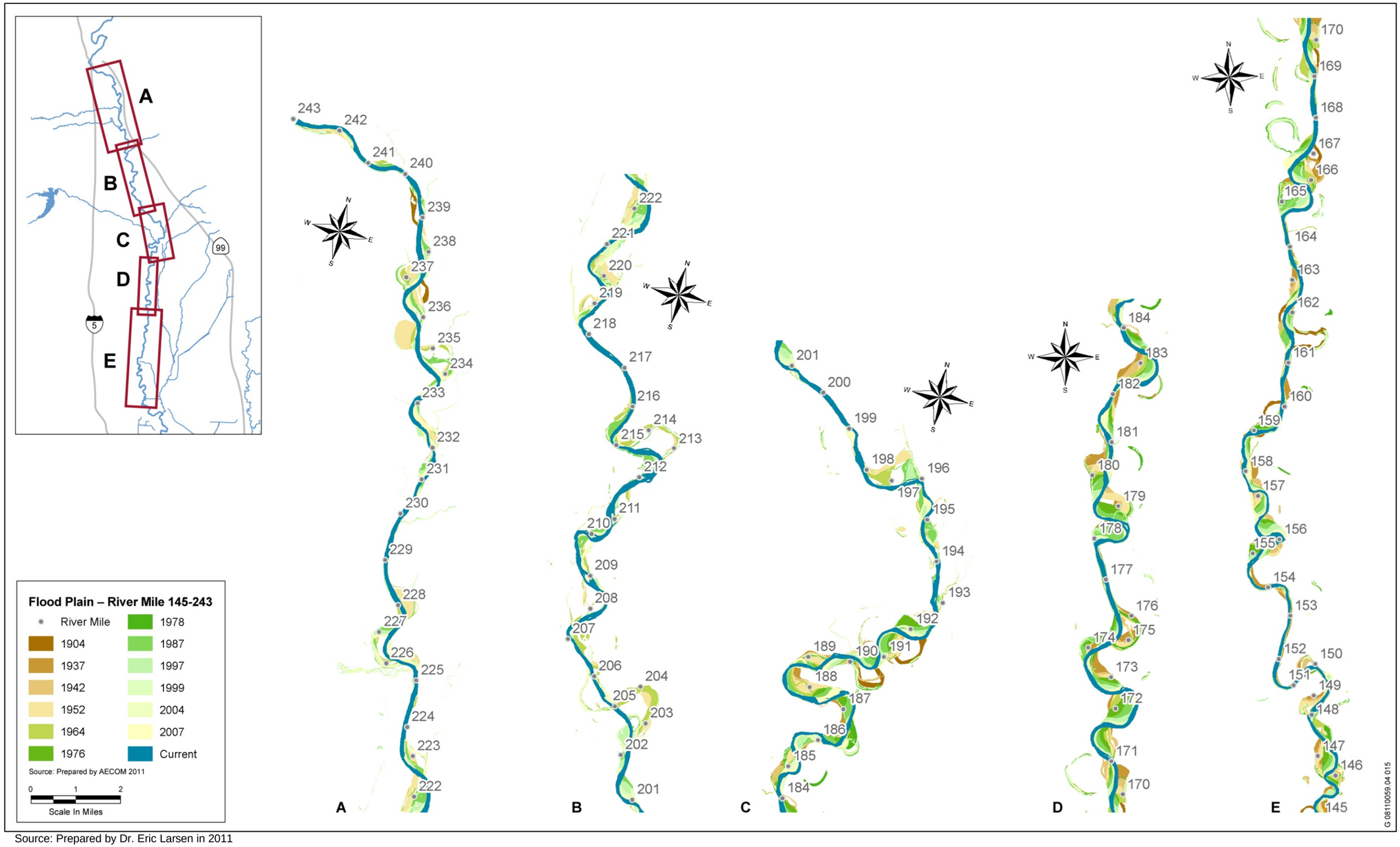
Source: Larsen, 2010

Figure 4-11. Area of Floodplain Reworked over Time for the Middle Sacramento River (RM 143 to RM 244)

floodplain surface and the mechanism by which new floodplain was created (i.e., floodplain created by progressive channel migration rather than channel abandonment). A full description of the methodology used to calculate floodplain age is provided elsewhere (Fremier and Girvetz, in prep.; Figure 1).

Metric Summary An example of the floodplain age analysis is shown on Figure 4-12 (different colors represent different floodplain ages). Like the floodplain reworked metric, the floodplain age metric provides a useful measure by which riparian habitat ecosystem functions can be assessed (Fremier et al., 2009). Figure 4-13 shows the acreages of floodplain patches of different ages in a reach of the Sacramento River. Because riparian ecosystems undergo relatively predictable patterns of vegetation succession following disturbance, it can be assumed that river reaches with a wide

diversity of floodplain ages will have a diversity of vegetation communities. This diversity would include early successional species on younger floodplains, a mixture of early and late successional species on middle-aged floodplains, and late successional species on older floodplains (Greco and Plant, 2003; Fremier et al., 2009). An assumed positive relationship exists between floodplain age diversity and species diversity, as described in Section 3.4.1.



Source: Prepared by Dr. Eric Larsen in 2011

Figure 4-12. Floodplain Age Mapped Along the Middle Sacramento River (RM 145 to RM 243)

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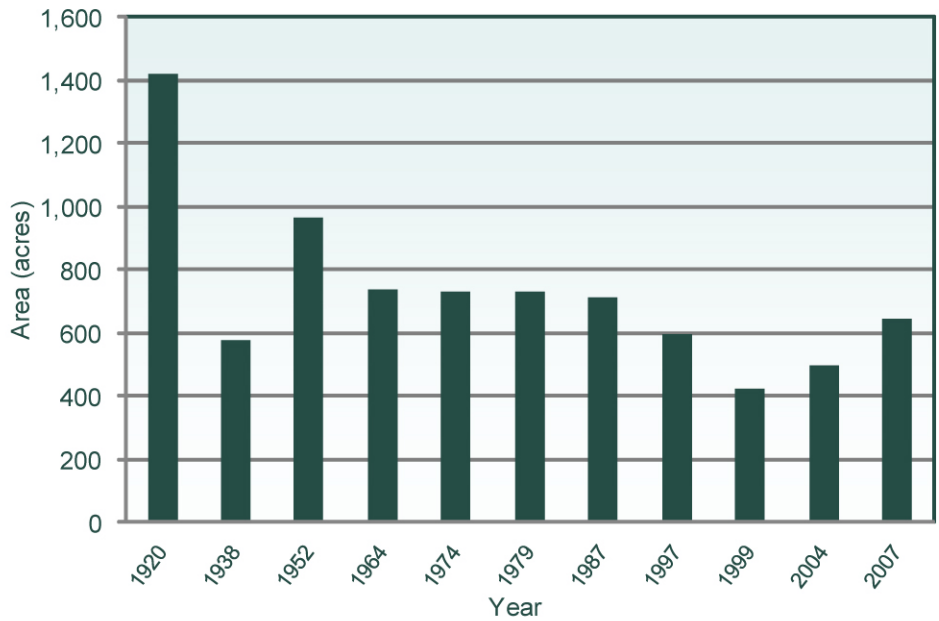


Source: Prepared by Dr. Eric Larsen in 2011

Figure 4-13. Area of Newly Created Floodplain by Year Along the Middle Sacramento River (RM 217 to RM 243)

4.1.3 Riparian and Riverine Habitats

A diversity of floodplain ages reflects ecosystem processes that lead to a diversity in habitats. Newly formed land undergoes primary succession and is colonized through this process by early successional woody species, such as willows and cottonwoods. These species provide habitat for important conservation target species. Conservation of primary and secondary successional processes is an important management goal (Greco et al., 2007).

Meander migration and channel cutoff processes are necessary to create and support the landscape heterogeneity of different riparian wildlife habitats. For example, Greco et al. (2002) showed that the yellow-billed cuckoo's habitat consists of cottonwood forest that is maintained by periodic disturbance.

Description of Metrics

The metrics chosen to represent the status and trends of riparian and riverine habitat are (1) SRA cover length, (2) habitat distribution and extent, and (3) species distribution and abundance. SRA cover length is presented in tabular format (i.e., summarized by reach). Habitat and species distributions are presented spatially. Species abundance ideally would be

presented as counts of representative species, but those data are not available.

Shaded Riverine Aquatic Cover

Methodology and Rationale SRA cover is defined as "the unique near-shore aquatic area occurring at the interface between a river (or stream) and adjacent woody riparian habitat. Key attributes of this aquatic area include (a) the adjacent bank being composed of natural, eroding substrates supporting riparian vegetation that either overhangs or protrudes into the water, and (b) the water containing variable amounts of woody debris, such as leaves, logs, branches and roots, often substantial detritus, and variable velocities, depths, and flows" (USFWS, 1992).

Three attributes of SRA cover make it an important component of fish and wildlife species habitat (USFWS, 1992):

- Overhanging vegetation and (sometimes) riverbanks provide at least six types of habitat values to fish and wildlife species:
  - Shade and cover reducing visibility to predators
  - Moderation of water temperatures important to salmonids
  - Input of plant material which provides instream cover for fish
  - Habitat of terrestrial and aquatic invertebrates which provide food to birds and aquatic species
  - Perches, nesting, and resting areas for bird species
- In-water cover, including (1) overhanging or fallen trees or branches, (2) aquatic vegetation, (3) diversity of substrate sizes, and (4) irregular banks, provides habitat complexity to fish and wildlife species, which supports a high diversity and abundance of invertebrate and fish species.
- Natural, eroding banks, often have cavities, depressions, and vertical faces that support bank-dwelling species, including bank swallow, belted kingfisher (*Megaceryle alcyon*), mink (*Neovison vison*), river otter (*Lontra canadensis*); and that provide cover and shelter for fish. The bank dwelling species may use these banks and their cavities as access points for the water or for nesting. Erosion of natural bank substrates provides instream spawning substrate for aquatic species, including salmonids.

SRA cover data are available for three reaches of the Sacramento River: Red Bluff to Chico Landing, Chico Landing to Colusa, and Colusa to Verona. Data for the reaches from the latter two (downstream) reaches were collected by the USFWS and USACE in spring and summer 2002. Data for the reach from Red Bluff to Chico Landing were collected by DWR in 2007. The methods were developed jointly by DWR, USFWS, and USACE, and followed the protocol of the *Standard Assessment Method for the Sacramento River Bank Protection Project* (USACE, 2004).

The following data were mapped along the three reaches:

- Bank type: mostly erosional or mostly stable (which are SRA cover types), or mostly depositional or revetment (which are non-SRA cover types)
- Vegetative cover: more than 75 percent cover of woody vegetation (an SRA cover type), less than 75 percent woody vegetation (a non-SRA cover type)
- Woody vegetation type: riparian forest (taller than 20 feet), riparian scrub (shorter than 20 feet)
- LWM cover: percentage bank length with large woody material
- Overhead cover: percentage of riverbank line shaded at noon (not analyzed in this report)

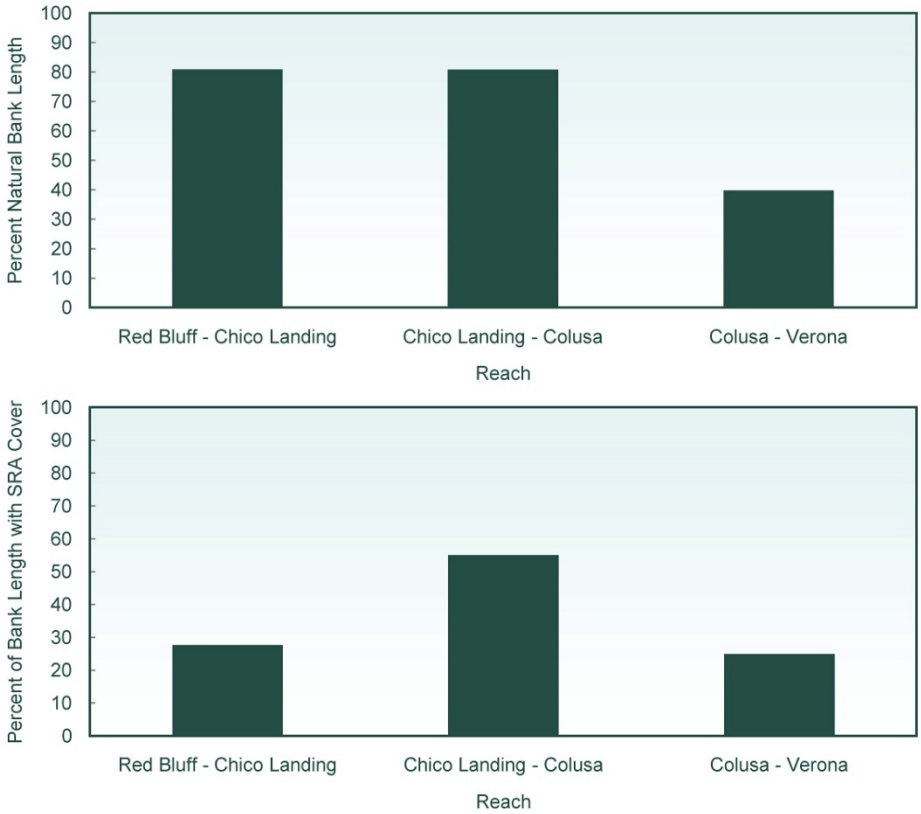
Overhead cover height: cover mostly less than 10 feet high, cover mostly more than 10 feet high (not analyzed in this report). Sites were only considered to have SRA cover when they had mostly erosional or mostly stable bank types, more than 75 percent woody vegetative cover, with shaded bank line, and LWM present.

Metric Summary Approximately 81 percent of the banks between Red Bluff and Colusa are natural (i.e., without revetment) (Figure 4-14). Between Colusa and Verona the amount of revetment is much greater and the natural bank portion is about 40 percent. The percentage of banks with SRA cover is greatest between Chico Landing and Colusa (55 percent), and considerably less upstream and downstream (approximately 28 and 25 percent, respectively) (Figure 4-14).

For natural banks, the type of SRA cover (riparian forest versus scrub, and LWM cover) differs substantially among the three reaches. The majority of the SRA cover in the reach from Red Bluff to Chico Landing consists of riparian scrub (62.2 percent), while from Chico Landing to Colusa the

percentage of scrub is much less (22.8 percent), and from Colusa to Verona the scrub percentage is very much less (1.8 percent) (Figure 4-15). Almost all SRA cover between Colusa and Verona consists of riparian forest.

Approximately 38 percent of the natural banks between Red Bluff and Chico Landing are in the highest LWM cover class (Figure 4-15). Most of this LWM is contributed by riparian scrub, and presumably consists of relatively small material. Only 8 percent of the natural banks in the reach between Chico Landing and Colusa are in the largest LWM class, and all this material is associated with riparian forest, presumably including logs and large tree branches (Figure 4-15).

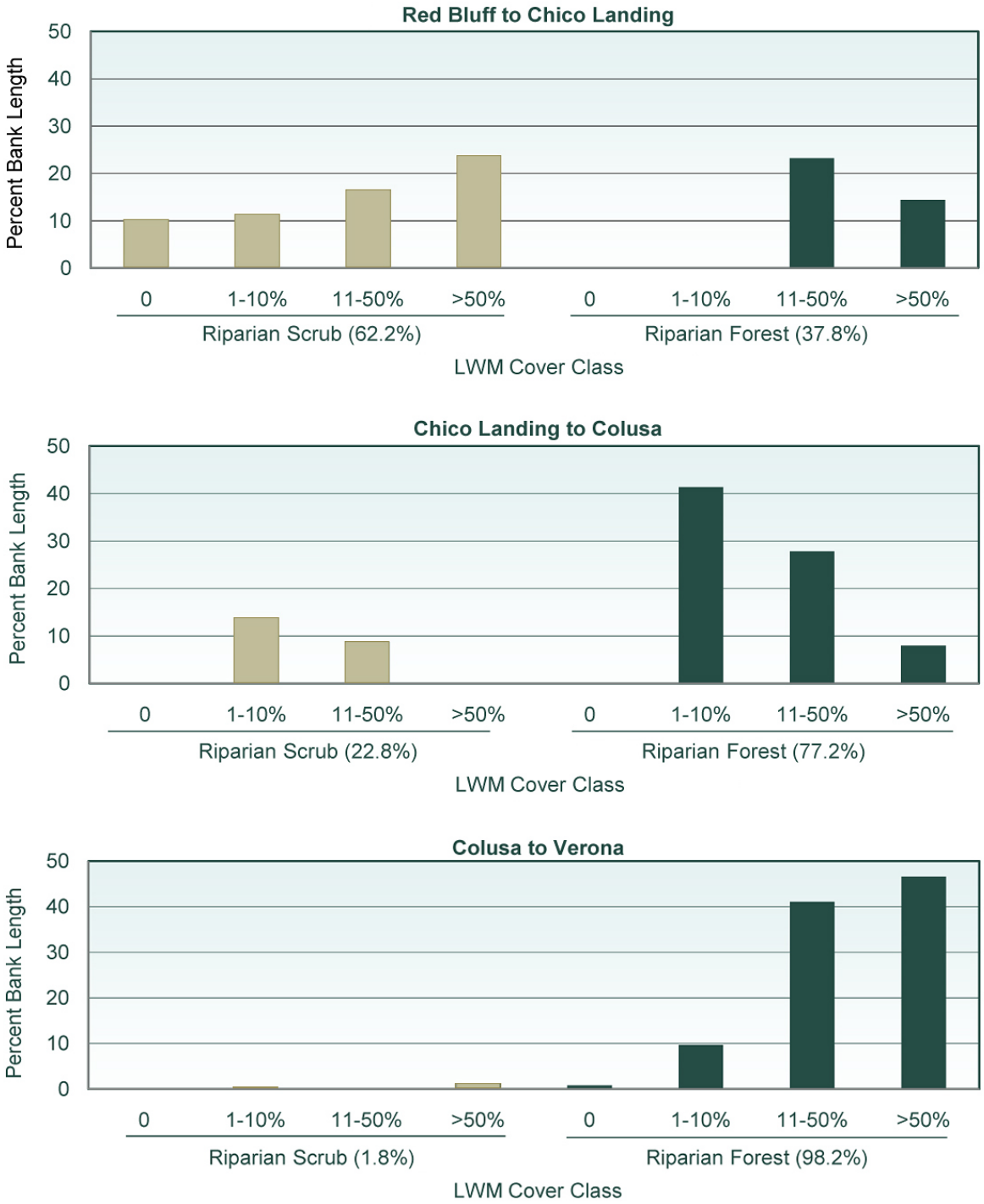


Source: Prepared by Dr. Eric Larsen in 2011

Figure 4-14. Percent Natural Bank Length and SRA Cover by Reach

Overall bank length with more than 50 percent LWM cover can be calculated by multiplying the overall natural bank percentage (Figure 4-14A) with the percentage of bank length in a particular LWM cover class (Figure 4-15). For the reaches from Red Bluff to Chico Landing, Chico Landing to Colusa, and Colusa to Verona, bank lengths with more than 50 percent LWM cover represent 31 percent, 6 percent, and 19 percent of the total bank lengths, respectively. Overall bank lengths with LWM cover

between 1 percent and 50 percent for the reaches from Red Bluff to Chico Landing, Chico Landing to Colusa, and Colusa to Verona are 42 percent, 74 percent, and 20 percent, respectively.



Source: Prepared by Dr. Eric Larsen in 2011

Figure 4-15. LWM Cover Class Distribution of Riparian Scrub and Forest by Reach

Habitat Distribution and Extent

Methodology and Rationale Habitat distribution and extent were analyzed using the Central Valley Riparian Mapping Project GIS database prepared by California State University, Chico, and DFG. The data were developed for the CVFPP SPA to inventory riparian vegetation, wetlands, and other natural communities in the SPA. Land-use types were mapped to the broadest categories (i.e., agriculture and urban). The data were heads-up digitized at a scale of 1:2,000 using National Agricultural Inventory Program 2009 aerial imagery (USDA, 2009). The minimum mapping unit (MMU) for natural vegetation is 1 acre with an average width equal or greater to 33 feet for polygons mapped to the National Vegetation Classification System (NVCS) Group Level; provisional NVCS groups are as presented by Sawyer et. al. (2009) and temporary provisional groups are as presented by Todd Keeler-Wolf (pers. comm., 2009).

For the production of the large-scale maps in this report, natural vegetation types were combined into the following broad wetland and riparian habitat type categories: riparian forest, riparian scrub, freshwater permanent wetland, seasonal wetland, vernal pool complex, and alkali seasonal wetland complex. Acreages were calculated for each of these broad habitat types, and maps showing the distribution of these habitat types were created. To indicate the extent of change from historical conditions, the extent of riparian and perennial wetland vegetation from The Bay Institute's (1998) map of historical riparian and wetland vegetation of the Central Valley is also displayed on the maps.

Metric Summary Figures 4-16 through 4-22 display the known distribution of riparian and wetland habitat in the Sacramento and San Joaquin valleys. As described in Section 2, riparian and wetland habitats are greatly restricted relative to their likely historical distribution. Although the historical trend has been a widespread decline in wetland and riparian habitats, recent restoration efforts have likely reversed this trend in parts of the Sacramento and San Joaquin valleys. It should be noted that most habitat restoration efforts to date have involved planting riparian vegetation and, occasionally, creating wetlands rather than restoring fluvial and geomorphic processes that would promote "natural" habitat regeneration. The locations and acreages of riparian and wetland habitat restoration projects completed in the Sacramento and San Joaquin valleys were not tabulated for preparation of this report.

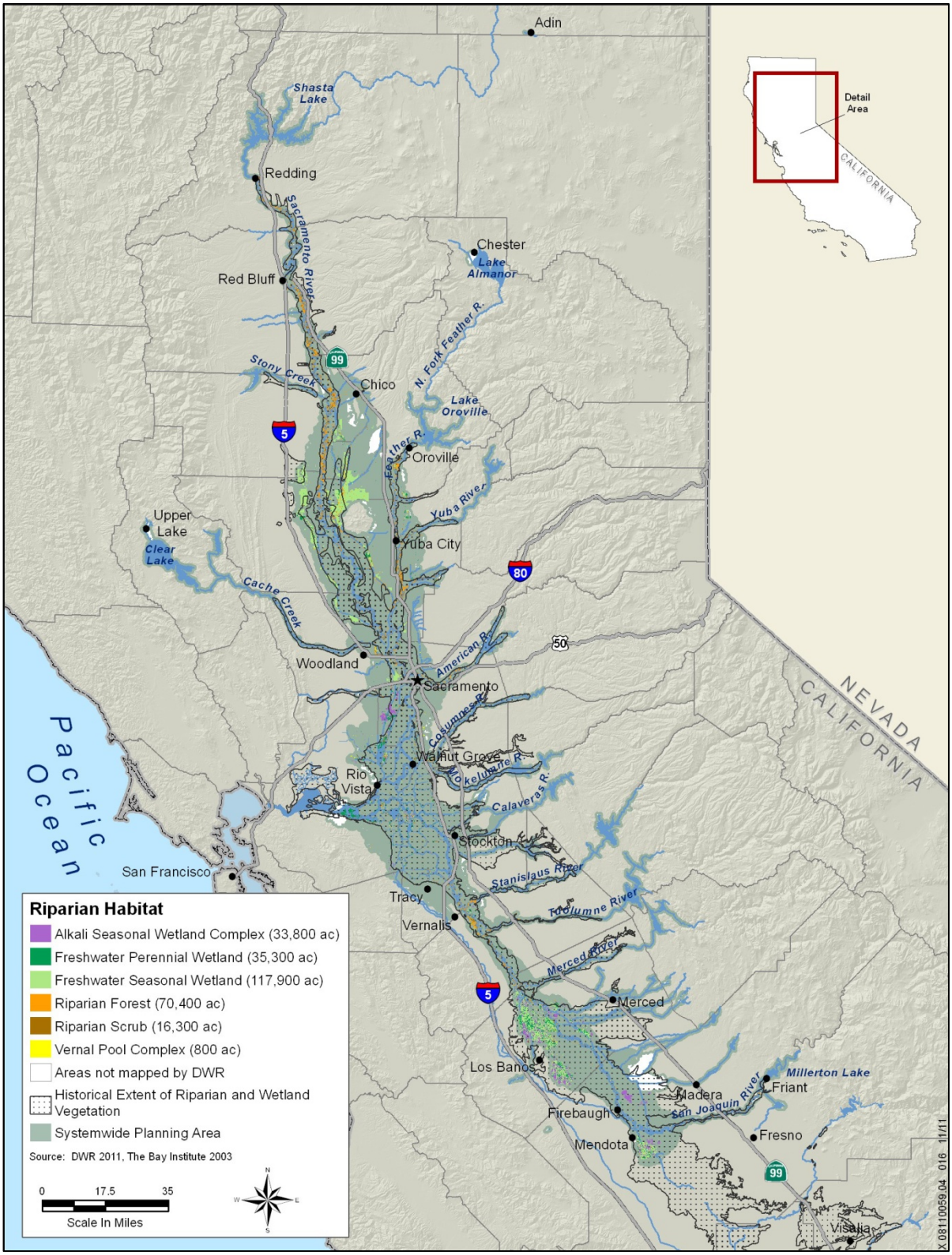


Figure 4-16. Riparian and Wetland Habitat in the Central Valley

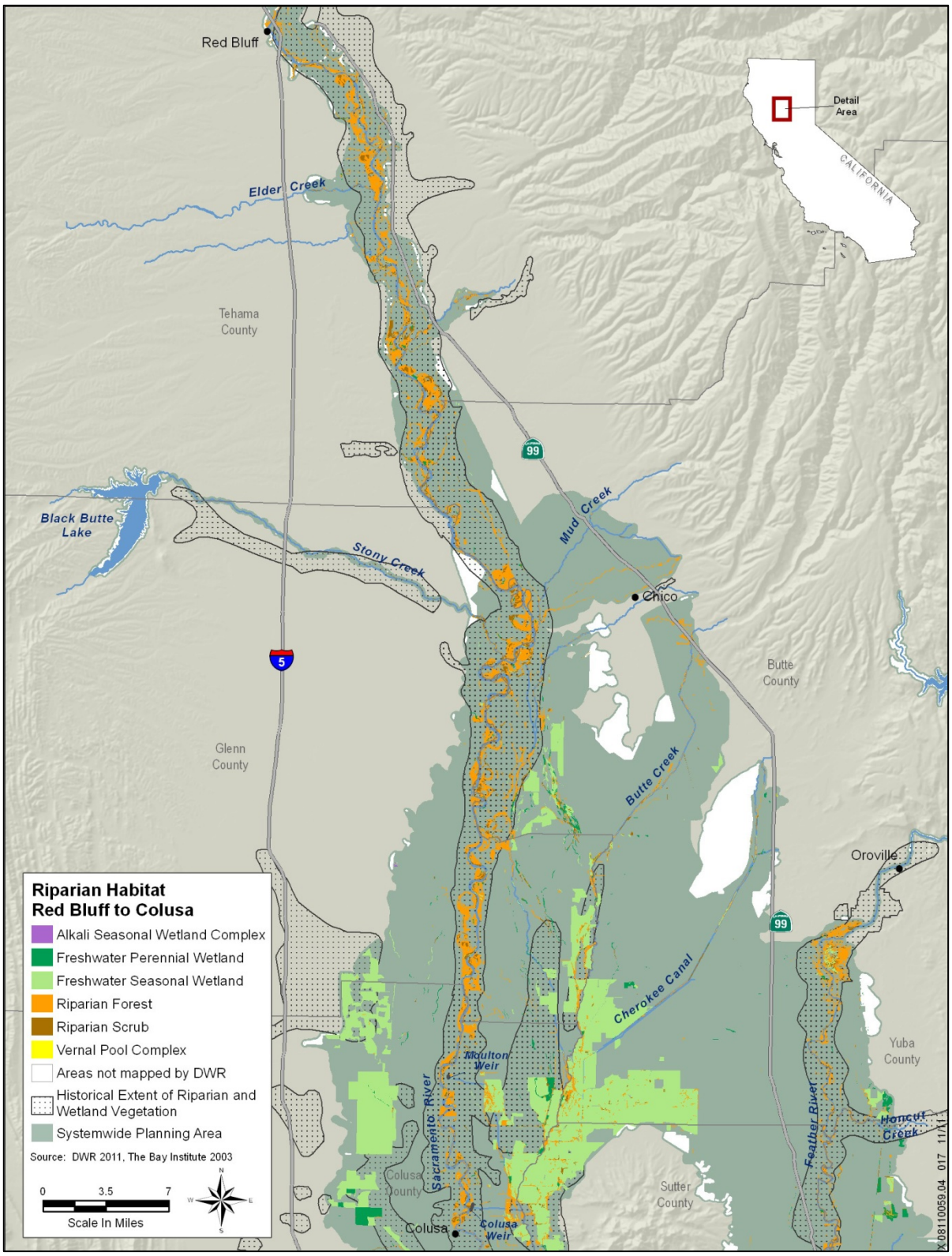


Figure 4-17. Riparian and Wetland Habitat in the Central Valley: Red Bluff to Colusa

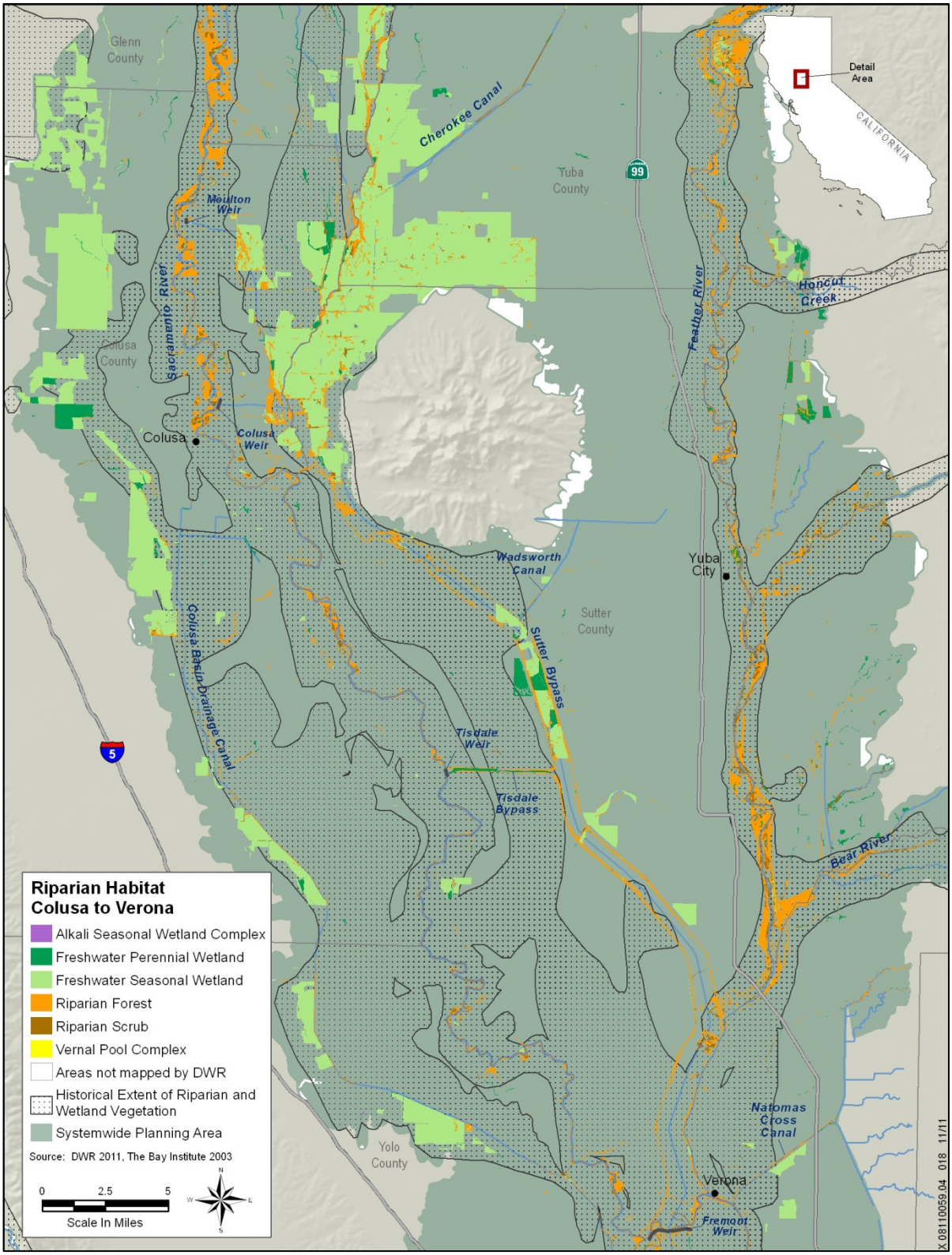


Figure 4-18. Riparian and Wetland Habitat in the Central Valley: Colusa to Verona

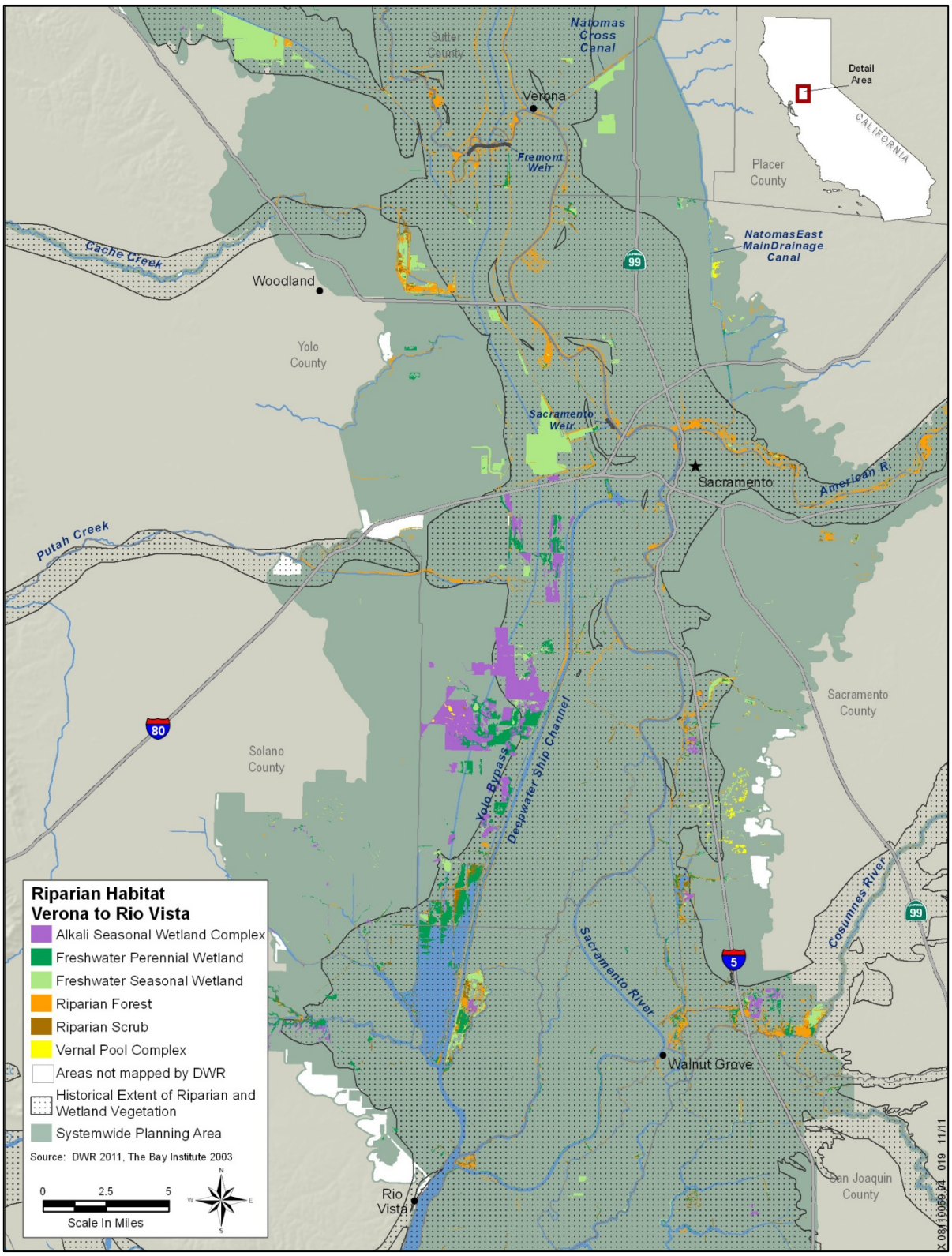


Figure 4-19. Riparian and Wetland Habitat in the Central Valley: Verona to Rio Vista

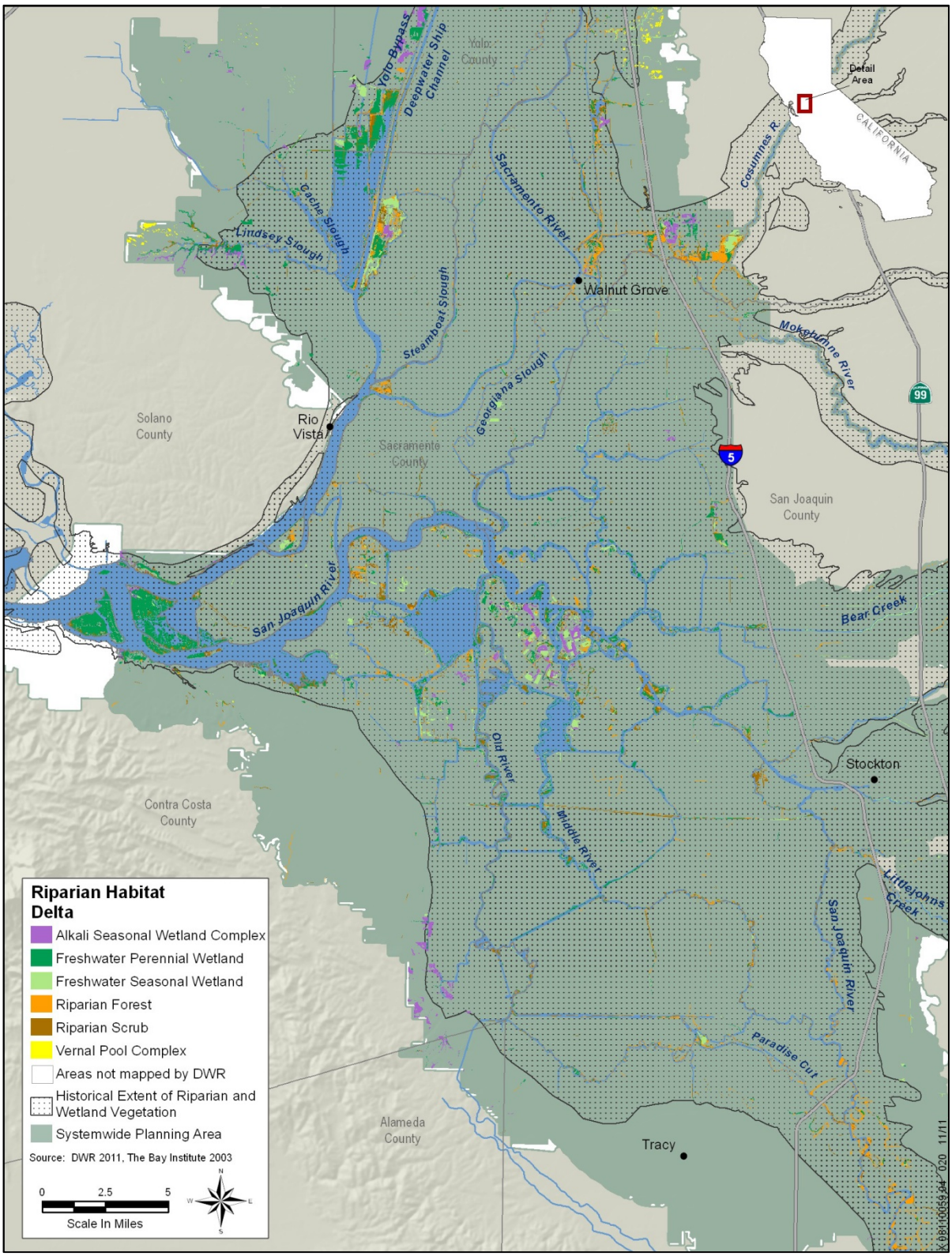


Figure 4-20. Riparian and Wetland Habitat in the Central Valley: Delta

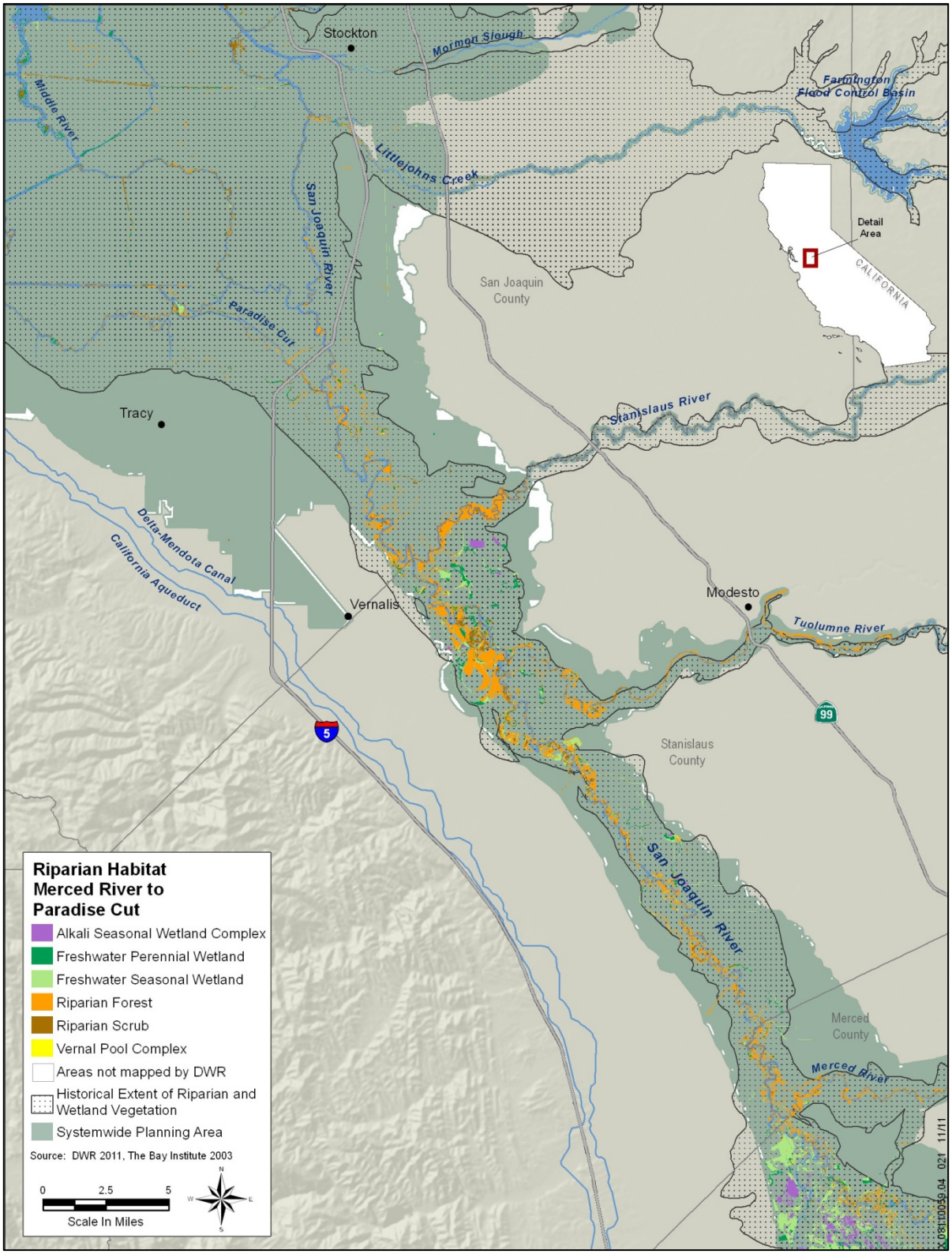


Figure 4-21. Riparian and Wetland Habitat in the Central Valley: Paradise Cut to Merced River

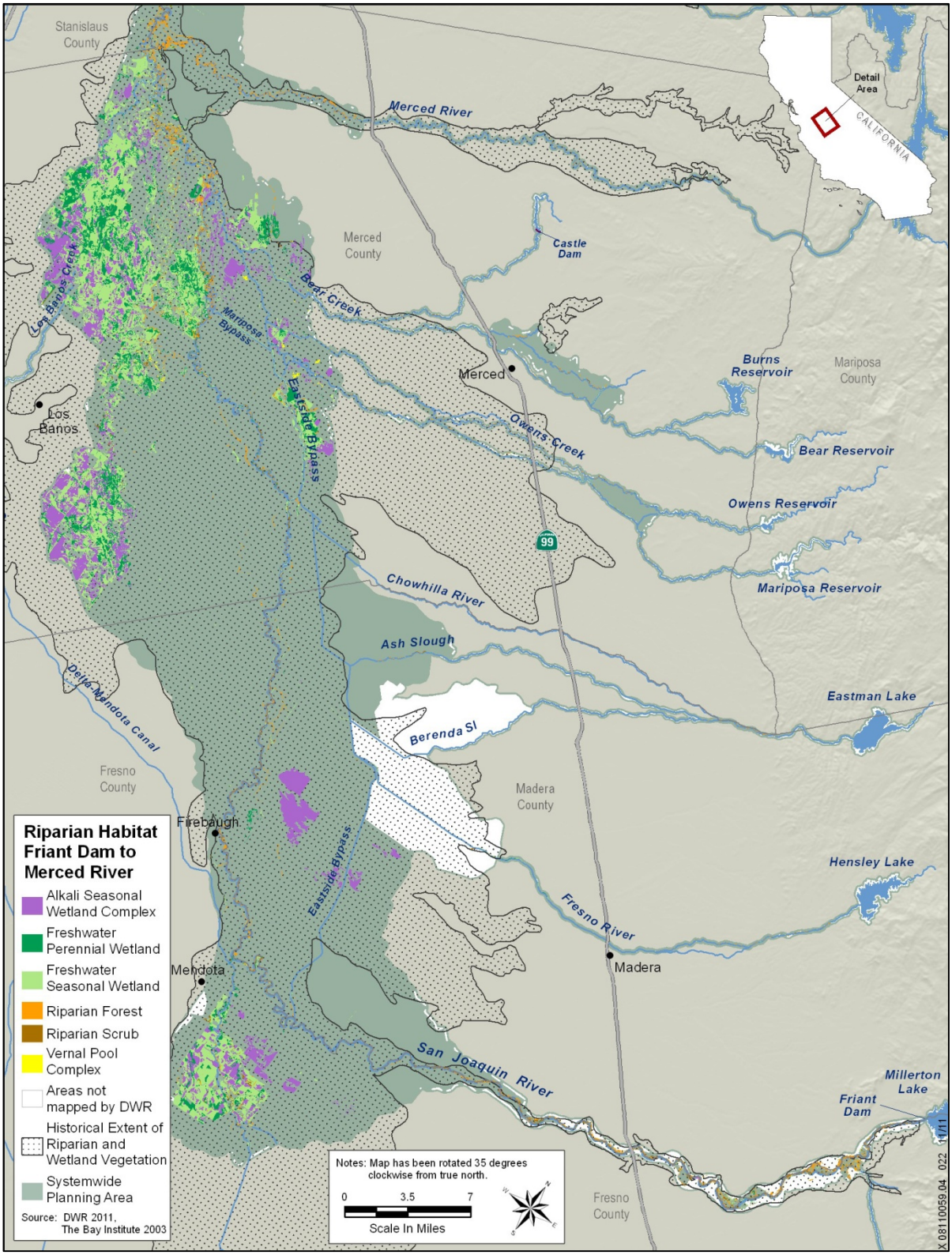


Figure 4-22. Riparian and Wetland Habitat in the Central Valley: Merced River to Friant Dam

Areas of riparian and wetland habitat that still exist, including areas of restored habitat, are primarily found between the levees or within historical flood basins that serve as flood bypasses or are protected as wildlife refuges by federal or state agencies. Although these areas still provide valuable wildlife habitat (e.g., San Luis National Wildlife Refuge Complex, Yolo Bypass Wildlife Area), much of the remnant habitat exists as linear strips adjacent to the Sacramento and San Joaquin rivers and their tributaries. Linear strips of habitat frequently lack the structural characteristics and landscape attributes (e.g., patch size, edge-to-interior-habitat ratios, connectivity) that are required for many species of riparian wildlife; therefore, the habitat values of these remnant patches are limited in many cases.

Although not shown in these data, various studies and anecdotal observations (see Sections 2 and 3) indicate that much of this remnant riparian habitat is characterized by late succession vegetation, such as valley oak woodland. Early succession vegetation preferred by some species of migratory songbirds, including sensitive species like yellow-billed cuckoo and yellow-breasted chat (i.e., cottonwood-willow scrub and woodland), is absent from much of the Sacramento and San Joaquin valleys because the disturbance and specific combination of flow events required to encourage germination and recruitment of early succession species is lacking.

Species Distribution and Abundance

Methodology and Rationale For terrestrial species, the California Natural Diversity Database (CNDDB) (Version 3.1.0) was used to depict species distribution. The CNDDB is maintained by the Habitat Conservation Division of DFG. The primary function of the CNDDB is to gather and disseminate data on the status and locations of rare and endangered plants, animals, and vegetation types (Bittman, 2001). The goal of the CNDDB is to provide the most current information available on the state's most imperiled elements of natural diversity and to provide tools to analyze these data (DFG, 2011a). Although more detailed data are available for some species in some parts of the state, the CNDDB provides data that are consistently compiled for a large number of sensitive species throughout the Sacramento and San Joaquin valleys.

The CNDDB was queried for occurrence records for the following species: valley elderberry longhorn beetle (VELB) (*Desmocerus californicus dimorphus*), bank swallow, yellow-billed cuckoo, yellow-breasted chat, riparian brush rabbit (*Sylvilagus bachmani riparius*), riparian woodrat (*Neotoma fuscipes riparia*), and least Bell's vireo. These species were selected because they are highly dependent on riparian habitats in the Sacramento and San Joaquin valleys for foraging, breeding, or other

important life history requirements. They also were selected because each is considered by state or federal resource agencies to be rare, threatened, or endangered.

Although the number of individuals of each species observed at each CNDDB occurrence is usually recorded in CNDDB records, it is not always reliably reported, nor is it systematically collected at the same location over time. Therefore, it is difficult, if not impossible, to determine the number of individuals observed at each occurrence and how these population sizes have changed over time. Furthermore, CNDDB contains information only on areas that have been surveyed for species and therefore is an incomplete record of historical and current species' distributions.

For aquatic species, the current distribution of Chinook salmon and steelhead, as determined by the National Marine Fisheries Service (NMFS), was analyzed using the Chinook and Steelhead Distribution GIS (NOAA Fisheries, 2005). This dataset was compiled by the NMFS Southwest Regional Office in an effort to designate critical habitat for Chinook salmon and steelhead in the Sacramento and San Joaquin valleys. The data represent an approximation of Chinook salmon and steelhead occupancy in the region and are best suited for mapping at a regional scale. Historical occupancy was inferred from published reports (McEwan, 2001; Yoshiyama et al., 2001), and GIS maps depicting historical occupancy were prepared for Chinook salmon and steelhead using the information contained in these reports.

The GrandTab report from 2009 (DFG, 2009) was used to display the current status and historical trend of Chinook salmon abundance in the Sacramento and San Joaquin valleys. It contains annual population estimates (escapement) for the Sacramento and San Joaquin river systems compiled from various sources by the Fisheries Branch Anadromous Resources Assessment Unit of DFG. Estimates are based on counts of fish entering hatcheries and migrating past dams, carcass surveys, live fish counts, and ground and aerial redd (Chinook salmon or steelhead nest) counts. The 2009 report includes data from 1960 through 2008.

The current status and historical trend of steelhead abundance was determined from the CalFish database (CalFish, 2009a). Adult return estimates of the spawning population in the upper Sacramento River system (between Keswick Dam and the mouth of the Feather River) are available from 1953 through 1988. This dataset was used because it is the most complete record of steelhead abundance in the Sacramento and San Joaquin valleys (despite the fact that it lacks information on San Joaquin Valley steelhead entirely).

Metric Summary Figures 4-23 through 4-25 display the current known distribution of the seven key riparian species identified above. Bank swallow and VELB have a wide geographic range throughout the Sacramento and San Joaquin valleys (Figures 4-23 and 4-24) but are highly dependent on riverine and riparian habitat, which has been significantly reduced in the Sacramento and San Joaquin valleys. Bank swallow has been described as historically common throughout lowland California (Grinnell and Miller, 1944; DFG, 1995). No historical distribution or abundance information is available for VELB.

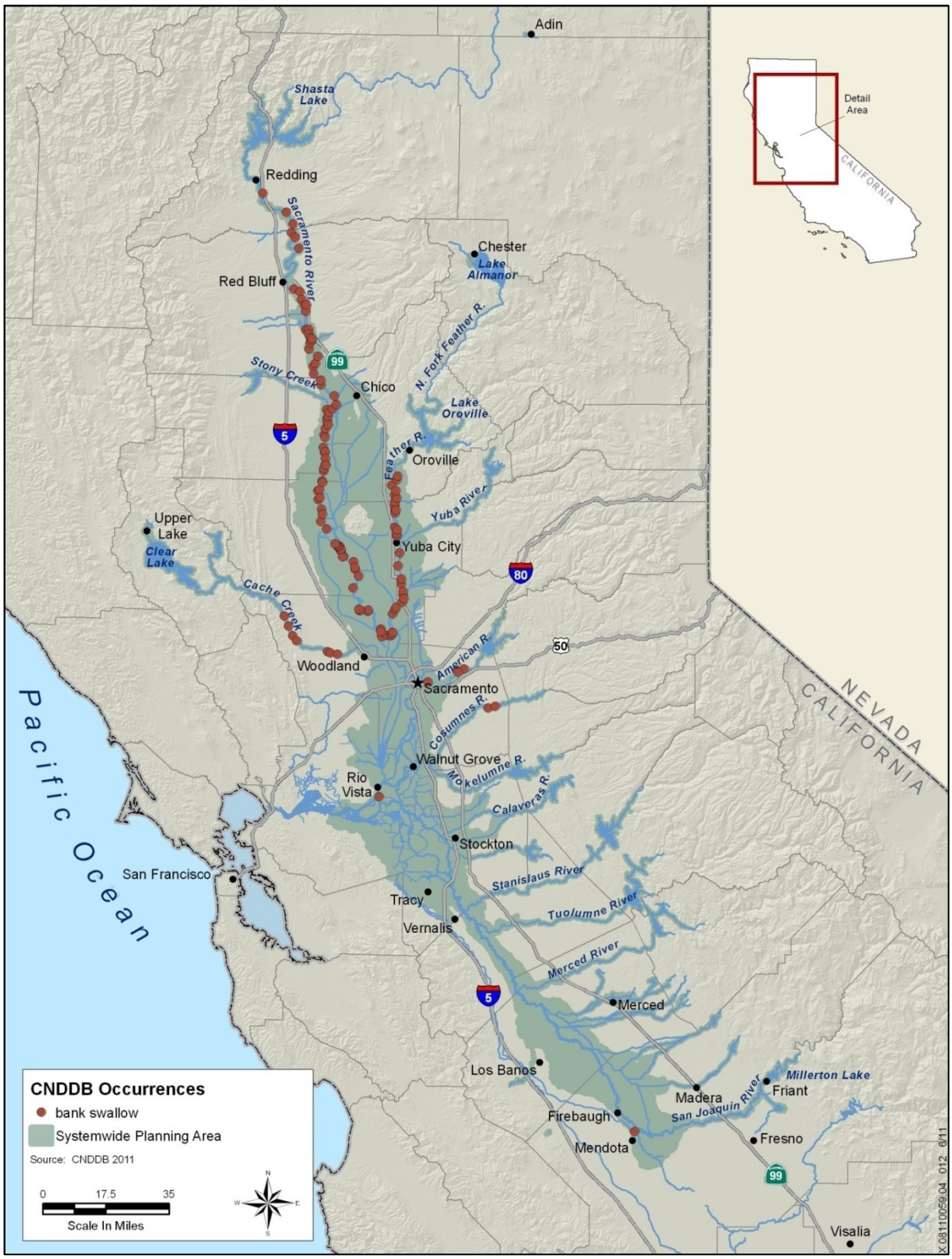


Figure 4-23. CNDDB Occurrences: Bank Swallow

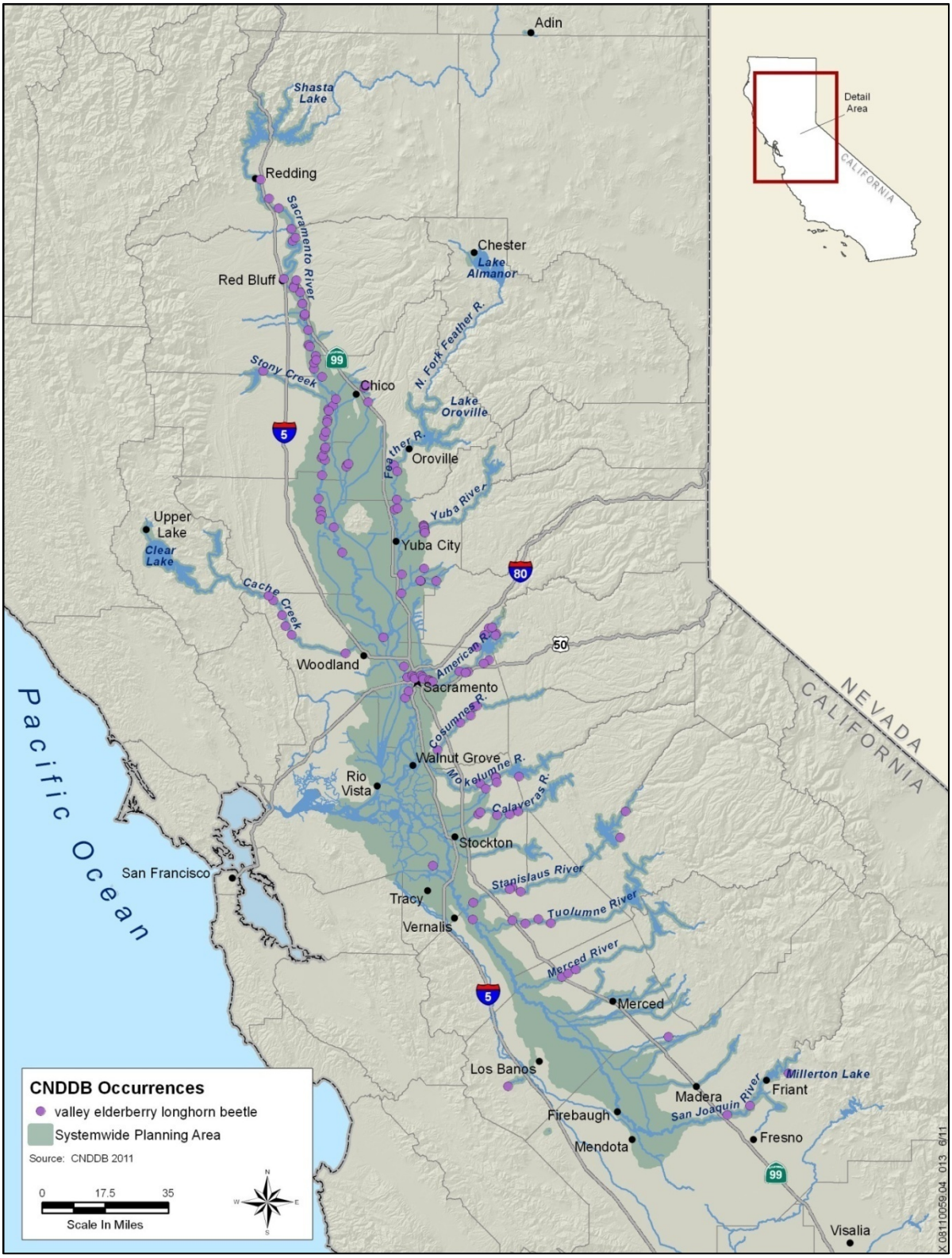


Figure 4-24. CNDDB Occurrences: Valley Elderberry Longhorn Beetle

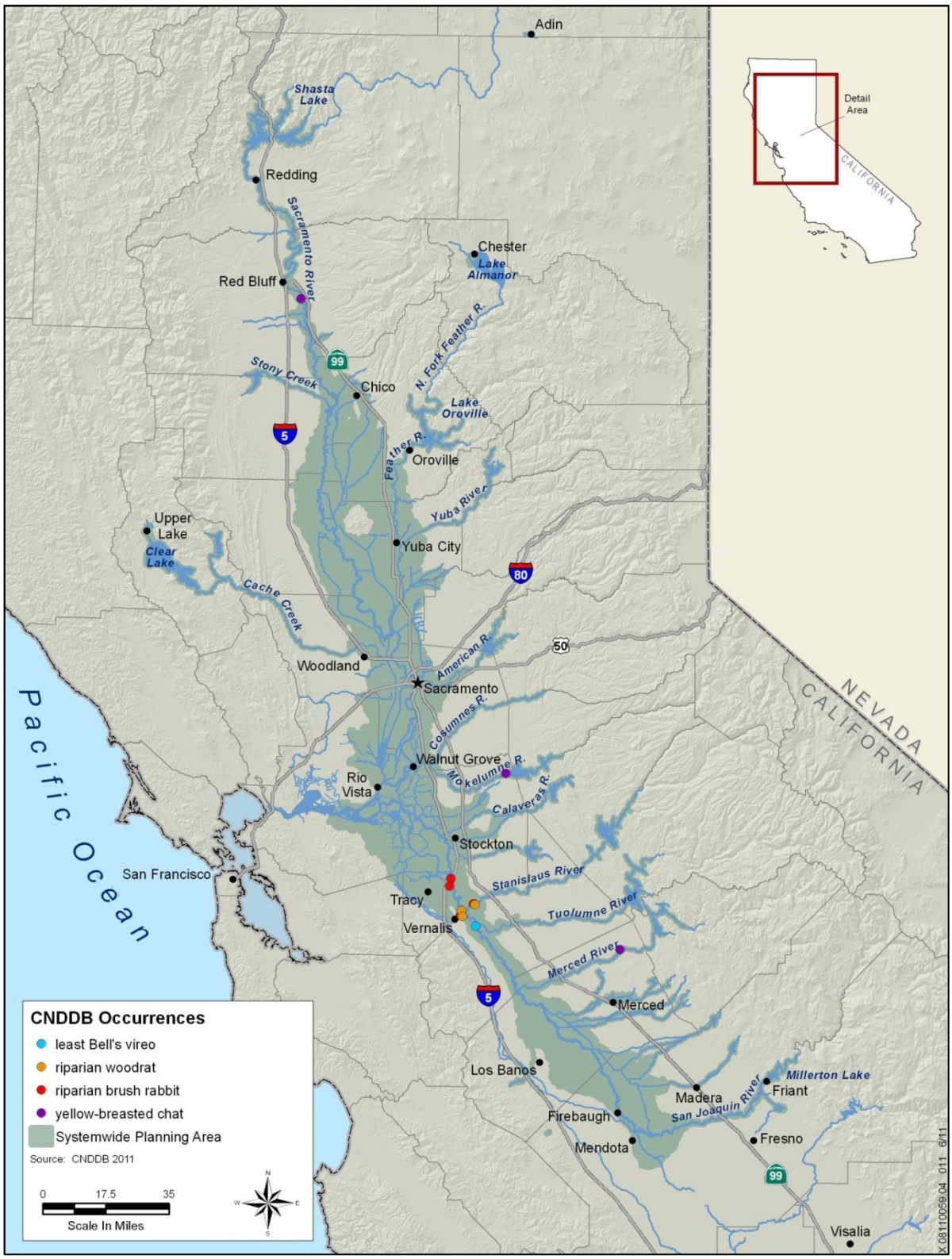


Figure 4-25. CNDDB Occurrences: Least Bell's Vireo, Riparian Woodrat, Riparian Brush Rabbit, and Yellow-Breasted Chat

Surveys conducted in 2009 by DFG, USFWS and DWR estimate the Sacramento River bank swallow population at 8,180 breeding pairs, down 38 percent from the 1986 estimate of 13,170 pairs (DFG, 2010). The Feather River population was estimated at 1,260 in 2009, less than half of the estimate for 1988 of 2,970 breeding pairs (DFG, 2010). Bank swallow population declines have been documented at least since the 1970s (Garcia et al., 2008).

Yellow-breasted chat has specific habitat requirements that do not restrict it to Sacramento Valley and San Joaquin Valley riparian habitat, but according to CNDDB records it is present in only one location in the Sacramento and San Joaquin valleys (Figure 4-25). Historically, yellow-breasted chats were found throughout California and more abundantly in the Sacramento and San Joaquin valleys (Grinnell and Miller, 1944). As late as 1973, singing males were common on the upper Sacramento River in northern Colusa County (Gaines, 1974, cited in Ricketts and Kus, 2004).

Riparian woodrat and riparian brush rabbit are restricted to the Sacramento and San Joaquin valleys and known from only a few locations. Both species probably historically occurred throughout the extensive riparian forests along major streams in the northern San Joaquin Valley (62 Federal Register 62277, November 21, 1997).

Historically, least Bell's vireo commonly bred throughout the Sacramento and San Joaquin valleys, but before 2005 no nesting pairs had been confirmed for more than 50 years (Howell et al., 2010). Since 2005, this bird has been breeding at a restoration site in the San Joaquin River National Wildlife Refuge in Stanislaus County (Howell et al., 2010). In 2010 and 2011, least Bell's vireos also have been observed in spring in the Yolo Bypass (E. Whistler, pers. comm. 2010 and 2011).

Historically, yellow-billed cuckoo was common to locally abundant in lowland riparian habitat, ranging from coastal Southern California through the Sacramento and San Joaquin valleys as far north as Red Bluff (Grinnell and Miller, 1944; Kus, 2004). There are no recorded occurrences of yellow-billed cuckoo in the CNDDB. It has been described as historically common throughout riparian habitat in lowland California, but it had been extirpated from many locations by 1944 (Grinnell and Miller, 1944). A survey conducted in 2010 estimated the Sacramento River population to be up to 38 breeding pairs (Dettling and Howell, 2011).

Although historical occurrence records or population estimates for these species are lacking, these species were likely relatively common in the Sacramento and San Joaquin valleys (see references in above paragraph and Table 4-2). Therefore, the current range of these species and number of

observations in that range can be interpreted, and a probable trend can be inferred, relative to an assumed baseline condition for each species (Table 4-2).

Table 4-2. Probable Historical Distribution of Key Riparian-Associated Species

Species	Historical Distribution	Historical Population Size	References	Inferred Trend
Valley elderberry longhorn beetle	No information available	No information available	NA	Unknown
Bank swallow	Throughout lowland California	Common	Grinnell and Miller, 1944; DFG, 1995	Declining
Yellow-breasted chat	Throughout California	Common to abundant	Grinnell and Miller, 1944; Gaines, 1974, cited in Ricketts and Kus, 2004	Declining
Yellow-billed cuckoo	Riparian habitat throughout lowland California	Common	Grinnell and Miller, 1944	Declining
Least Bell's vireo	Lowland riparian habitat from coastal Southern California through the Sacramento and San Joaquin valleys	Common to locally abundant	Grinnell and Miller, 1944; Kus, 2004	Declining
Riparian brush rabbit	Along major streams in the northern San Joaquin Valley	No information available	62 Federal Register 62277, November 21, 1997	Declining
Riparian woodrat	Along major streams in the northern San Joaquin Valley	No information available	62 Federal Register 62277, November 21, 1997	Declining

Source: AECOM, 2011

Key:
NA = none available

Figures 4-26 and 4-27 display the historical and current distribution of Chinook salmon and steelhead in the Sacramento and San Joaquin valleys. Historically, salmon and steelhead travelled much farther upstream to spawn. The construction of dams and other passage barriers has greatly restricted available habitat for these species, as described in Section 3.5.5. As a result, Chinook salmon and steelhead have been extirpated from the upper reaches of their historical range, including the upper San Joaquin River system (upstream from the confluence with the Merced River). Overall estimates of salmonid habitat loss in the Sacramento and San Joaquin valleys range from 80 percent to 95 percent (Moyle et al., 2008).

Most of the historically available habitat is now behind impassable dams and other barriers (Lindley et al., 2006; McEwan, 2001; Yoshiyama et al., 2001), and the habitat that remains is at lower elevations that were historically used as migration corridors and, except for small reaches, are not ideal for spawning, rearing, or holding (Yoshiyama et al., 2001; McEwan, 2001).

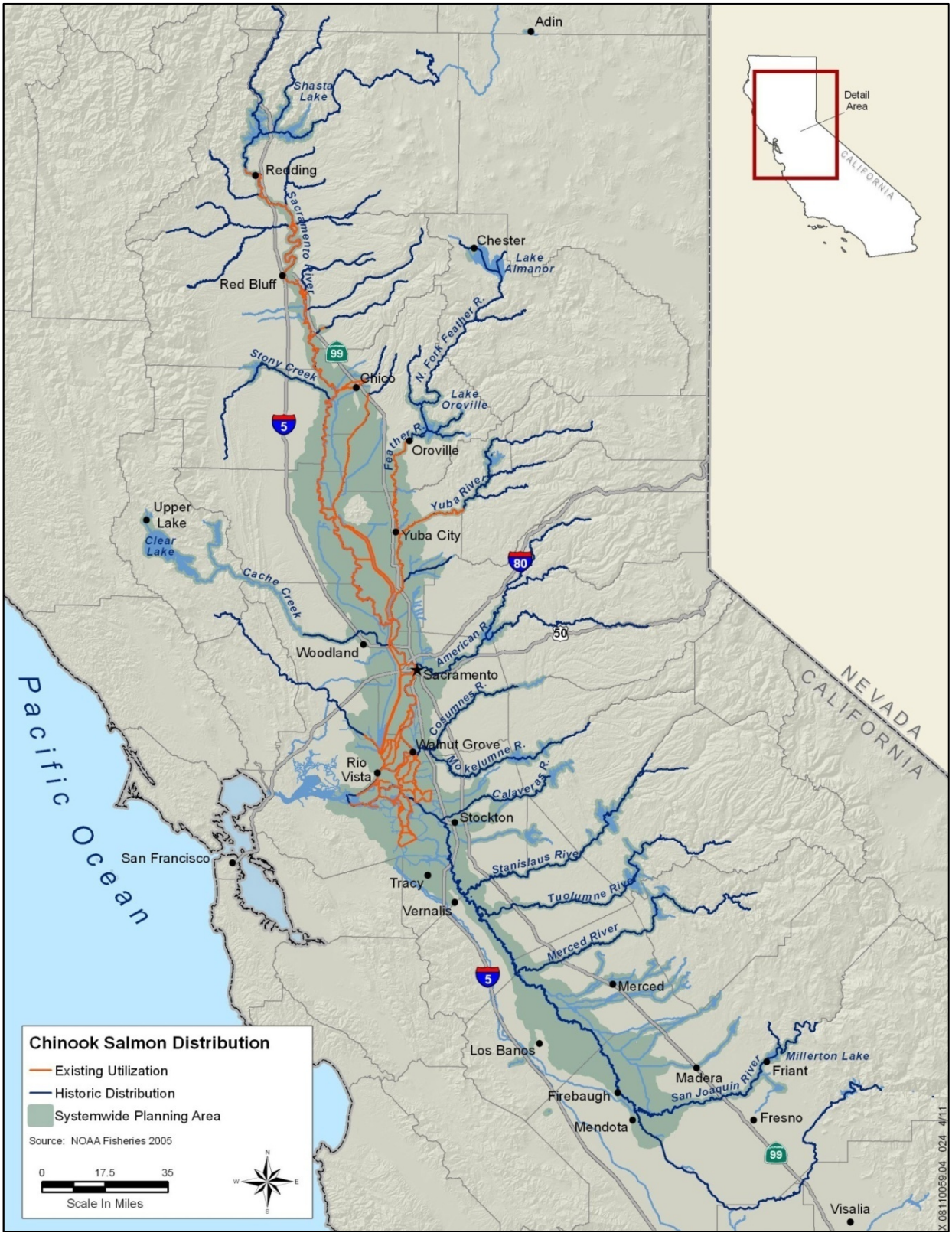


Figure 4-26. Chinook Salmon Historic and Current Distribution in the Central Valley

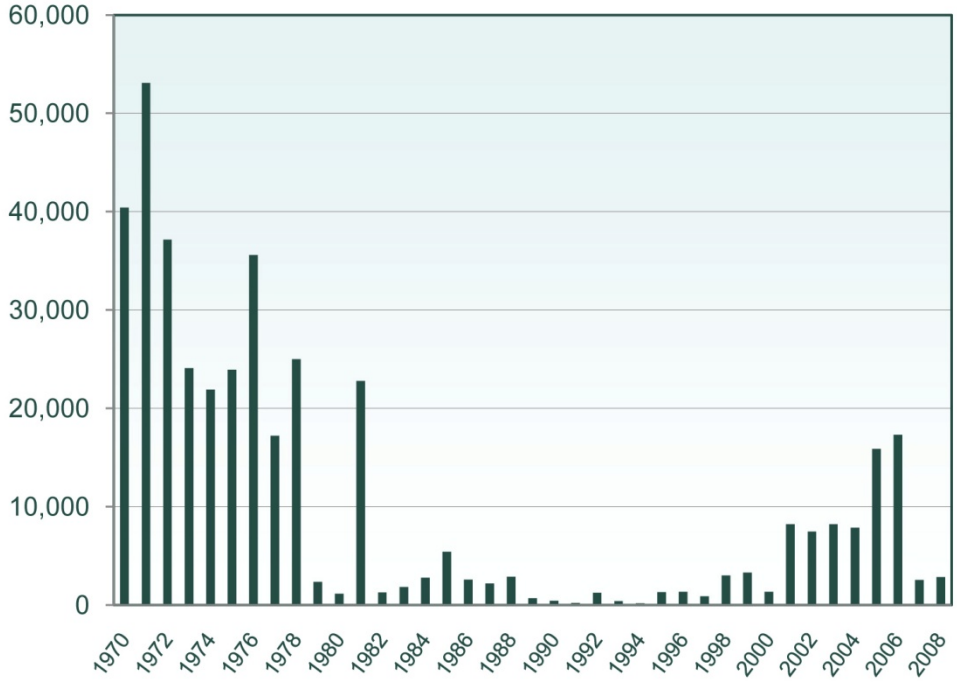
Figure 4-27. Central Valley Steelhead Historic and Current Distribution in the Central Valley

Figures 4-28 through 4-31 display the annual population estimates of fall, late fall, winter, and spring runs of Chinook salmon in the Sacramento and San Joaquin river systems. Figure 4-32 displays the adult return estimates of steelhead in the upper Sacramento River system.

Winter-run Chinook salmon have declined significantly since the 1970s (Figure 4-28). They historically spawned in spring-fed headwaters in the upper Sacramento River system (Yoshiyama et al., 2001), most of which are now behind impassable dams (Figure 4-26). Blocked access to historical spawning habitat, impaired passage at Red Bluff Diversion Dam, ocean harvest, elevated water temperatures, water quality effects of Iron Mountain Mine, and entrainment at large, unscreened diversions are all plausible mechanisms for low winter-run abundance (TNC, 2007). Abundance data on winter-run Chinook escapement before dam construction are rare, but there is some indication from gill net studies and other observations that winter-run abundance may have been in the hundreds of thousands before construction of Shasta Dam (TNC, 2007). This species persists today largely because of cold-water releases from Keswick Dam during the summer months, when winter-run fish are holding and spawning in the upper reaches of the lower Sacramento River.

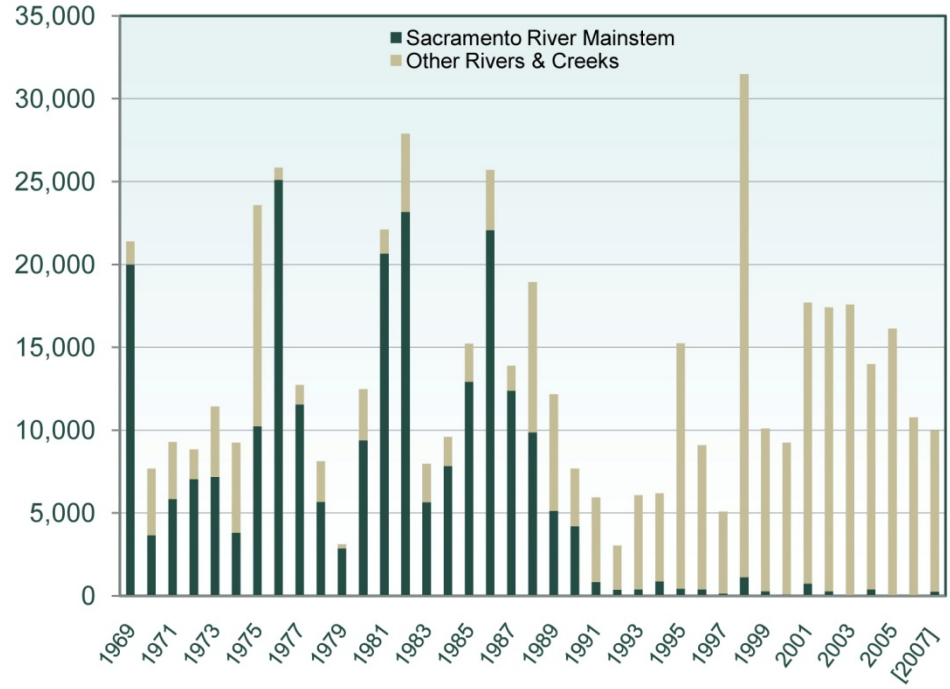
Although spring-run Chinook salmon abundance throughout the Sacramento River system has not changed significantly since 1969, numbers of the fish in the mainstem Sacramento River have decreased significantly (Figure 4-29). Spring-run Chinook salmon historically spawned in high-elevation streams (Yoshiyama et al., 2001), and dams have blocked access to much of this historical spawning habitat (Figure 4-26). Dams may also have reduced or eliminated spatial and temporal segregation between spawning spring- and fall-run Chinook salmon in some areas, particularly in the mainstem Sacramento River, leading to increased potential for hybridization on the spawning grounds (TNC, 2007). At one time, spring-run Chinook salmon may have been the most abundant race throughout the Central Valley, with escapement in the hundreds of thousands (Mills and Fisher, 1994, cited in TNC, 2007).

The fall run of Chinook salmon is the most abundant run in the Sacramento and San Joaquin valleys (Figure 4-30), in large measure because it has suffered relatively less displacement from historical habitats by dam construction (TNC, 2007). Fall-run Chinook salmon historically spawned on the valley floor and in lower foothill reaches below 500 feet to 1,000 feet in elevation, depending on location (Yoshiyama et al., 2001). The relatively high abundance of fall-run Chinook salmon is also a function of hatchery supplementation because they have been the primary target of hatchery production at Central Valley hatcheries for several decades (TNC, 2007).



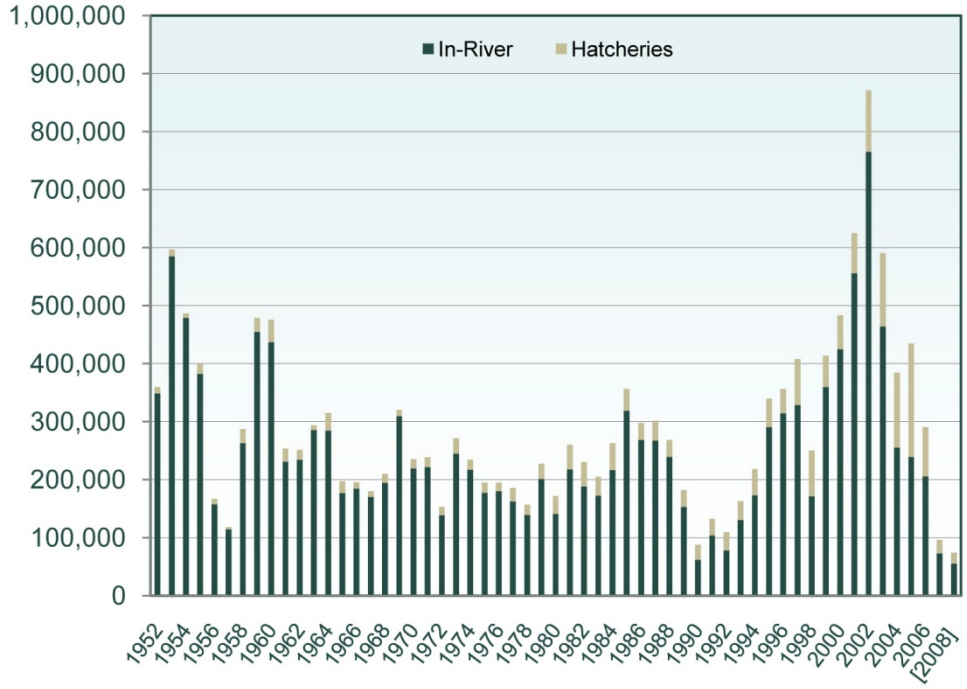
Source: DFG, 2009

Figure 4-28. Winter-Run Chinook Salmon Escapement in the Central Valley



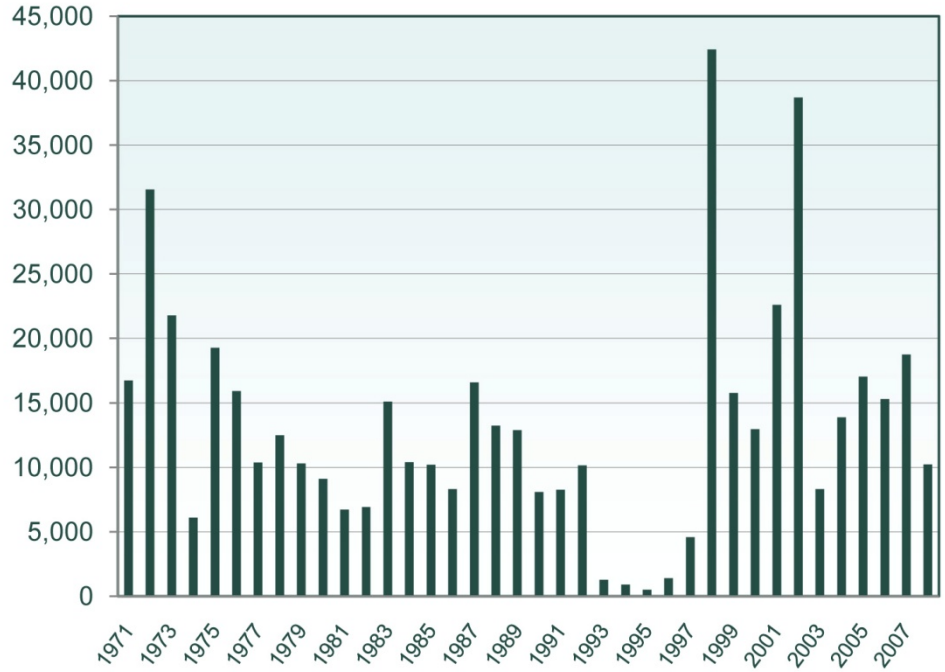
Source: DFG, 2009
Note: Year is shown in brackets when numbers are preliminary.

Figure 4-29. Spring-Run Chinook Salmon Escapement in the Central Valley



Source: DFG, 2009
Note: Year is shown in brackets when numbers are preliminary.

Figure 4-30. Fall-Run Chinook Salmon Escapement in the Central Valley



Source: DFG, 2009

Figure 4-31. Late Fall-Run Chinook Salmon Escapement in the Sacramento River System

The lack of reliable escapement data for most of the past decades may hinder the identification of a clear trend in the abundance of late fall-run Chinook salmon (Figure 4-31). Escapement data on late fall-run Chinook salmon is available only for the Sacramento River system, and escapement estimates made after 1985 are unreliable for a variety of reasons (TNC, 2007). Little information is available to indicate the historical abundance of late fall-run salmon in the Sacramento River Basin; they were first recognized by fishery agencies as a distinct run only after the construction of Red Bluff Diversion Dam in 1966 (TNC, 2007).

Steelhead abundance in the upper Sacramento River system has declined since the 1960s (Figure 4-32). An accurate estimate of current steelhead abundance throughout the remainder of the Sacramento and San Joaquin valleys is unavailable. Historically, steelhead spawned and reared in high-gradient reaches of tributaries to the Sacramento and San Joaquin rivers (TNC, 2007), nearly all of which are now blocked by impassable dams (Figure 4-27). There may have been as many as 1 million to 2 million adult steelhead spawning in these reaches annually before 1850 (McEwan, 2001).

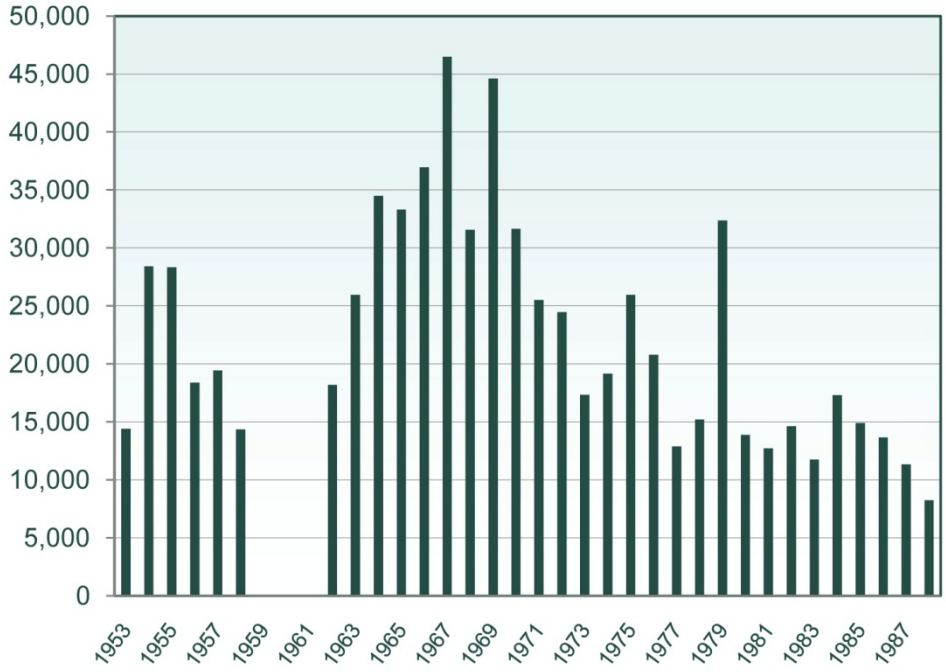
4.2 Stressor Metrics

4.2.1 Levees and Bank Revetment

Description of Metrics

Channel migration, meander cutoff, and other important ecosystem processes are severely limited by bank revetment and near-channel levees. Such constraints reduce the potential for these ecosystem processes to occur, which can be estimated by quantifying the degree of meander potential. Analyses performed for this report quantified the area available for future migration. In this report, an area where the channel could potentially migrate is called a “meander potential” area.

Two categories of meander potential were quantified: natural and existing. The difference between the two estimates is the difference between the natural channel dynamics and the dynamics limited by current bank restraints. The methods used to quantify these categories are described below.



Source: CalFish, 2009a

Figure 4-32. Central Valley Steelhead Adult Return Estimates in the Upper Sacramento River System

Methodology and Rationale

In a study of the meander migration patterns of RM 80 to RM 243 of the middle Sacramento River, it was shown that providing the full range of meander migration and cutoff dynamics required that channel constraints be set back approximately three channel widths (Larsen et al., 2006a).

This setback width was overstated. Not all levees need to be set back three channel widths because (1) geology is limiting in some cases, and (2) levees are already set back in some areas (i.e., in some areas they are not exactly on the banks). The total needed setback would be less in these cases.

To estimate the extent of meander potential, a zone was identified that was three bankfull channel widths from the centerline of the river. Then, areas under geologic constraints were removed from that zone, creating a *natural meander zone*. Areas within the natural meander zone that were restrained by levees, bank revetment, structures (e.g., wastewater facilities, docks, pump stations), and roads were removed, creating an *existing meander zone*. The difference between the natural and existing meander zones represents the *area of meander potential* that has been lost because of engineered, permanent features, such as levees, bank revetment, structures, and roads.

Metric Summary

Levees in the Sacramento and San Joaquin valleys are shown on Figure 4-33. Bank revetment along the Sacramento River is shown on Figure 4-34. Levees and bank revetment are major limitations to channel migration and meandering. Meander potential on the Sacramento River is shown in the maps of Figures 4-35A and 4-35B.

Note that although the metric as calculated gives a precise number, the metric is best used to identify overall trends. A number of assumptions and estimates were made to produce maps that illustrate the metric. For example, in many areas, the meander potential on the concave side (inside) of a meander bend is shown as a meander potential area. Most meander bends migrate outward, not inward. The area on the inside of a bend in most cases does not represent potential floodplain generation and therefore ecosystem benefit. If all bends were limited from moving by restraining their outside bank, but not the inside bank, essentially 100 percent of the migration would be limited; however, the current metric would show that 50 percent of the area is available for meander potential. Similarly, where levees are located on the inside of a bend (e.g., south of Colusa), the metric would show limitations of meander potential where the meander would in most cases not migrate. Regardless, the meander potential metric provides a reasonable quantitative estimate of the relative degree of ecosystem limitation and potential for restoration in the areas measured on the middle Sacramento River.

The meander potential as shown with the metric differs significantly upstream and downstream from Colusa (RM 145) because downstream from Colusa, the river is generally lined on both banks by levees. Upstream from Colusa, the relative potential migration ranges between about 50 percent and 75 percent; downstream from Colusa, the potential ranges between about 10 percent and 25 percent. These maps could potentially be used to identify site-specific areas where revetment removal and levee setback could be considered to restore ecosystem function or where existing habitat potential exists in areas of high meander potential.

4.2.2 Reservoirs

Methodology and Rationale

Reservoirs are major stressors on riparian and riverine ecosystems. The many effects of reservoirs on the ecosystem interact in multiple ways. Each of the metrics used in Section 4.1 to characterize the status and trends of the riparian and riverine ecosystems is affected by reservoirs. The effects of reservoirs on hydrologic processes are described in Section 4.1, where the effects of Shasta Dam on downstream flows in the Sacramento River and the effects of Friant Dam on downstream flows in the San Joaquin River were discussed in detail.

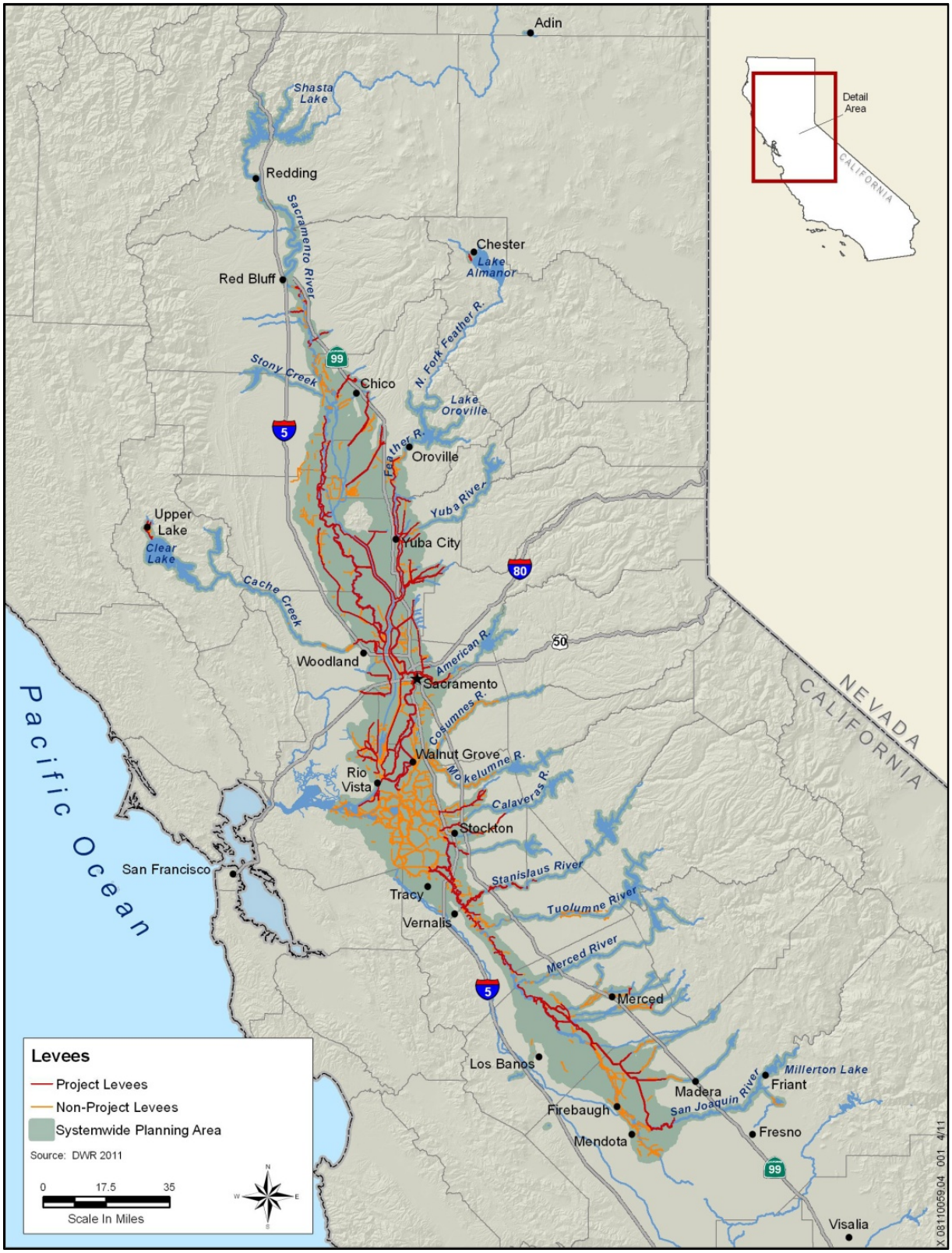


Figure 4-33. Levees in the Central Valley

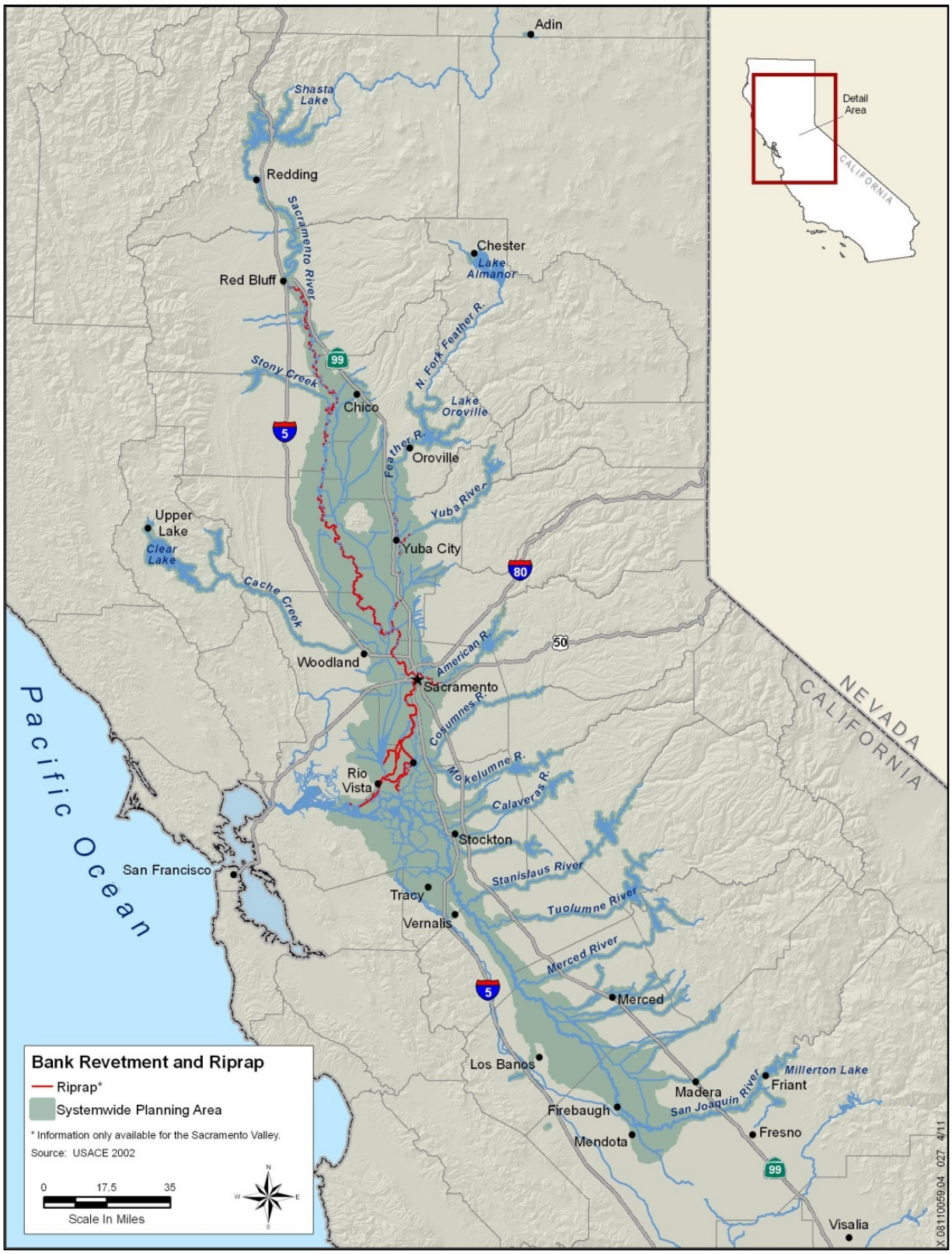


Figure 4-34. Bank Revetment in the Sacramento Valley

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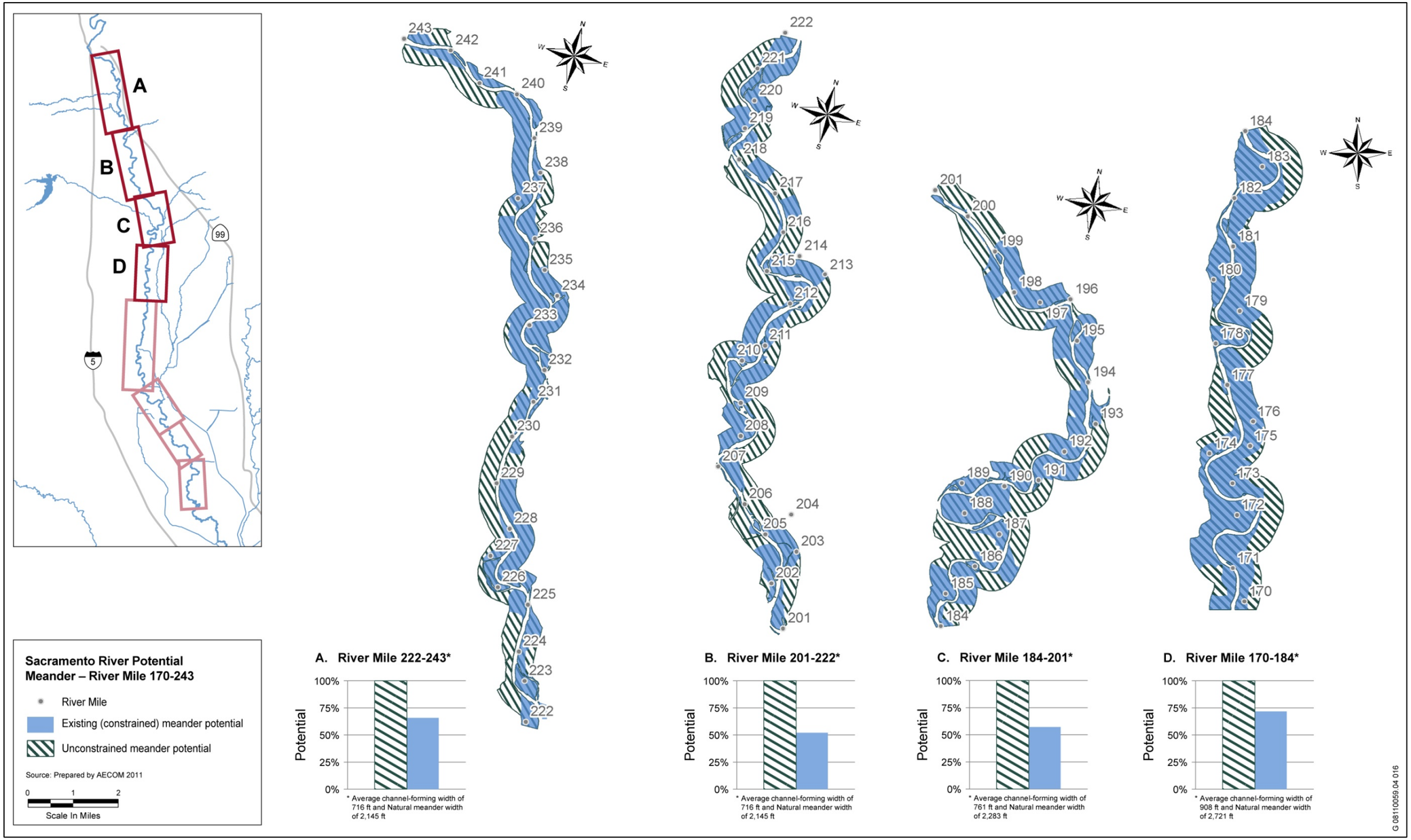

Sources: USACE, 2004; DWR, 2002 , 2010; Dr. Eric Larsen, 2011; MWH, 2011 ; AECOM, 2011

Note: Sixty-six percent of natural river meander potential is available.

Figure 4-35A. Meander Potential Along the Sacramento River (RM 170 to RM 243)

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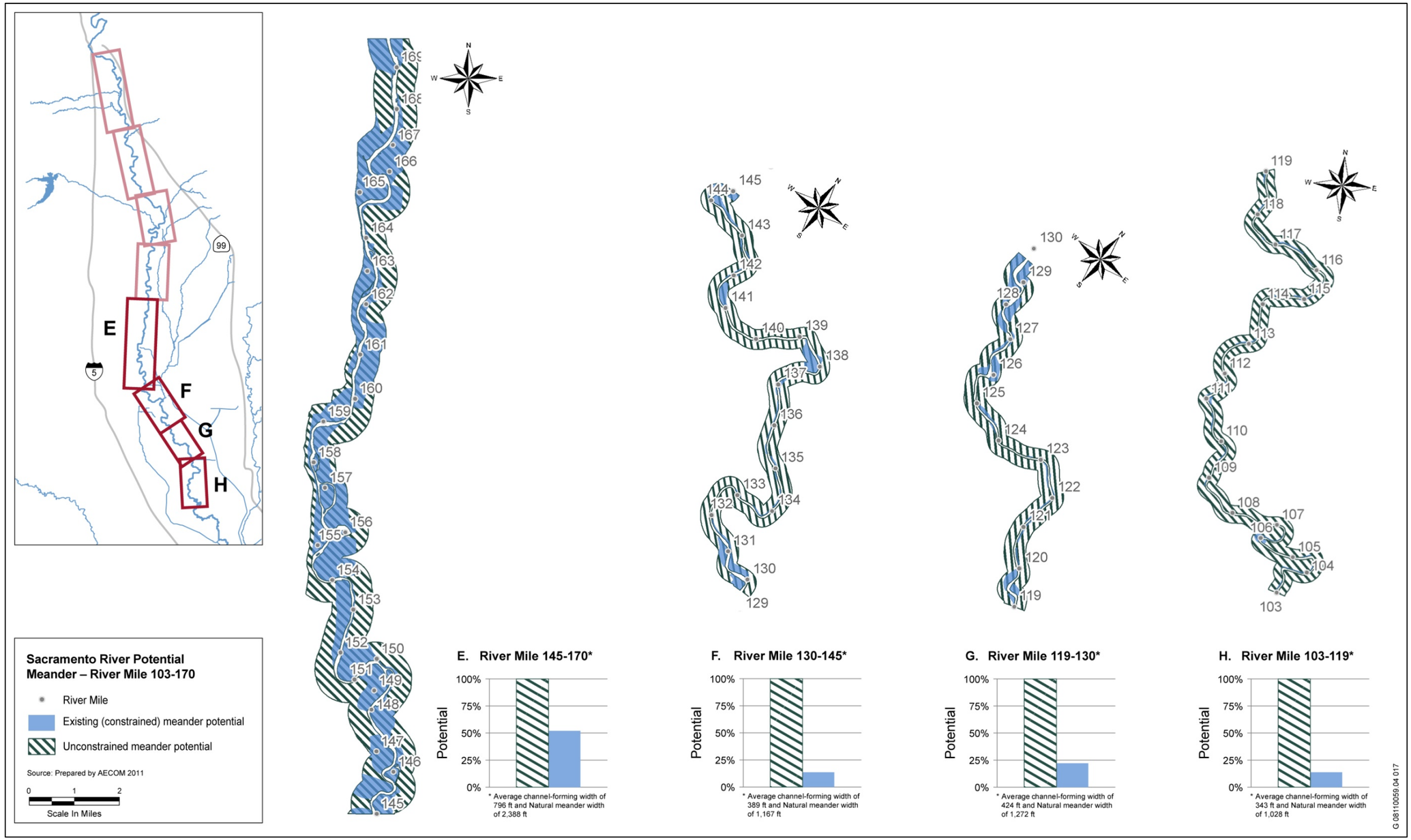

Sources: USACE, 2004; DWR, 2002 , 2010; Dr. Eric Larsen, 2011; MWH, 2011 ; AECOM, 2011

Note: Fifty-three percent of natural river meander potential is available.

Figure 4-35B. Meander Potential Along the Sacramento River (RM 103 to RM 170)

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The geomorphic effects of dams include the effects of hydrologic modifications, as well as interruption of sediment transport. Because the hydrology-related effects of dams on geomorphology are confounded with the effects of land-use changes and revetment on fluvial geomorphology, no analysis was done to assess the effect of reservoirs on geomorphology.

A promising analysis method was presented by Singer (2007), who identified the IRI, which is the ratio of reservoir capacity to median annual flood runoff volume. Singer calculated the IRI for the major reservoirs in the Sacramento River watershed. An analysis for the San Joaquin River watershed reservoirs was beyond the scope of that preliminary report.

Metric Summary

The effects of dams on hydrology were discussed in detail in Section 4.1.1; therefore, no separate discussion of those effects is provided here.

4.2.3 Diversions

Description of Metrics

Two related metrics, the number and distribution of known diversions, were selected to depict the current status of water diversions as a stressor. As described in Sections 3.5.3. and 3.5.5, water diversions are not a stressor in terms of the total volume of water diverted (in the Sacramento River system); however, they are likely significant stressors both on salmonid populations, because of juvenile fish entrainment at diversion points, and on cottonwood and willow recruitment, because of modifications to historical flow patterns that are required to facilitate water diversions. In the San Joaquin River, water diversions are a major stressor because water that would otherwise be carried downriver is diverted directly into canals for agricultural use. The reduced flows in the San Joaquin River negatively affect salmonids, riparian vegetation, and riparian wildlife.

Methodology and Rationale

The Passage Assessment Database (PAD) (CalFish, 2009b) was queried for screened and unscreened water diversions. The PAD is an ongoing, map-based inventory of known and potential migration barriers to anadromous fish in California. The PAD is compiled and maintained through a cooperative interagency agreement that gathers available fish passage information from many different sources and stores this information in a central standardized database. The PAD was used for this report because it is the most current, readily available geo-spatial database of water diversions throughout the Sacramento and San Joaquin valleys.

Metric Summary

Figure 4-36 displays the known distribution of screened and unscreened diversions in the Sacramento and San Joaquin valleys. The total amount of water diverted from the river system through these structures is unknown, although, as previously indicated, the volume of water diverted from the San Joaquin River is likely significant and results in significant ecological impacts. The volume of water diverted from the Sacramento River is not likely significant, but the correlated effects of fish entrainment and modified flows related to facilitating diversions during the summer months likely have significant adverse ecological effects.

4.2.4 Invasive Species

Description of Metrics

Metrics selected to depict the status of invasive species as a stressor are the number of invasive plant species and the distribution of two important invasive plants: red sesbania and giant reed. The following discussion of invasive species focuses on terrestrial and aquatic plants documented in the Sacramento and San Joaquin valleys. Other invasive species, such as invasive aquatic animal species, are also potential stressors in the region; however, the effects of these species are more apparent in the San Francisco Bay-Delta (Cohen and Carlton, 1998) than in the Sacramento and San Joaquin valleys.

Number of Invasive Species

Methodology and Rationale The California Invasive Plant Inventory was searched for invasive plant species found in riverine, riparian, and wetland habitat in the Sacramento and San Joaquin valleys (Cal-IPC, 2007). The inventory is maintained by the California Invasive Plant Council (Cal-IPC) to catalog and rank nonnative invasive plants in California. Threats described in the inventory include competition with and displacement of native species, hybridization with native species, other types of alteration of biological communities, and alterations of ecosystem processes (e.g., wildfire return intervals). The inventory categorizes plants as high, moderate, or limited, reflecting the potential for each species (based on its life history characteristics, growth form, reproductive output, current distribution, and other factors) to negatively affect native species and habitats in California.

Although the number of invasive species is a simple metric, it provides a baseline condition against which future enumerations of invasive species can be compared as a means of tracking the number of invasive species over time. The listing of invasive species also ranks each species by its potential to cause ecological and economic harm, providing an additional baseline condition against which future, similar tabulations of invasive species can be compared (e.g., to see if a species' threat status is elevated over time or to track the relative proportion of high-threat species to low-threat species over time).

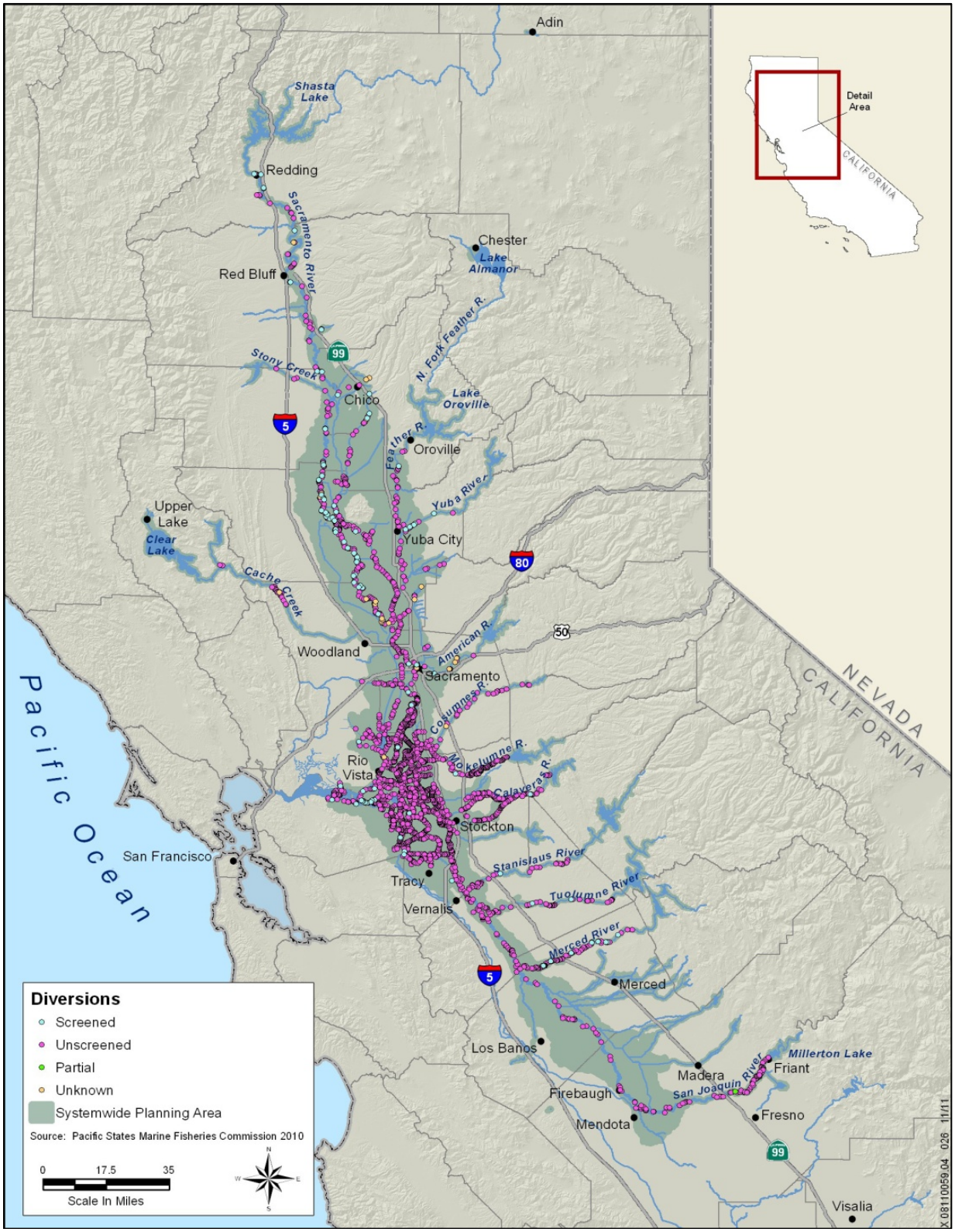
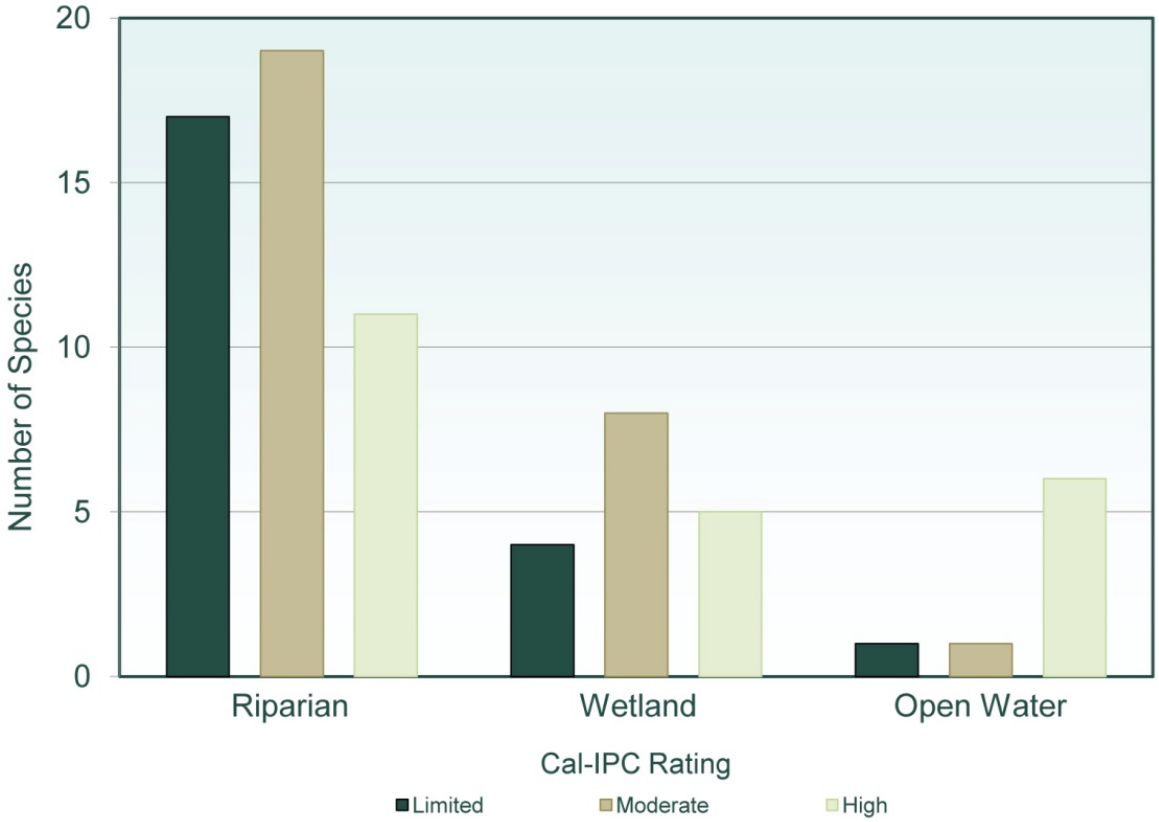


Figure 4-36. Diversions in the Central Valley

Metric Summary For each species, the inventory lists the regions where the species is found and the habitat of concern for that species. The numbers of species found in riparian, wetland, and aquatic habitats in the Great Central Valley floristic province (defined as the Central Valley floor and foothill regions where oak and pine woodlands become the dominant vegetation communities) are shown on Figure 4-37. A total of 61 invasive plant species is presumed extant in riparian, wetland, and open water habitat in the Sacramento and San Joaquin valleys. Riparian habitat is the most heavily invaded habitat; three-quarters of the invasive plant species are located in riparian habitat, and two-thirds of these species are rated high or moderate by Cal-IPC.



Source: Cal-IPC, 2007

Figure 4-37. Invasive Plant Species in Riparian and Riverine Habitat in the Central Valley

Distribution of Invasive Species

Methodology and Rationale Although the California Invasive Plant Inventory documents which invasive plant species are found in a region, it does not identify the exact locations or extent of invasive plant populations. Information on the location and extent of these populations is compiled by DFG in the Biogeographic Information and Observation System (BIOS). BIOS is designed to enable the management, visualization, and analysis of biogeographic data collected by DFG and its partner organizations. BIOS is the best available source for data on the mapped extent of invasive plant species in the Sacramento and San Joaquin valleys. Other sources are available but are either more coarsely mapped or mapped over more limited areas. The BIOS data were used to map the extent of two species of concern in the Sacramento and San Joaquin valleys: giant reed and red sesbania.

Giant reed is a tall perennial grass that typically forms dense stands in riparian areas and wetlands (Cal-IPC, 2011c). It threatens riparian ecosystems by outcompeting native species for water, reducing habitat quality and food supply for special-status species, interfering with levee maintenance and wildlife management, altering hydrological regimes and reducing groundwater availability, altering channel morphology by retaining sediments and restricting flows, and promoting bank erosion (Dudley, 2000).

Red sesbania is a deciduous shrub or small tree that forms dense thickets in riparian areas. It displaces native plants used by wildlife, contributes to bank erosion, and reduces water flow and flood conveyance in rivers (Cal-IPC, 2011b).

Giant reed and red sesbania are emphasized because mapped locations for these species are found in BIOS and because these species are widespread, characteristic invasive species of riparian areas. They also have a high potential to cause negative ecological effects. Many other invasive plants occur and have important effects on the ecosystem, including salt cedar and water primrose (*Ludwigia* sp.).

Metric Summary The known extent of giant reed and red sesbania in the Sacramento and San Joaquin valleys is presented on Figures 4-38 and 4-39. Giant reed is widely distributed throughout the Sacramento and San Joaquin valleys (Figure 4-38), and red sesbania in found in several riparian systems in the Sacramento and San Joaquin valleys (Figure 4-39).

Giant reed was brought to North America quite early and was abundant by 1820 in the Los Angeles River (Dudley, 2000). Horticultural propagation of the species is widely conducted, and invasive populations almost certainly resulted from escapes and displacement of plants from managed habitats (Dudley, 2000).

Red sesbania is a relatively recent invader in the Sacramento and San Joaquin valleys. Although introduced to California as an ornamental before 1930, it was not documented in riparian vegetation until 1987, and it was not acknowledged as a potential threat to riparian ecosystems until 2000 (Hunter and Platenkamp, 2003).

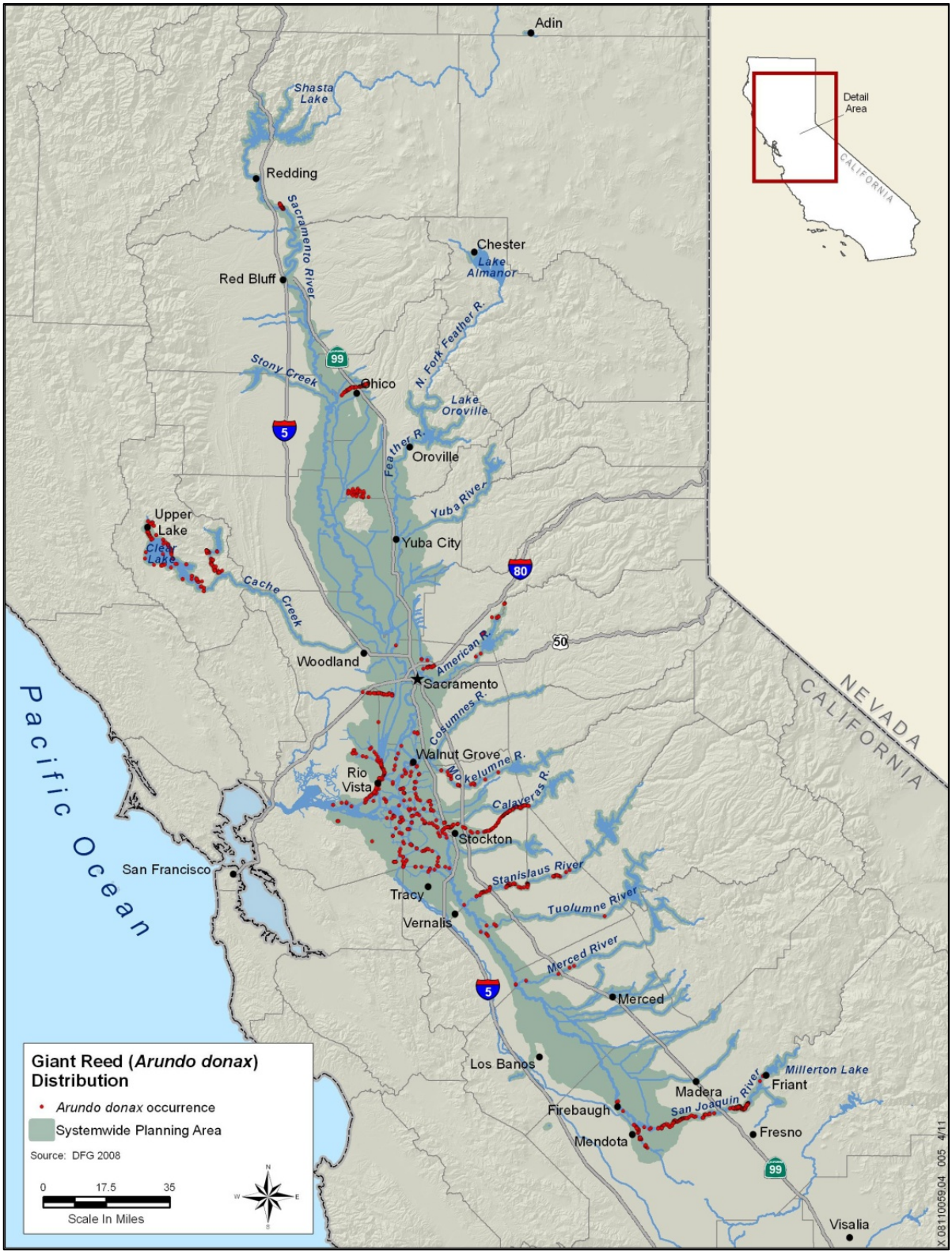


Figure 4-38. Giant Reed Distribution in the Central Valley

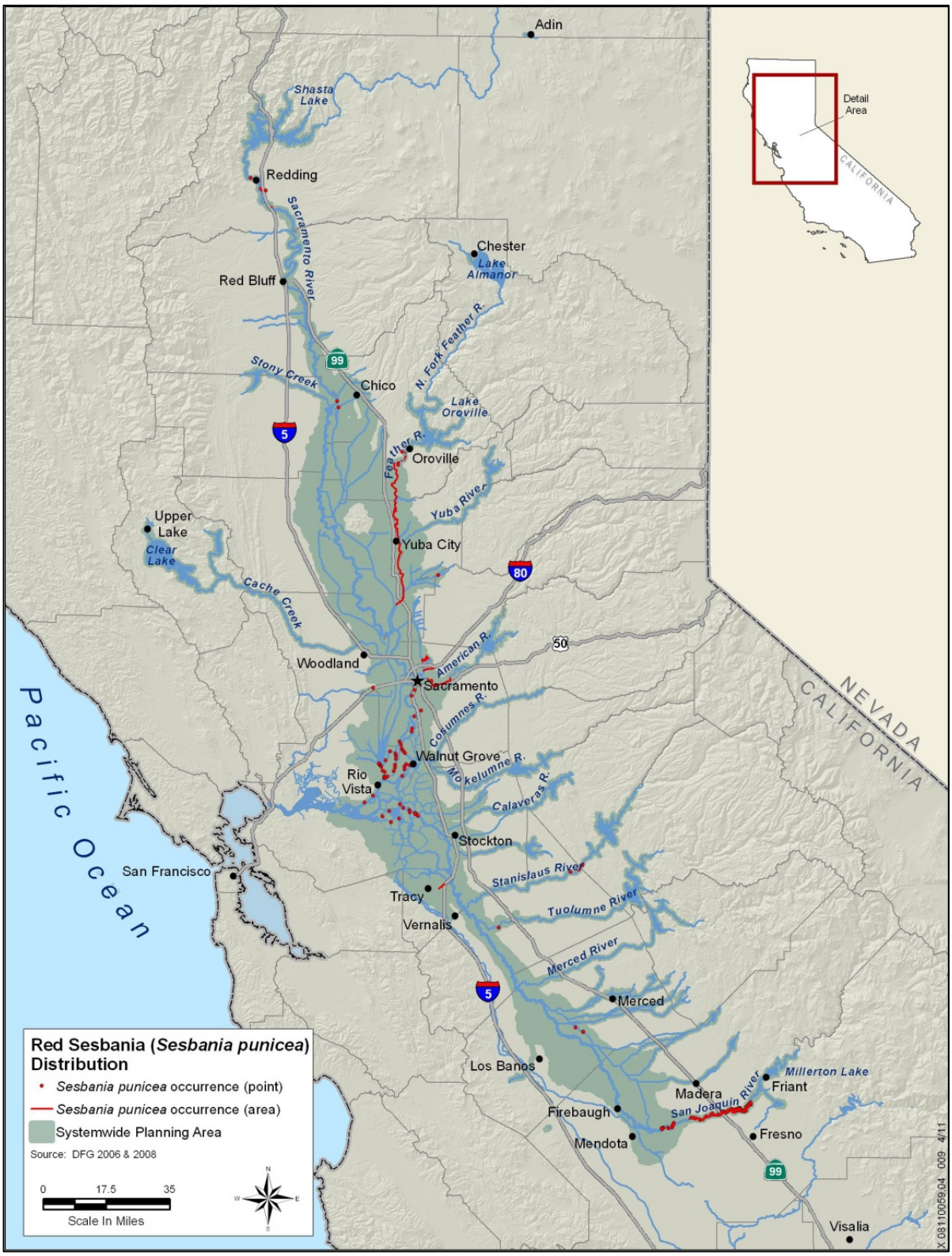


Figure 4-39. Red Sesbania Distribution in the Central Valley

4.2.5 Fish Passage Barriers

Description of Metrics

The metrics chosen to represent the status of fish passage barriers are the location and number of human-made barriers documented in the PAD (CalFish, 2009b). These data are further refined as described below to include all barriers in the SPFC that may not be reflected in the PAD.

Methodology and Rationale

The PAD was queried for human-made barriers, not including water diversions (see Section 4.2.3 for information on water diversions in the Sacramento and San Joaquin valleys). It was used for this report because it is the most up-to-date database of fish passage barriers in the Sacramento and San Joaquin valleys.

This data set was further refined by identifying only those barriers in the PAD on anadromous streams in the SPA. A buffer of approximately 1,000 feet was used to account for positional accuracy between data layers. PAD entries that were not relevant (e.g., nonstructural barriers and barriers that are in the database but that have been removed) were excluded. Finally, any SPFC components that were known barriers but that were not included in the PAD were added to the dataset. Further details on these methods can be found in the technical memorandum prepared by DWR on fish and flood management as part of the CVFPP (DWR, 2011b).

Metric Summary

The refined metric was assembled using GIS analysis, expert knowledge, and available written information, and identified 180 barriers in the SPA (107 dams, 59 road crossings, 11 gravel pits, 2 flood control channels, and 1 flow measurement weir) (Figure 4-40). These include total and partial barriers, as well as barriers of unknown passage status. Approximately 26 of these barriers are total barriers. If these 26 barriers were removed, approximately 940 miles of salmonid habitat would become at least partially available (some upstream partial barriers may exist).

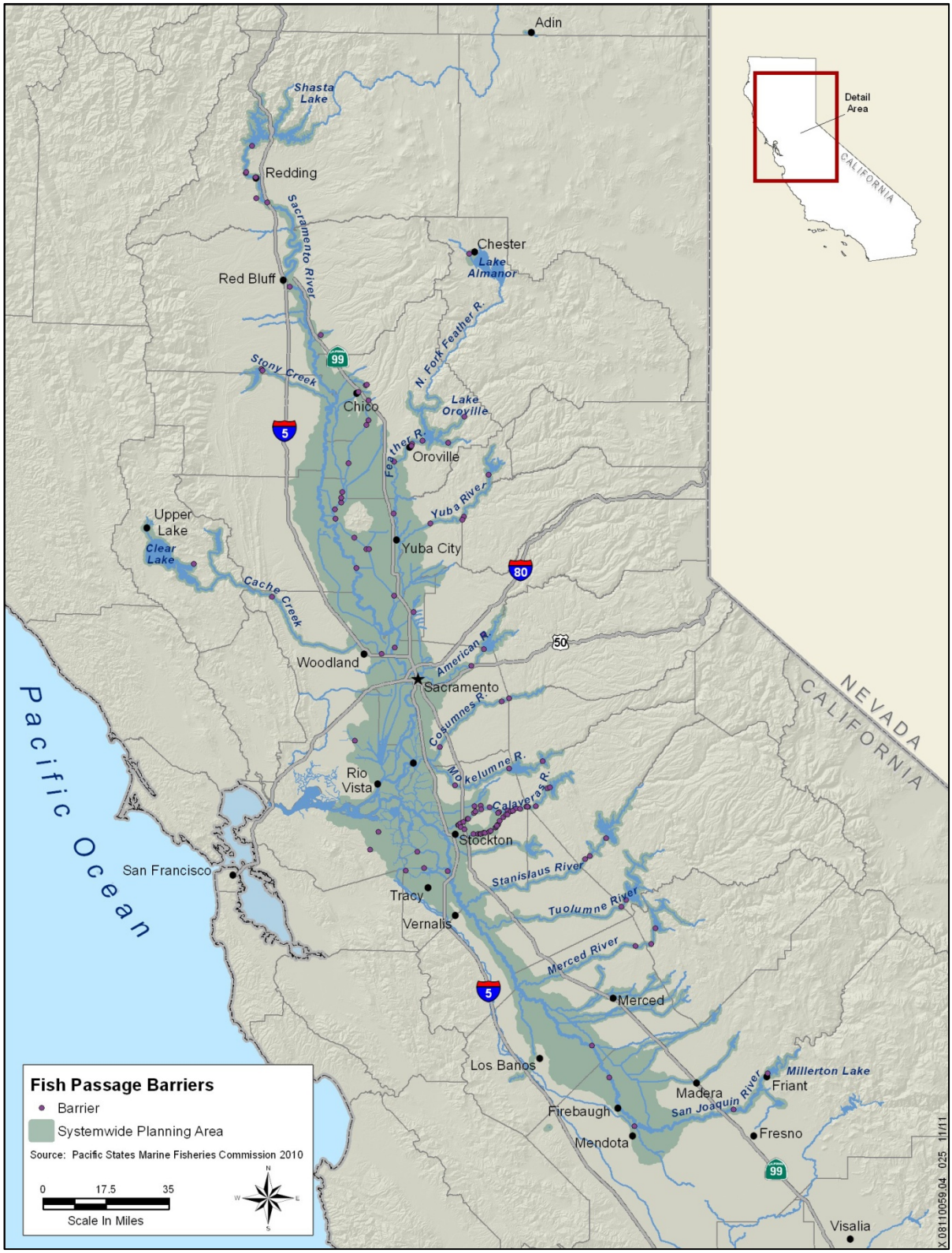


Figure 4-40. Fish Passage Barriers in the Central Valley

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5.0 Recommendations and Conclusions

This section identifies data gaps and areas where additional analysis would benefit the development of the 2017 CVFPP. The section also provides specific recommendations to fill the data gaps and conduct needed analysis. In addition, it addresses the development of conceptual models.

5.1 Data Gaps and Analysis Needs

This report assesses the status and trends of hydrologic and geomorphic variables, habitats, and stressors of riparian and riverine ecosystems in the SPA. It also describes the effects of the flood control system on riparian and riverine ecosystems because elements of the system are stressors on these ecosystems. However, our understanding of riparian and riverine status and trends, and of the effect of flood control systems on them, is limited by gaps in our knowledge of historical and current conditions and by the limited extent of analyses conducted to date. This section recommends additional data collection and analyses to increase the availability and analysis of data related to the hydrologic and geomorphic variables, habitats, and stressors assessed in this report and therefore increase our understanding of the riparian and riverine ecosystems in the SPA.

5.1.1 Hydrologic Processes

Recommendation 1: Analyze hydrologic data from gages in addition to the Friant and Bend Bridge gages. A more complete understanding of the hydrologic processes of the Sacramento and San Joaquin rivers and their tributaries should be developed to help guide riparian and riverine ecosystem conservation and restoration throughout the Sacramento and San Joaquin valleys.

Gage data were analyzed for only two gages. Additional analyses of data for the other dozen or so gages with a long-term record in the SPA could be conducted. Information on other gages would aid interpretation of the effects of reservoir operation on tributaries, import of water from the Delta to the San Joaquin River through the Delta-Mendota Canal, and diversions along the Sacramento and San Joaquin rivers. A more complete understanding of the hydrologic processes along the Sacramento and San

Joaquin rivers and their tributaries should be developed to help guide riparian and riverine conservation efforts. A more thorough understanding of hydrology would assist with identifying those areas where restoration would likely be most successful. Additional tools for assessing relationships between flow and ecological properties could be assessed, for example the Sacramento River Ecological Flows Tool (SacEFT) (ESSA Technologies, 2005).

Recommendation 2: Analyze the effect of groundwater decline on riparian plant species, especially as it relates to channel incision. The effect of groundwater tables on riparian habitat restoration potential should be assessed.

This report analyzes surface water hydrology. However, groundwater hydrology may also be important for riparian systems in the Sacramento and San Joaquin valleys. Especially in reaches where rivers have incised, the groundwater table may have dropped substantially compared to historical conditions. Groundwater overdraft may also cause a decline in groundwater that affects riparian plant species. In areas where groundwater has declined, riparian habitat restoration may face more challenges than in areas with shallower water tables.

5.1.2 Channel and Floodplain Dynamics

Recommendation 3: Analyze the geomorphology of the Sacramento and San Joaquin valleys, and analyze the channel and floodplain dynamics of reaches in addition to the middle Sacramento River. A better understanding of geomorphology could identify fluvial processes that can be restored and thereby guide riparian habitat restoration.

The geomorphology of the middle Sacramento River is fairly well understood, and channel and floodplain dynamics of this reach have been analyzed in detail. The geomorphology of other parts of the Sacramento and San Joaquin valleys is less understood. A better understanding of geomorphic processes operating throughout the Sacramento and San Joaquin valleys would help to guide riparian habitat restoration. Restoring fluvial processes is fundamental to restoring habitats.

Total river length, floodplain reworked, and floodplain age are metrics that represent the status and trends of channel and floodplain dynamics. These metrics are presented in Section 4.1.2 of this report for the middle reach of the Sacramento River (RM 143 to RM 244). These metrics were not calculated for other reaches of the Sacramento River, tributaries to the Sacramento River, or the San Joaquin River and tributaries. They could be calculated for other rivers in the Sacramento and San Joaquin valleys and foothills as part of the 2017 CVFPP.

5.1.3 Riverine and Riparian Habitats

Shaded Riverine Aquatic Cover

Recommendation 4: Develop consistent SRA cover data for the Sacramento and San Joaquin rivers and their major tributaries.

SRA cover data were available for analysis for three reaches of the Sacramento River; however, no data were available for the San Joaquin River, or for the tributaries of these rivers. Sacramento River SRA cover data from different reaches were collected at two different points in time (2002 and 2007), which made them not entirely comparable, because bank revetment was likely added in that 5-year period.

SRA cover is an important habitat component for native fish, bird, and mammal species. However, at this time a consistent baseline for this habitat is not available for the SPA. A consistent GIS database of SRA cover would help in identifying riparian habitat restoration and conservation opportunities and would provide a baseline against which the effects of future bank protection projects could be measured. Although estimates are currently available about the historical loss of SRA cover (e.g., USFWS, 1992) these estimates are not based on sufficient baseline data.

Species Distribution and Abundance

Recommendation 5: Conduct systematic surveys for specific rare wildlife species that are good indicators for specific habitat conditions.

The CNDDB is the only comprehensive data source on occurrence for all special-status species in the SPA. Other sources are available, but they do not provide coverage for all groups of species. Unfortunately, the CNDDB is not an exhaustive and complete inventory of all rare species and natural communities statewide (DFG, 2011a). It contains records of where species have been observed in a specific location, usually in conjunction with a focused survey effort; it does not contain records where species have been surveyed for but not found. It is biased toward areas where survey efforts are greater and toward species that receive more survey effort. In addition, data are reported to the CNDDB with varied precision. Some occurrences are well documented with explicit locations (e.g., Global Positioning System coordinates), whereas others are reported with more general location information (e.g., the boundary of a park where an occurrence is documented). Although the number of individuals and general notes about the condition of the habitat at the occurrence location are usually recorded, the data cannot be used to draw conclusions about the health or viability of the population. These data are not always reliably reported, nor are they systematically collected at the same location over time. It is therefore difficult to evaluate any population trends from CNDDB records. Finally,

the vast majority of CNDDB records are not independently verified, either by additional field visits or by photographs, and observer error is a concern. No readily available data source is available to describe the abundance of representative species in the Central Valley. A better understanding of the distribution of rare species would assist with identifying those areas where habitat restoration would aid in the recovery of these species. Additional surveys should focus on species that are indicators for habitat quality (e.g., western yellow-billed cuckoo, yellow-breasted chat).

Recommendation 6: Assess status of selected common species that use relevant habitats.

DFG's Wildlife Habitat Relationships database could be used to identify common wildlife species that use riparian habitat, riverine habitat and potentially other habitats of interest. The status (e.g., abundance or density) of these species could be monitored over time. Because of their greater abundance, common species may show responses to habitat area and quality changes over time more clearly than rare special-status species.

Recommendation 7: Collect population counts of Central Valley salmonids throughout the SPA.

The best data for Central Valley salmonid abundance is available from GrandTab and CalFish. Each of these sources compiles data from various sources that use several different estimation methods. The reliability of each of these data sources varies, and comparison across years may be problematic, especially for late fall-run Chinook salmon. Additionally, accurate estimates of late fall-run Chinook salmon and Central Valley steelhead are unavailable for the entire Central Valley. Their current status throughout the SPA is therefore unknown.

5.1.4 Levees and Bank Revetment

Recommendation 8: Periodically update GIS databases of bank revetment for the Sacramento and San Joaquin rivers and major tributaries to help identify restoration opportunities.

Bank revetment (e.g., riprap) often strongly interferes with channel dynamics and other geomorphic processes. GIS databases for bank revetment along the Sacramento and San Joaquin rivers are available. Similar GIS databases should be developed for the major tributaries and these databases should be periodically updated to document changes in revetment conditions and to update restoration opportunities.

5.1.5 Reservoirs

Recommendation 9: Calculate the IRI for reservoirs in the San Joaquin River watershed, and analyze the combined operations of reservoirs to develop a better understanding of the effects of reservoir operations on the riverine and riparian ecosystems.

The IRI is a useful index of the effect of dams on downstream hydrology. It is the ratio of reservoir capacity to median annual flood runoff volume (Singer, 2007). This index was calculated by Singer (2007) for major reservoirs in the Sacramento River watershed. Calculation of the IRI for reservoirs in the San Joaquin River watershed may provide a better understanding of the effects of reservoirs on the hydrology of the watershed and help improve operations to benefit ecosystem restoration.

5.1.6 Diversions

Recommendation 10: Inventory the permitted flow capacity of each water diversion in the SPA.

Although the current number and distribution of water diversions in the SPA is available through the PAD, the total amount of water diverted from the river system through these structures is unknown. Knowledge of the capacity and diverted amount of water would be useful in identifying the potential effects of diversions on the riverine ecosystem and native fishes.

5.1.7 Invasive Species

Recommendation 11: Map the extent of invasive species with significant ecological effects on the riverine and riparian habitat in the SPA. This effort may be included in the fine-scale vegetation mapping (see Recommendation 4).

The California Invasive Plant Inventory provides limited information on the status of invasive species in riparian and riverine habitat in the Central Valley. Because the data are presented at a coarse scale (i.e., floristic province), they cannot be used to determine whether and where a species has been documented in the SPA or the extent of the invasion. The Cal-IPC rating represents cumulative impacts statewide, but the impact of each species varies regionally. BIOS and data collected by other entities, such as The Nature Conservancy, California Department of Parks and Recreation and USDA, contain detailed information on some invasive plant species in the state but is not a comprehensive inventory of the location and extent of invasive species in the SPA. Invasive species to be mapped should be selected based on their habitat (e.g., riparian or floodplain), and their impact (e.g., species rated by the California Invasive Plant Council (CalIPC, 2007) as having a “High” and “Moderate” impact).

5.1.8 Fish Passage Barriers

Recommendation 12: Complete the prioritization of fish passage barriers in the fish and flood management technical memorandum consistent with the Fish Passage Forum.

A fish passage technical memorandum prepared by DWR (2011) identifies the known and potential barriers in the SPA that are within the control of DWR. The barriers were prioritized for removal or modification based on an initial analysis that includes the following criteria: (1) barriers in the SPFC, and (2) prioritization of recovery actions in the NMFS (2009) "Fisheries Public Draft Recovery Plan for ESUs of the Sacramento River Winter-Run Chinook, Spring-Run Chinook and DPS of Central Valley Steelhead." This initial analysis will be refined based on statewide prioritization conducted by the Fish Passage Forum[1] so that the barriers in the SPFC are addressed in a manner that is consistent throughout the state.

Recommendation 13: For those fish passage barriers with an unknown status, complete a field assessment to determine status and finalize the ranking.

In some instances, the barrier status is unknown. The DWR (2011) fish and flood management technical memorandum identifies and ranks these barriers for assessment. Assessments of these barriers should be completed to ensure proper ranking in the prioritization for removal or modification.

5.2 Development of Conceptual Models

Recommendation 14: Develop conceptual models of the relationships between flood management and riparian and riverine ecosystem attributes in the SPA.

Our understanding and management of riparian and riverine ecosystems of the SPA is limited not only by gaps in the availability and analysis of relevant data, but also by the extent to which available data and analyses have been synthesized and communicated. Riparian and riverine ecosystems are complex, and the processes that sustain them are influenced by many variables. Thus, identifying and communicating what is known about these relationships – and their relative importance – is challenging.

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[1] The Fish Passage Forum is an association of public, private, and governmental organizations that promote collaboration among private landowners, community groups, and public agencies on fish passage restoration programs and activities that contribute to the protection and recovery of listed anadromous salmonid species throughout California. DWR is a member of the forum.

Furthermore, to increase the conservation benefits of flood management, it is necessary to synthesize and communicate our understanding of relationships between components of the flood management system and riverine and riparian ecosystems.

Conceptual models provide a framework for organizing information that can be useful in synthesizing and communicating the current understanding of ecosystems. These models, which can consist of diagrams, text, and tables, provide a formal description of relationships among factors affecting ecosystem processes, habitats, and species; they also serve to define the components of the ecosystem that are of interest.

An essential part of a conceptual model is usually one or more diagrams that depict the (assumed or postulated) relationships among variables. The diagram usually identifies different types of variables that are linked by relationships with different attributes. The model diagram is an important communication tool for depicting our understanding of the modeled system.

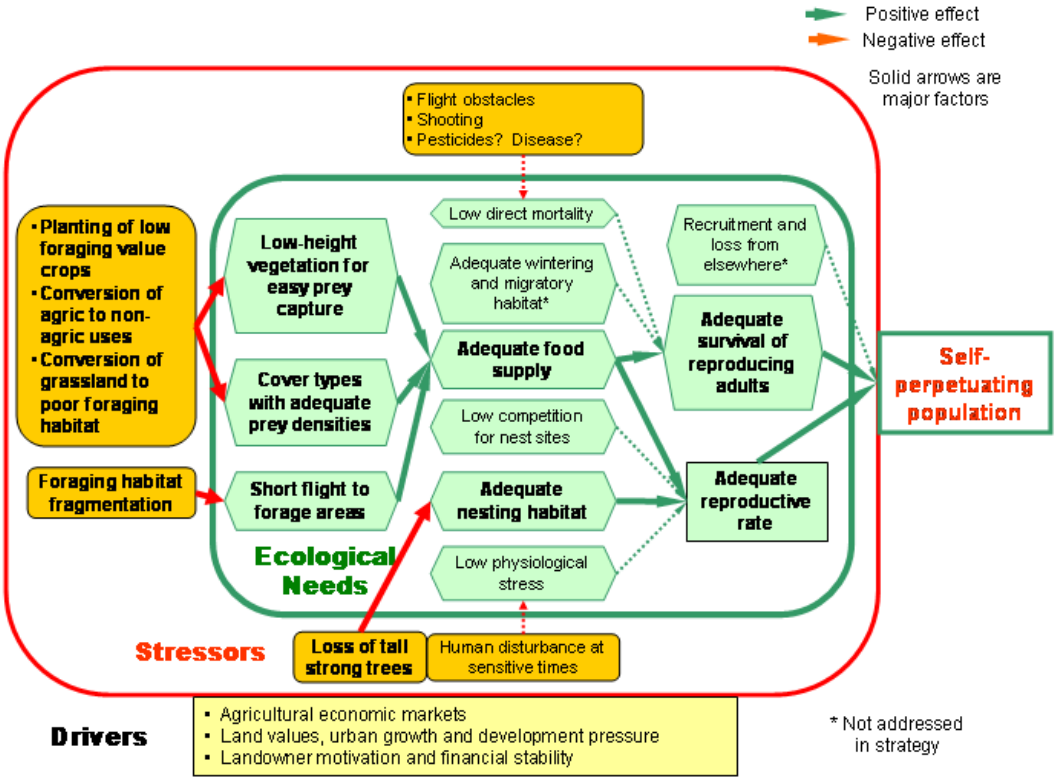
Figure 5-1, for example, shows a diagram for a conceptual model of the major ecological attributes, stressors, and broader drivers related to a self-sustaining population of Swainson's hawks in the Central Valley (DFG, 2011b). This diagram follows conventions by Ogden et al. (2005). It presents external driving forces that have large-scale influences on the natural system as rectangles; it also presents internal stressors (ovals) and important ecological attributes (hexagons). The relationships can be either positive (green) or negative (red) and be either major (solid arrow) or minor (dotted arrow). Other attributes that could be assigned to relationships are the level of understanding of the relationship (high, medium, or low) and the level of predictability (high, medium, or low) (Fremier et al., 2008).

To be most useful, conceptual models for the effect of flood management on ecosystems should be developed specifically for that purpose. Conceptual models developed for a different purpose will have only limited or no usefulness. For example, Fremier et al. (2008) developed a conceptual model for the riparian vegetation in the Delta. The model is not specifically focused on the relationships between flood management actions and the riparian ecosystem and is therefore not suitable for the CVFPP, although some relationships in the model may be useful components of a conceptual ecosystem model for the CVFPP.

The usefulness of a conceptual model for the CVFPP depends on how specific it is to the problem at hand (i.e., the relationship between flood management and ecosystem functioning) and whether it includes and adequately characterizes the most essential relationships. For example, a

conceptual model of the effect of flood management on riverine and riparian species may include the following relationships (among many others):

- Reservoir operations–bankfull flow frequency
- Bankfull flow frequency–channel migration rate
- Bank revetment–channel migration rate
- Channel migration rate–floodplain age
- Floodplain age–successional stage of riparian vegetation



Source: DFG, 2011b

Figure 5-1. Conceptual Model Diagram Example for Central Valley Swainson's Hawk Conservation

For several reasons, conceptual models help to guide management actions related to improving ecosystem conditions. First, conceptual models are particularly effective for developing a shared understanding of an ecosystem, and as a communication tool among scientists, decision makers, and system managers. Second, the organization of information in a conceptual model may assist with identifying areas where our understanding and knowledge needs to be improved to better understand the interactions between management and ecosystems. Third, in addition to

summarizing the current (conceptual) understanding of the system, a conceptual model can be a tool for integrating new knowledge into our understanding of the system as a whole, which may force the modification of relationships in the model. Development of conceptual models is therefore recommended for the 2017 CVFPP.

5.3 Conclusions

The riparian and riverine ecosystems of the SPA have been greatly modified since 1850 by flood management activities and other human activities, such as agricultural, industrial, and urban development. An analysis of the status and trends of hydrologic and geomorphic processes, habitats, and key wildlife and fish species shows that the modification of these physical processes has reduced their ability to support important ecosystem functions.

Analysis of hydrologic data at one gage downstream from Shasta Dam and one gage downstream from Friant Dam shows that the presence of the dams has substantially changed the annual median flows, floodplain inundation flows, bankfull flows, and summer low flows.

In the Sacramento River, monthly median flows in winter and spring have been reduced, summer and fall flows have been increased, and the variability in median spring flows has been greatly reduced. The frequency of small floods (i.e., flow events with 2- to 10-year return interval, or approximately floodplain inundation flows) and the duration of small floods have increased. The frequency of small pulse flows (i.e., flow events with a 1.5- to 2-year return interval, which approximate bankfull flows) has been greatly reduced, and the duration of these flows has been increased. Geomorphic processes have been affected by these changes, especially by reduction in the frequency of bankfull flows, which are responsible for most of the channel migration work performed by the river.

Shasta Dam also has interrupted and strongly affected sediment transport. The geomorphic processes along the Sacramento River between Red Bluff and Colusa, a reach where the river still actively meanders, have been affected by these changes in hydrology and sediment transport, and they have been affected by land-use changes (loss of riparian forest), increased bank revetment, and construction of levees. The result has been a reduction in total river length, reduction in area of floodplain reworked by the river, and reduction in the variability of floodplain age.

These changes in the physical processes of the Sacramento River have resulted in a loss of riparian forest, scrub, and wetland area; habitat and

species diversity; and the ability to support wildlife species. The processes that maintain the diversity of habitats and species supported by them have been greatly affected. In addition, the spread of invasive plant species has deteriorated riparian habitat quality.

Riverine habitats for salmonids and other native fishes have also been greatly affected by the change in physical processes and the response of the riparian plant species. Two important habitat components – area of SRA cover and the quantity of LWM – have been reduced. In addition, dams, diversions, and other obstacles have strongly affected salmonid migration. Many miles of spawning habitat are no longer accessible to Chinook salmon and steelhead, and diversions and the water management needed to maintain them have greatly affected fish habitat. Salmonids and other native fish species have been greatly affected by the isolation of floodplains from channels, because floodplains provide important rearing habitat that is no longer accessible when floodplains and habitats are disconnected. Bypasses in the Sacramento Valley still partially perform a floodplain function for native species.

In the San Joaquin River, Friant Dam has had an even greater effect on physical fluvial processes. Median annual flows have been greatly reduced year-round because flows are diverted at the dam into two major irrigation canals. The frequency of floodplain inundation flows and bankfull flows has been greatly reduced. The average duration of floodplain inundation floods has been reduced, but the duration of bankfull floods has been increased. Large reaches of the San Joaquin River below Friant Dam have been dry during part of the year or for several years in a row. Increased flows have been released to the San Joaquin River since 2009 because of Reclamation's San Joaquin River Restoration Program.

The geomorphology of the San Joaquin River has been much less studied than that of the Sacramento River. However, it still apparent that hydrologic changes and land-use changes have greatly reduced riparian habitat area, habitat and species diversity, and the ability to support wildlife species along the San Joaquin River. Levees have disconnected floodplains from river channels in the San Joaquin River and its tributaries. Dams and other obstacles have greatly reduced salmonid migration and access to historical spawning grounds. Diversions have also deteriorated the habitat of native fish species. In-channel mining pits have created habitat for nonnative predatory fish, increased water temperatures, and opportunities for invasive plant species, such as red sesbania and giant reed, in the San Joaquin River and its tributaries, which have further deteriorated the quality of riverine and riparian habitat.

Our knowledge of the relationships between physical processes and habitats and between habitats and species is limited by data gaps and lack of conceptual models that organize our understanding of the crucial relationships between management actions and ecosystem responses. The recommendations described above address the data gaps and the lack of a conceptual model.

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6.0 References

Alexander, B.S., G.H. Mendell, and G. Davidson. 1874. Report of the Board of Commissioners on the Irrigation of the San Joaquin, Tulare, and Sacramento Valleys of the State of California. U.S. Government Printing Office. Washington, D.C.

Allan, J., and M. Castillo. 2007. Stream Ecology: Structure and Function of Running Waters. Springer Publishing. Dordrecht, The Netherlands.

Bittman, R. 2001. The California Natural Diversity Database: A Natural Heritage Program for Rare Species and Vegetation. Fremontia 29 (3-4):57–62.

Boano, F., C. Camporeale, R. Revelli, and L. Ridolfi. 2006. Sinuosity-Driven Hyporheic Exchange in Meandering Rivers. Geophysical Research Letters 33, L18406, doi:10.1029/2006GL027630.

Bossard, C.C., J.M. Randall, and M.C. Hoshovsky (eds.). 2000. Invasive Plants of California Wildlands. University of California Press. Berkeley, California.

Brookes, A. 1987. The Distribution and Management of Channelized Streams in Denmark. Regulated Rivers: Research & Management 1:3–16.

Brunke, M., and T. Gonser. 1997. The Ecological Significance of Exchange Processes between Rivers and Groundwater. Freshwater Biology 37:1–33.

Buer, Koll. 2011. Northern District, California Department of Water Resources. Personal Communication.

Cain, J.R. 1997. Hydrologic and Geomorphic Changes to the San Joaquin River between Friant Dam and Gravelly Ford and Implications for Restoration of Chinook Salmon (*Oncorhynchus tshawytscha*). MLA Thesis. University of California. Berkeley, California.

CalFish. 2009a. CalFish tabular data. Available at <http://www.calfish.org/DataampMaps/CalFishTabularData/tabid/92/Default.aspx>. Accessed March 10, 2011.

———. 2009b. Fish passage assessment database. Available at <http://www.calfish.org/portals/0/Programs/CalFishPrograms/FishPassageAssessment/tabid/83/Default.aspx>. Accessed March 18, 2011.

California Department of Fish and Game (DFG). 1995. Five-Year Status Review: Bank Swallow (*Riparia riparia*). Wildlife Management Division, Bird and Mammal Conservation Program. Sacramento, California.

———. 2009. GrandTab 2009.2.18 CE. Available at <http://www.calfish.org/LinkClick.aspx?fileticket=wBrov44wiSY%3d&tabid=104&mid=524>. Accessed March 8, 2011. February 18.

———. 2010. 2009 Bank Swallow Population Survey, Sacramento and Feather Rivers. Contact: David Wright, North Central Region, Resource Assessment Program. February 3, 2010. Available at <http://www.sacramentoriver.org/bankswallow/files/banssrvy-2009_(draft).pdf >. Accessed November 2, 2011.

———. 2011a. California Natural Diversity Database Info. Available at <http://www.dfg.ca.gov/biogeodata/cnddb/cnddb_info.asp>. Accessed February 17, 2011.

———. 2011b. Interim Conservation Strategy for Central Valley Swainson's Hawk. Sacramento, California. [Unpublished draft].

California Department of Water Resources (DWR). 1994. Sacramento River Bank Erosion Investigation Memorandum Progress Report. Prepared by Koll Buer, Northern District.

———. 2005. Fish Passage Improvement, Bulletin 250. Sacramento, California.

———. 2011a. Central Valley Flood Protection Plan Progress Report. Central Valley Flood Protection Plan. Sacramento, California.

———. 2011b. Fish and Flood Management. Technical Memorandum in a Supplement to the 2012 Central Valley Flood Protection Plan. Sacramento, California.

California Invasive Plant Council (Cal-IPC). 2007. California Invasive Plant Inventory Database. Available at <http://www.cal-ipc.org/ip/inventory/weedlist.php>. Accessed February 8, 2011.

———. 2011a. The Impact of Invasive Plants. Available at <http://www.cal-ipc.org/ip/definitions/impact.php>. Accessed March 15, 2011.

———. 2011b. *Sesbania punicea* (Red Sesbania, Scarlet Wisteria) plant profile. Available at <http://www.cal-ipc.org/ip/management/plant_profiles/Sesbania_punicea.php>. Accessed February 23, 2011.

———. 2011c. *Arundo donax* (Giant Reed) plant profile. Available at <http://www.cal-ipc.org/ip/management/plant_profiles/Arundo_donax.php>. Accessed February 23, 2011.

Cal-IPC. *See* California Invasive Plant Council.

Cohen, A.N., and J.T. Carlton. 1998. Accelerating Invasion Rate in a Highly Invaded Estuary. Science 27:555–558.

Dettling, M.D. and C.A. Howell. 2011. Status of the Yellow-Billed Cuckoo along the Sacramento River in 2010. Report to California Department of Fish and Game. PRBO Conservation Science Contribution #1794. Available at <http://www.nrm.dfg.ca.gov/FileHandler.ashx?DocumentVersionID=55330.> Accessed on November 3, 2011.

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

Dixon, M.D., M.G. Turner, and C. Jin. 2002. Riparian Tree Seedling Distribution on Wisconsin River Sandbars: Controls at Different Spatial Scales. Ecological Monographs 72:465–485.

Dudley, T. 2000. *Arundo donax*. In Invasive Plants of California's Wildlands, eds. C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, 53–58. University of California Press. Berkeley, California.

DWR. *See* California Department of Water Resources.

ESSA Technologies. 2005. Sacramento River Decision Analysis Tool: Workshop Backgrounder. Prepared for The Nature Conservancy, Chico, CA. Available at <http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=5046.> Accessed on November 4, 2011.

Fares, Y.R., and J.G. Herbertson. 1990. Partial Cut-Off of Meander Loops: A Comparison of Mathematical and Physical Model Results. In International Conference on River Flood Hydraulics, ed. W.R. White, 289–296. John Wiley & Sons. New York, New York.

Fischer, K.J. 1994. Fluvial Geomorphology and Flood Control Strategies: Sacramento River, California. In The Variability of Large Alluvial Rivers, eds. S.A. Schumm and B.R. Winkley, 115–138. ASCE Press. New York, New York.

Fleckenstein, J.H., M. Anderson, G.E. Fogg, and J.F. Mount. 2004. Managing Surface Water–Groundwater to Restore Fall Flows in the Cosumnes River. Journal of Water Resources Planning and Management 130(4):301–310. Available at <http://baydelta.ucdavis.edu/files/crg/reports/Fleckenstein_WRPM_2004.pdf>. Accessed March 26, 2011.

Fremier, A.K. 2003. Floodplain Age Modeling Techniques to Analyze Channel Migration and Vegetation Patch Dynamics on the Sacramento River, CA. Master's thesis. Environmental Design. University of California. Davis, California.

Fremier, A., E. Ginney, A. Merrill, M. Tompkins, J. Hart, and R. Swenson. 2008. Riparian Vegetation Conceptual Model. Delta Regional Ecosystem Restoration Implementation Plan. Sacramento, California. Available http://www.science.calwater.ca.gov/pdf/drerip/DRERIP_riparian_veg_conceptual_model_final_101408.pdf>. Accessed June 17, 2011.

Fremier, A.K., and E.H. Girvetz. In prep. A Geospatial Analysis Tool to Quantify River Channel Meander Migration and Channel Abandonment Rates.

Fremier, A.K., J.H. Viers, R.A. Hutchinson, and E.W. Larsen. 2009. Shifts in Species Composition as Interpreted through Floodplain Age on the Sacramento River. A Technical Report to the CALFED Ecosystem Restoration Program. C.E.R. Program. University of California. Davis, California.

Friedman, J.M., W.R. Osterkamp, M.L. Scott, and G.T. Auble. 1998. Downstream Effects of Dams on Channel Geometry and Bottomland Vegetation: Regional Patterns in the Great Plains. Wetlands 18:619-633.

Gaines, D. 1974. A New Look at the Nesting Riparian Avifauna of the Sacramento Valley, California. Western Birds 5:61–79. Cited in Ricketts and Kus 2004.

Garcia, D., R. Schlorff, and J. Silveira. 2008. Bank Swallows on the Sacramento River, a 10-year Update on Populations and Conservation Status. Central Valley Bird Club Bulletin 11(1):1–12. Available at <http://www.cvbirds.org/CVBC_Bull/V.11no.1/11(1)1-12.Garciaetal.2008.pdf.> Accessed on November 2, 2011.

Garrison, B.A. 1999. Bank Swallow (*Riparia riparia*). In The Birds of North America No. 414, eds. A. Poole and F. Gill. The Birds of North America. Philadelphia, Pennsylvania.

Gay, G.R., H.H. Gay, W.H. Gay, and H.A. Martinson. 1998. Evolution of Cutoffs across Meander Necks in Powder River, Montana, USA. Earth Surface Processes and Landforms 23:651–662.

Greco, S.E. 2008. Long-Term Conservation of the Yellow-Billed Cuckoo Will Require Process-Based Restoration on the Sacramento River. Ecesis 18(3):4–7.

Greco, S.E., A.K. Fremier, E.W. Larsen, and R.E. Plant. 2007. A Tool for Tracking Floodplain Age Land Surface Patterns on a Large Meandering River with Applications for Ecological Planning and Restoration Design. Landscape and Urban Planning 81:354–373.

Greco, S.E., R.E. Plant, and R.H. Barrett. 2002. Geographic Modeling of Temporal Variability in Habitat Quality of the Yellow-Billed Cuckoo on the Sacramento River, Miles 196–219, California. In Predicting Species Occurrences: Issues of Accuracy and Scale, eds. J.M. Scott, P.J. Heglund, F. Samson, J. Haufler, M. Morrison, M. Raphael, and B. Wall, 183–196. Island Press. Covelo, California.

Greco, S.E., and R.E. Plant. 2003. Temporal Mapping of Riparian Landscape Change on the Sacramento River, Miles 196–218, California, USA. Landscape Research 28:405–426.

Grinnell, J., and A.H. Miller. 1944. The Distribution of Birds in California. Pacific Coast Avifauna 27:35–557.

Hall, W.H. 1887. Topographical and Irrigation Map of the Great Central Valley of California: Embracing the Sacramento, San Joaquin, Tulare and Kern Valleys and the Bordering Foothills. California State Engineering Department, Sacramento. Britton & Rey. San Francisco, California. Cited in The Bay Institute 1998.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, and K.W. Cummins. 1986. Ecology of Coarse Woody Debris in Temperate Ecosystems. Advances in Ecological Research 15:133–302.

Harwood, D.S., and E.J. Helley. 1987. Late Cenozoic Tectonism of the Sacramento Valley, California. Professional Paper 1359. U.S. Geological Survey.

Helley, E.J., and D.S. Harwood. 1985. Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California. Map MF-1790. U.S. Geological Survey.

Herren, J.R., and S.S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. In Contributions to the Biology of Central Valley Salmonids, Fish Bulletin 179, Volume 2, ed. R. L. Brown, 343–355. California Department of Fish and Game. Sacramento, California.

Hooke, J.M. 1984. Changes in River Meanders: A Review of Techniques and Results of Analysis. Progress in Physical Geography 8:473–508.

———. 1995a. Processes of Channel Planform Change on Meandering Channels in the UK. In Changing River Channels, eds. A. Gurnell and G. Petts, 87–115. John Wiley & Sons.

———. 1995b. River Channel Adjustment to Meander Cutoffs on the River Bollin and River Dane, Northwest England. Geomorphology 14:235–253.

Howell, C. A., J. K. Wood, M. D. Dettling, K. Griggs, C. C. Otte, L. Lina, and T. Gardali. 2010. Least Bell's Vireo Breeding Records in the Central Valley Following Decades of Extirpation. Western North American Naturalist 70 (1):105–113.

Hughes, F.M.R. 1997. Floodplain Biogeomorphology. Progress in Physical Geography 21:501–529.

Hughes, J. 1999. Yellow-billed Cuckoo (*Coccyzus americanus*). In The Birds of North America, Vol. 418. A. Poole and F. Gill, eds., 1–28. Philadelphia, PA. Cited in 66 Federal Register 38614, July 25, 2001

Hunter, J.C., and G.A.J. Platenkamp. 2003. The Hunt for Red Sesbania: Biology, Spread, and Prospects for Control. California Exotic Pest Plant Council News 11(2):4–6.

Hupp, C.R., and W.R. Osterkamp. 1996. Riparian Vegetation and Fluvial Geomorphic Processes. Geomorphology 14:277–295.

IMST. *See* Independent Multidisciplinary Science Team.

Independent Multidisciplinary Science Team (IMST). 2002. Recovery of Wild Salmonids in Western Oregon Lowlands. Technical Report 2002-1. Governor's Natural Resources Office. Salem, Oregon.

James, A.B.W., and I.M. Henderson. 2005. Comparison of Coarse Particulate Organic Matter Retention in Meandering and Straightened Sections of a Third-Order New Zealand Stream. River Research and Applications 21:641–650.

James, L.A., and M.B. Singer. 2008. Development of the Lower Sacramento Valley Flood-Control System: Historical Perspective. Natural Hazards Review 9(3):125–135.

Johannesson, H., and G. Parker. 1989. Linear Theory of River Meanders. In River Meandering, eds., S. Ikeda and G. Parker, 181–214. American Geophysical Union. Washington, DC.

Johnson, W.C., R.L. Burgess, and W.R. Keammerer. 1976. Forest Overstory Vegetation and Environment of the Missouri River Floodplain in North Dakota. Ecological Monographs 46:59–84.

Jones, B.L., N.L. Hawley, and J.R. Crippen. 1972. Western Tributaries of the Sacramento River, California. U.S. Geological Survey Water Supply Paper 1798-J.

Jones & Stokes Associates. 1998a. Analysis of Physical Processes and Riparian Habitat Potential of the San Joaquin River—Friant Dam to the Merced River. (JSA 97- 303.) Sacramento, California. Prepared for U.S. Bureau of Reclamation, Fresno, California. October.

———. 1998b. Historical Riparian Habitat Conditions of the San Joaquin River—Friant Dam to the Merced River. (JSA 97-302.)

Sacramento, California. Prepared for U.S. Bureau of Reclamation, Fresno, California. April.

———. 2002. San Joaquin River Restoration Plan Background Report. Draft. January. Sacramento, CA. Prepared for Friant Water Users Authority, Lindsay, CA, and Natural Resources Defense Council, San Francisco, CA.

Jungwirth, M., O. Moog, and S. Muhar. 1993. Effects of River Bed Restructuring on Fish and Benthos of a Fifth Order Stream, Melk, Austria. Regulated Rivers: Research & Management 8:195–204.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. In Proceedings of the International Large River Symposium, ed. D.P. Dodge, 110–127. Canadian Special Publication of Fisheries and Aquatic Sciences 106. Cited in The Nature Conservancy 2007.

Katibah, E.F. 1984. A Brief History of Riparian Forests in the Central Valley of California. In California Riparian Systems: Ecology, Conservation and Productive Management, eds. R.E. Werner and K.M. Hendrix, 23–29. University of California Press. Berkeley, California.

Keeler-Wolf, Todd. 2009. Senior Vegetation Ecologist. Biogeographic Data Branch. California Department of Fish and Game. Personal Communication.

Keeley, E.R. 2001. Demographic Responses to Food and Space Competition by Juvenile Steelhead Trout. Ecology 82:1247–1259. Available at <http://www.isu.edu/~keelerne/Keeley_2001.pdf>. Accessed March 26, 2011.

Kondolf, G.M. 2000. Assessing Salmonid Spawning Gravel Quality. Transactions of the American Fisheries Society 129:262–281.

Kondolf, G.M., T. Griggs, E.W. Larsen, S. McBain, M. Tompkins, J.G. Williams, and J. Vick. 2000. Flow Regime Requirements for Habitat Restoration along the Sacramento River between Colusa and Red Bluff. CALFED Bay Delta Program, Integrated Storage Investigation. Sacramento, California.

Kus, B. 2004. Least Bell's Vireo (*Vireo bellii pusillus*). In The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian-Associated Birds in California. California Partners in Flight and Riparian Habitat Joint Venture. Sacramento, California.

Larsen, E.W. 1995. Mechanics and Modeling of River Meander Migration. Department of Civil Engineering, University of California. Berkeley, California.

———. 2007. Sacramento River Ecological Flows Study: Meander Migration Modeling Final Report. Prepared for The Nature Conservancy, Chico, CA. Prepared by Eric W. Larsen, Davis, CA. Available at: http://132.241.99.23/SRCAF/library_doc/ Meander_Migration_Modeling_Final_Report_(Larsen_2007).pdf>. Accessed August 30, 2011.

———. 2010. Middle Sacramento River Meander Bend Attributes and Ecosystem Health Indicator Metrics. California Bay-Delta Authority Ecosystem Restoration Program. C.R. Foundation, University of California. Davis, California.

Larsen, E.W., A.K. Fremier and S.E. Greco. 2006a. Cumulative Effective Stream Power and Bank Erosion on the Sacramento River, California, USA. Journal of American Water Resources Association 42:1077–1097.

Larsen, E.W., E.H. Girvetz, and A.K. Fremier. 2006b. Assessing the Effects of Alternative Setback Channel Constraint Scenarios Employing a River Meander Migration Model. Environmental Management 37:880–897.

Leopold, L., M. Wolman, and J. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman Company. San Francisco, California.

Lindley, S.T., R.S. Schick, A. Agrawal, M. Goslin, T.E. Pearson, and E. Mora. 2006. Historical Population Structure of Central Valley Steelhead and Its Alteration by Dams. San Francisco Estuary and Watershed Science 4(1):1–19. Available at <http://escholarship.org/uc/item/1ss794fc>. Accessed March 8, 2011.

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

Mahoney, J.M., and S.B. Rood. 1998. Streamflow Requirements for Cottonwood Seedling Recruitment—An Integrative Model. Wetlands 18(4):634–645.

Malanson, G.P. 1993. Riparian Landscapes. Cambridge University Press. New York, New York.

Marchetti, M.P., and P.B. Moyle. 2001. Effects of Flow Regime and Habitat Structure on Fish Assemblages in a Regulated California Stream. Ecological Applications 11(2):530–539.

Maser, C., and J.R. Sedell (eds.). 1994. From the Forest to the Sea. St. Lucie Press. Delray Beach, Florida.

McEwan, D.R. 2001. Central Valley Steelhead. In Contributions to the Biology of Central Valley Salmonids, Fish Bulletin 179, Volume 1, ed. R.L. Brown, 1–43. California Department of Fish and Game. Sacramento, California.

Micheli, E.R., J.W. Kirchner, and E.W. Larsen. 2004. Quantifying the Effect of Riparian Forest Versus Agricultural Vegetation on River Meander Migration Rate, Central Sacramento River, California, USA. River Research and Applications 20:537–548.

Micheli, E.R., and E.W. Larsen. 2011. River Channel Cutoff Dynamics, Sacramento River, California, USA. River Research and Applications 27:328–344.

Mills, T.J., and F. Fisher. 1994. Central Valley Anadromous Sport Fish Annual Run-Size, Harvest, and Population Estimates, 1967 through 1991. California Department of Fish and Game. Sacramento, California. August. Cited in TNC 2007.

Morken, I., and M. Kondolf. 2003. Evolution Assessment and Conservation Strategies for Sacramento River Oxbow Habitats. The Nature Conservancy. Chico, California.

Moyle, P.B. 2002. Inland Fishes of California. Revised and expanded. University of California Press. Berkeley, California.

Moyle, P.B., J.A. Israel, and S.E. Purdy. 2008. Salmon, Steelhead, and Trout in California. Status of an Emblematic Fauna. Center for Watershed Sciences, University of California. Davis, California.

Moyle, P.B., and D. White. 2002. Effects of Screening Diversions on Fish Populations in the Central Valley: What Do We Know? A report for the Science Board, CALFED Ecosystem Restoration Program. University of California. Davis, California. January.

Moyle, P.B., and R.M. Yoshiyama. 1992. Fisheries, Aquatic Diversity Management Areas, and Endangered Species: A Plan to Protect California's Native Aquatic Biota. The California Policy Seminar, University of California. Berkeley, California. Cited in The Bay Institute 1998.

Mussetter Engineering and Jones & Stokes Associates. 2002. Geomorphic and Sediment Baseline Evaluation of the San Joaquin River from the Delta to the Confluence with the Merced River and Major Tributaries. Final Report. Sacramento and San Joaquin Rivers Comprehensive Study. Prepared for U.S. Army Corps of Engineers, Sacramento District. Prepared by Mussetter Engineering Inc. Fort Collins, CO, and Jones & Stokes Associates Inc., Sacramento, CA.

Naiman, R.J., H. Decamps, and M.E. McClain. 2005. Riparia: Ecology, Conservation and Management of Streamside Communities. Elsevier. New York, New York.

Naiman, R.J., H. Decamps, and M. Pollock. 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. Ecological Applications 3:209–212.

National Marine Fisheries Service (NMFS). 2009. Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Sacramento Protected Resources Division. Sacramento, California. October.

National Oceanic and Atmospheric Administration (NOAA Fisheries). 2005. Central Valley Steelhead and Chinook Distribution GIS data. August. Available at <http://swr.nmfs.noaa.gov/salmon/layers/finalgis.htm>. Last updated September 7, 2005. Accessed March 8, 2011.

NMFS. *See* National Marine Fisheries Service.

NOAA Fisheries. *See* National Oceanic and Atmospheric Administration.

Ogden, J.C., S.M. Davis, K.J. Jacobs, T. Barnes, and H.E. Fling. 2005. The Use of Conceptual Ecological Models to Guide Ecosystem Restoration in South Florida. Wetlands 25:795–809.

Poff, N.L., J.D. Allan, M.B. Bain, J.R Karr, K.R Prestegaard, B.D. Richter, and J.C. Stromberg. 1997. The Natural Flow Regime: A Paradigm for River Conservation and Restoration. BioScience 47(11):521–529. Available at <http://www.fs.fed.us/stream/Poffetal_1997.pdf>. Accessed April 4, 2011.

Reclamation. *See* U.S. Department of the Interior, Bureau of Reclamation.

Reclamation Board, 1966. Lower San Joaquin River Flood Control Project, Dedication, Los Banos, California, October 6, 1966.

RHJV. *See* Riparian Habitat Joint Venture.

Ricketts, M., and B. Kus. 2004. Yellow-Breasted Chat (*Icteria virens*). In The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian-Associated Birds in California. California Partners in Flight and Riparian Habitat Joint Venture. Sacramento, California.

Riparian Habitat Joint Venture (RHJV). 2004. The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian Associated Birds in California. Version 2.0. PRBO Conservation Science. Stinson Beach, California.

Robertson, K.G. 1987. Paleochannels and Recent Evolution of the Sacramento River, California. Master of Science Thesis. University of California. Davis, California.

Sands, A., and G. Howe. 1977. An Overview of Riparian Forest in California: Their Ecology and Conservation. In Importance, Preservation and Management or Riparian Habitat: A Symposium, eds. R.R. Johnson and D.A. Jones, 35–47. Tucson, Arizona.

Sawyer, J.O., T. Keeler-Wolf and J.M. Evens. 2009. A Manual of California Vegetation, 2nd edition. California Native Plant Society Press, Sacramento, CA.

Scott, M.L., G.T. Auble, and J.M. Friedman. 1997. Flood Dependency of Cottonwood Establishment along the Missouri River, Montana, USA. Ecological Applications 7:677–690.

Scott, M.L., J.M. Friedman, and G.T. Auble. 1996. Fluvial Process and the Establishment of Bottomland Trees. Geomorphology 14:327–339.

Shafroth, P.B., G.T. Auble, J.C. Stromberg, and D.T. Patten. 1998. Establishment of Woody Riparian Vegetation in Relation to Annual Patterns of Streamflow, Bill Williams River, Arizona. Wetlands 18(4):577–590.

Singer, M.B. 2007. The Influence of Major Dams on Hydrology through the Drainage Network of the Sacramento River Basin, California. River Research and Applications 23:55–72.

Singer, M.B., R. Aalto, and L.A. James. 2008. Status of the Lower Sacramento Valley Flood-Control System within the Context of Its Natural Geomorphic Setting. Natural Hazards Review 9(3):104–115.

Singer, M.B., and T. Dunne. 2001. Identifying Eroding and Depositional Reaches of Valley by Analysis of Suspended-Sediment Transport in the Sacramento River, California. Water Resources Research 37(12):3371–3381.

Sommer, T.R., W.C. Harrell, M.L. Nobriga, and R. Kurth. 2003. Floodplain as Habitat for Native Fish: Lessons from California's Yolo Bypass. In California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration, 2001 Riparian Habitat and Floodplains Conference Proceedings, ed. P.M. Faber, 81–87. Riparian Habitat Joint Venture. Sacramento, California.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. Canadian Journal of Fisheries and Aquatic Sciences 58(2):325–333.

Steiger, J., E. Tabacchi, S. Dufour, D. Corenblit, and J.L. Peiry. 2005. Hydrogeomorphic Processes Affecting Riparian Habitat within Alluvial Channel-Floodplain River Systems: A Review for the Temperate Zone. River Research and Applications 21:719–737.

Stella, J.C., J.J. Battles, J.R. McBride, and B.K. Orr. 2010. Riparian Seedling Mortality from Simulated Water Table Recession, and the Design of Sustainable Flow Regimes on Regulated Rivers. Restoration Ecology 18:284–294. Available at <http://www.esf.edu/fnrm/stella/website_pubs/StellaEtAl_10_RestEcol_SeedlingMortalityWaterTableDecline.pdf>. Accessed April 4, 2011.

Stromberg, J.C., D.T. Patten, and B.D. Richter. 1991. Flood Flows and Dynamics of Sonoran Riparian Forests. Rivers 2(3):221–235.

The Bay Institute. 1998. From the Sierra to the Sea: The Ecological History of the San Francisco-Bay Delta Watershed. The Bay Institute of San Francisco. Novato, California. July.

The Nature Conservancy (TNC). 2003. Final Sacramento River Ecological Indicators Pilot Study. Chico, California. Prepared by Stillwater Sciences, Berkeley, California.

———. 2007. Linking Biological Responses to River Processes: Implications for Conservation and Management of the Sacramento River – A Focal Species Approach. Chico, California. Prepared by Stillwater Sciences, Berkeley, California. November**.**

TNC. *See* The Nature Conservancy.

URS Corporation. 2007. Status and Trends of Delta-Suisun Services. California Department of Water Resources. Sacramento, California.

USACE. *See* U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE). 1981. Sacramento River and Tributaries Bank Protection and Erosion Control Investigation, California. Water Resources Planning Branch.

———. 2002. Sacramento and San Joaquin River Basins Comprehensive Study. Appendix G: Ecosystem Functions Model. Sacramento, California.

———. 2004. Standard Assessment Methodology for the Sacramento River Bank Protection Project. Final report. Contract DACW05-99-D-0006. Task order 0017. Prepared for the U.S. Army Corps of Engineers, Sacramento District. Prepared by Stillwater Sciences, Berkeley, CA and Dean Ryan Consultants, Sacramento, CA. USDA. See U.S. Department of Agriculture

U. S. Department of Agriculture (USDA). 2009. 2009 National Agricultural Imagery Program Aerial Photography (California). USDA FSA Aerial Photography Field Office, Salt Lake City, Utah

U.S. Department of the Interior. 2000. Record of Decision Trinity River Mainstem Fishery Restoration Final Environmental Impact Statement/Environmental Impact Report. December 2000. Available at <http://odp.trrp.net/Library/Details.aspx?document=227>. Accessed November 8, 2011.

U.S. Department of the Interior, Bureau of Reclamation (Reclamation). 1997. Surface Water Supplies and Facilities Operations: Affected Environment. Technical Appendix to Draft Programmatic Environmental Impact Statement for the Central Valley Project Improvement Act. Sacramento, California.

U.S. Fish and Wildlife Service (USFWS). 1992. Shaded Riverine Aquatic Cover of the Sacramento River System: Classification as Resource Category 1 Under the FWS Mitigation Policy. Portland, Oregon.

———. 2004. Impacts of Riprapping to Aquatic Organisms and River Functioning, Lower Sacramento River. Second Edition. Sacramento, California.

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

van Coller, A.L., K.H. Rogers, and G.L. Heritage. 2000. Riparian Vegetation-Environment Relationships: Complimentarily of Gradients versus Patch Hierarchy Approaches. Journal of Vegetation Science 11:337–350.

Ward, J.V., and J. A. Stanford.1995. The Serial Discontinuity Concept: Extending the Model to Floodplain Rivers. Regulated Rivers 10:159–168.

Ward, J.V., K. Tockner, U. Uehlinger, and F. Malard. 2001. Understanding Natural Patterns and Processes in River Corridors as the Basis for Effective River Restoration. Regulated Rivers: Research and Management 17:311–323.

Whistler, Ed. Ornithologist. Davis, CA. May 31, 2010— Central_Valley_Birds Message Board posting: Yolo Bypass Wildlife Area – Least Bell's Vireo – Three Singing. (Available: http://dir.groups.yahoo.com/group/central_valley_birds/message/13158). Accessed November 1, 2011.

———. Ornithologist. Davis, CA. May 7, 2011— Central_Valley_Birds Message Board posting: Yolo Bypass Wildlife Area: Least Bell's Vireos. (Available: http://dir.groups.yahoo.com/group/central_valley_birds/message/14493). Accessed November 1, 2011.

Williams, P., E. Andrews, J. Opperman, S. Bozkurt, and P. Moyle. 2009. Quantifying Activated Floodplains on a Lowland Regulated River: Its Application to Floodplain Restoration in the Sacramento Valley. San Francisco Estuary and Watershed Science 7(1). Available at <http://escholarship.ucop.edu/uc/item/1sn8r310>. Accessed March 26, 2011.

Wolman, M.G., and L.B. Leopold. 1957. River Flood Plains: Some Observations on Their Formation. Professional Paper 282-C. U.S. Geological Survey.

Yoshiyama, R.M., F.W. Fisher, and P.B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region in California. North American Journal of Fisheries Management 18:487–521.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In Contributions to the Biology of Central Valley Salmonids, Fish Bulletin 179, Volume 1, ed. R.L. Brown, 71–176. California Department of Fish and Game. Sacramento, California.

7.0 Abbreviations and Acronyms

BIOS ..... Biogeographic Information and Observation System
Board ..... Central Valley Flood Protection Board
BOD ..... biological oxygen demand
Cal-IPC ..... California Invasive Plant Council
cfs ..... cubic feet per second
CNDDB ..... California Natural Diversity Database
CVFPP ..... Central Valley Flood Protection Plan
CVFSCS..... Central Valley Flood System Conservation Strategy
Delta ..... Sacramento-San Joaquin Delta
DFG ..... California Department of Fish and Game
DO..... dissolved oxygen
DWR ..... California Department of Water Resources
GIS ..... geographic information system
IHA..... Indicators of Hydrologic Alteration
IRI ..... impoundment runoff index
LWM..... large woody material
MMU ..... minimum mapping unit
NMFS..... National Marine Fisheries Service
NVCS..... National Vegetation Classification System
PAD..... Passage Assessment Database
Reclamation ..... U.S. Department of Interior, Bureau of Reclamation
RM ..... river mile
SPA..... Systemwide Planning Area
SPFC ..... State Plan of Flood Control
SRA..... shaded riverine aquatic
USFWS..... U.S. Fish and Wildlife Service
VELB..... valley elderberry longhorn beetle

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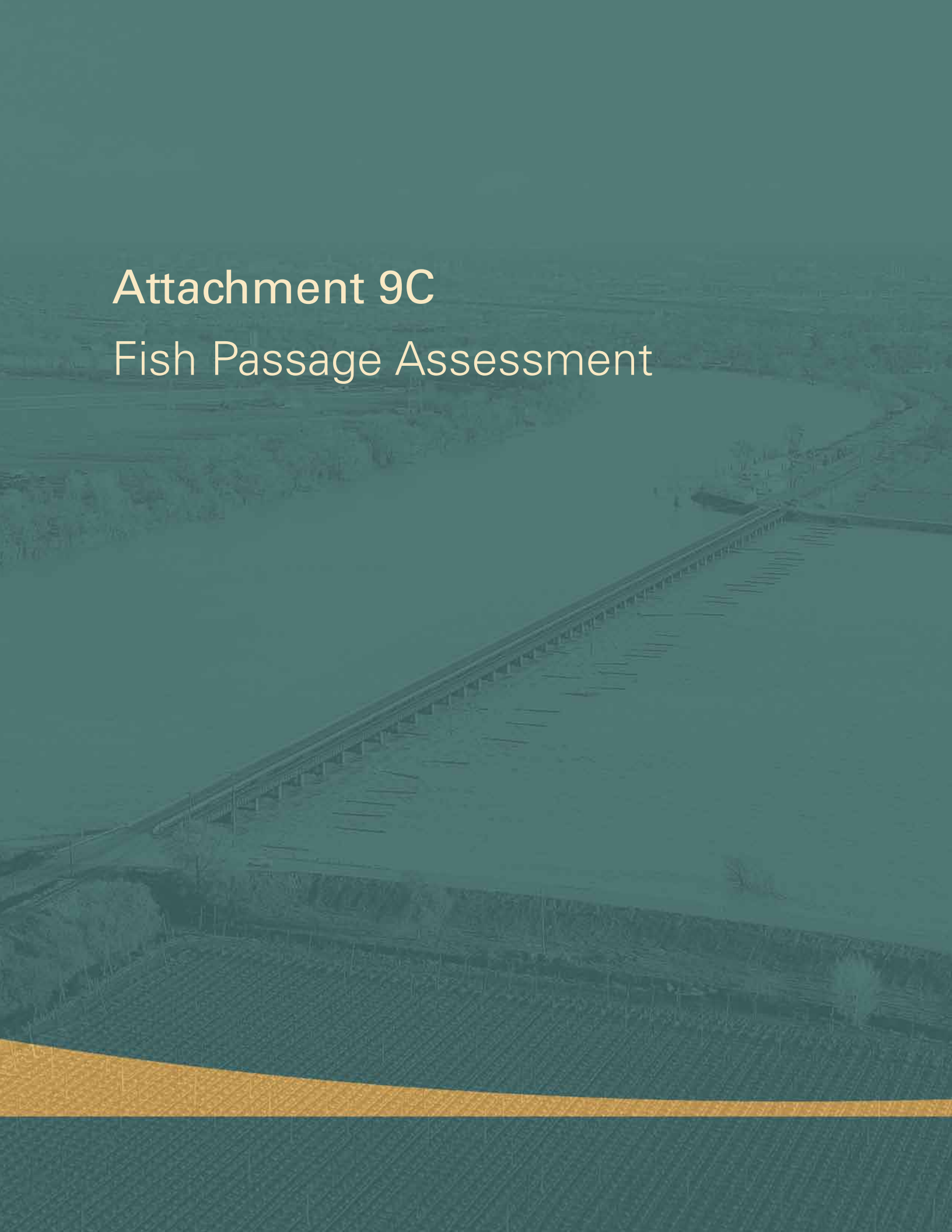
STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

Attachment 9C

Fish Passage Assessment



CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 9C: Fish Passage Assessment

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Table of Contents

1.0 Introduction 1-1

2.0 The Importance of Ecological Flows and Floodplain Flooding 2-1
2.1 Floodplains 2-1
2.2 Flows 2-3
2.2.1 Regulatory Requirements 2-3
2.2.2 Environmental Requirements 2-3
2.2.3 Example of Project to Restore Flows - San Joaquin River 2-5

3.0 Listed Anadromous Fish Within the Systemwide Planning Area 3-1

4.0 Historic and Current Populations of Listed Anadromous Fish in the Systemwide Planning Area 4-1
4.1 Chinook Salmon 4-1
4.1.1 Spring-Run Chinook Salmon 4-1
4.1.2 Sacramento River Winter-Run Chinook Salmon 4-3
4.1.3 Fall-Run Chinook Salmon 4-7
4.2 Central Valley Steelhead 4-10
4.3 Green Sturgeon 4-13

5.0 Reasons for the Decline in Anadromous Fish Populations 5-1

6.0 Climate Change 6-1

7.0 Identification and Prioritization of Passage Barriers in the Systemwide Planning Area 7-1
7.1 Identification of Barriers 7-1
7.1.1 Methods 7-1
7.1.2 Barrier Results 7-2
7.2 Stranding Risks 7-5
7.2.1 Flood Bypasses 7-5
7.2.2 In-stream Gravel Extraction 7-7
7.2.3 Rapid Changes in Flows 7-9
7.2.4 Research Needs 7-9

7.3 Prioritization of Fish Passage Barriers and Stranding Areas ... 7-10
7.3.1 Interim Prioritization Process ... 7-10
7.3.2 Interim Prioritization Results – Short Term ... 7-13
7.3.3 Interim Prioritization Results – Moderate Term ... 7-14
7.3.4 Interim Prioritization Results – Long Term ... 7-15

8.0 Possible Solutions for Fish Passage at Large Dams ... 8-1
8.1 Large Dams with Volitional Upstream Passage ... 8-3
8.1.1 Fishways ... 8-3
8.2 Large Dams with Non-Volitional Upstream Passage ... 8-6
8.2.1 Lifts ... 8-7
8.2.2 Locks ... 8-7
8.2.3 Collection and Transport ... 8-8
8.3 Large Dams with Volitional Downstream Passage ... 8-11
8.3.1 Turbine Passage ... 8-11
8.3.2 Spillway Passage ... 8-12
8.3.3 Bypass Systems ... 8-12
8.4 Large Dams with Non-Volitional Downstream Passage ... 8-14
8.4.1 Collection and Transport ... 8-14
8.5 Dam Removals ... 8-15
8.5.1 Removed Dams ... 8-15
8.5.2 Dams to be Removed ... 8-16
8.6 Conclusions ... 8-18

9.0 Recommendations and Conclusions ... 9-1
9.1 Recommended Priorities for Removing Fish Passage Barriers ... 9-1
9.2 Improve Fisheries Habitat ... 9-6
9.3 Improve Scientific Understanding of Stranding Effects ... 9-7

10.0 References ... 10-1

11.0 Acronyms and Abbreviations ... 11-1

List of Tables

Table 3-1. Anadromous Fish in the Upper Sacramento River 3-1

Table 7-1. Definitions of Barrier Status 7-2

Table 7-2. Number of Barriers and Diversions in the Systemwide Planning Area 7-2

Table 7-3. Geographic Priorities Identified by NOAA Fisheries 7-11

Table 9-1. State Plan of Flood Control Fish Passages Priorities 9-3

List of Figures

Figure 1-1. The Systemwide Planning Area and State Plan of Flood Control 1-3

Figure 4-1. Current and Historic Spring-Run Chinook Salmon Distribution 4-2

Figure 4-2. Estimated Spring-Run Chinook Salmon Run Size (1970 – 2008) 4-4

Figure 4-3. Current and Historic Winter-Run Chinook Salmon Distribution 4-5

Figure 4-4. Estimated Sacramento Winter-Run Chinook Salmon Run Size (1970 – 2008) 4-7

Figure 4-5. Current and Historic Fall-Run Chinook Salmon Distribution 4-8

Figure 4-6. Sacramento River Fall-Run Chinook Escapement, Ocean Harvest, and River Harvest (1983 – 2007) 4-10

Figure 4-7. Current and Historic Central Valley Steelhead Distribution 4-12

Figure 4-8. Steelhead Population Trends in the Sacramento River, Upstream from Red Bluff Diversion Dam from 1967 to 2005..... 4-13

Figure 4-9. Critical Habitat for Green Sturgeon in the Central Valley 4-15

Figure 7-1. Known and Potential Barriers, Including DWR-Owned Diversions, in the Systemwide Planning Area 7-3

Figure 7-2. Miles of Habitat Upstream from Total Barriers in the Systemwide Planning Area..... 7-4

Figure 7-3. Locations of Known Stranding Sites Within the Systemwide Planning Area..... 7-6

Attachments

Attachment 9C.1. Methods Used in Geographic Information System Analysis of Known and Potential Fish Passage Barriers in the Systemwide Planning Area

Attachment 9C.2. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area

Attachment 9C.3. Prioritized List of Potential Stranding Areas in the Systemwide Planning Area

1.0 Introduction

The Central Valley Flood Protection Act of 2008 requires DWR to develop a Central Valley Flood Protection Plan (CVFPP) that, among other objectives, improves habitat quantity, diversity, and connectivity and contributes to the recovery and stability of native species populations. This includes riverine aquatic habitats and anadromous fish species. One of the challenges to long-term viability of these fish is the obstacles that hinder or block their passage between the ocean and spawning streams in the Central Valley watershed.

This report identifies fish passage obstacles and recommends actions for modifying the Central Valley flood management system that could contribute to the recovery of native anadromous[1] fish in the Central Valley.

Within the geographical context of the CVFPP Systemwide Planning Area, this report discusses:

- The importance of ecological flows and floodplain flooding for fish
- The anadromous species present
- Anadromous fish population status and the reduction from their historic ranges
- Reasons for their decline, with a particular focus on physical passage barriers and stranding related to flood management
- The implications of passage barriers under climate change effects
- An identification and ranking of passage barriers and stranding areas
- A description of tested approaches for improving passage around major dams

Fish passage barriers can include, but are not limited to, dams, weirs, grade control structures, pumping stations, flood control gates, levees that cross or block stream channels, road crossings, and features of the flood control channels and bypasses that strand fish. Fish passage actions include

[1] Anadromous fish hatch from eggs laid in freshwater streams, migrate as juveniles to saltwater, and after living and growing in ocean waters return as adults to spawn in freshwater to complete their life cycle.

identifying barriers, evaluating and assessing the magnitude that each barrier impedes migration, and fixing barriers to allow unimpeded migration. These actions will assist in increasing and improving habitat connectivity and promoting the recovery of anadromous fish populations in the Sacramento-San Joaquin River Flood Management System.

The geographic scope of this report is the Systemwide Planning Area (Figure 1-1). This area includes lands that receive protection from the current facilities and operation of the Sacramento-San Joaquin River Flood Management System.[2] This area includes facilities that provide significant systemwide benefits (such as reservoirs on major tributaries) or that protect urban areas within the Sacramento and San Joaquin valleys. State Plan of Flood Control (SPFC) structures and components are contained within the Systemwide Planning Area. The structures and components, constructed over the last 150 years include dams, reservoirs, levees, channels, weirs, bypasses, and other flood control structures that provide varying levels of flood protection within the Central Valley.

[2] The Sacramento-San Joaquin River Flood Management System includes facilities of the SPFC and other flood management facilities that provide significant systemwide benefits for managing flood risks, or that protect urban areas, within the Sacramento-San Joaquin Valley (California Water Code, Section 9611).

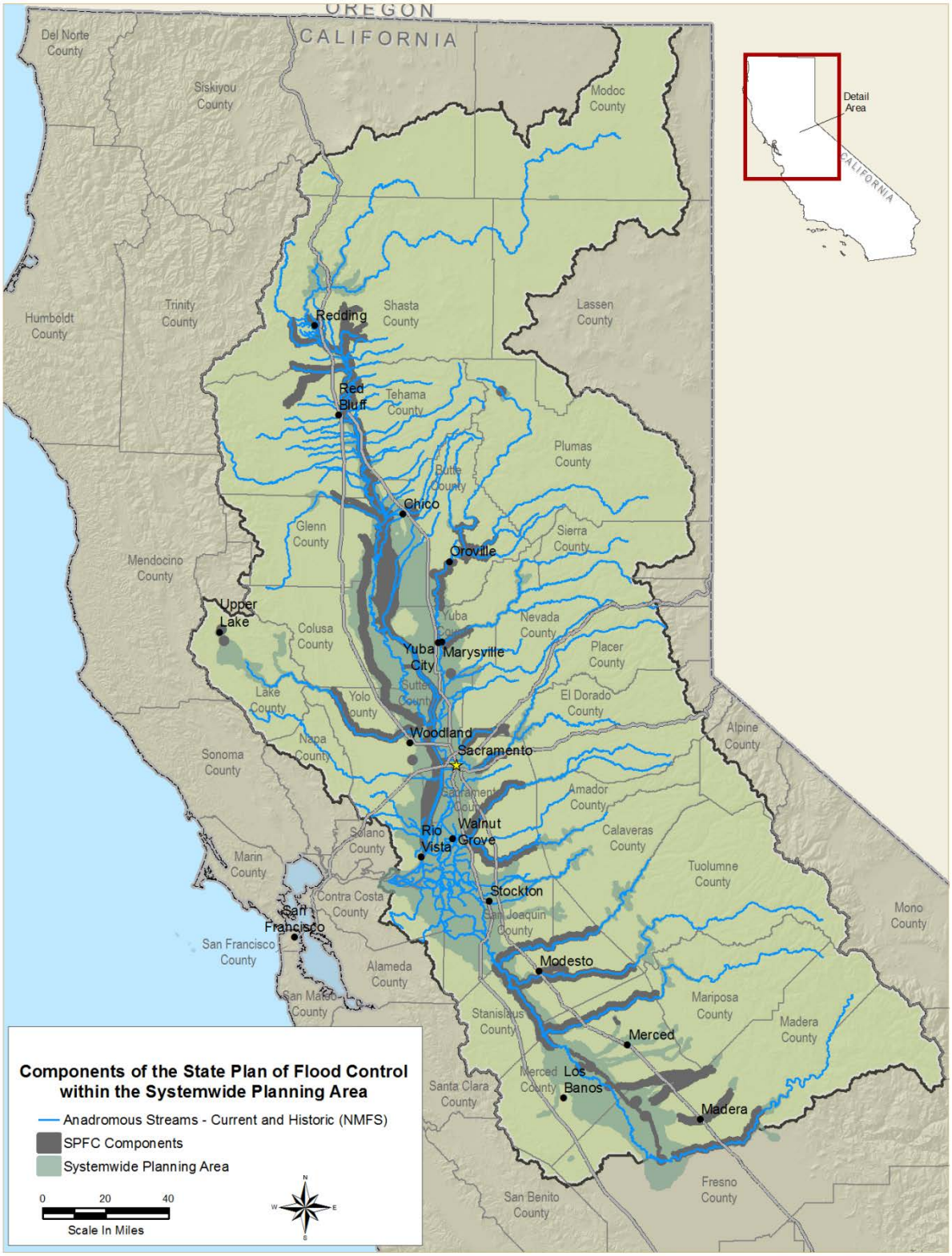

Figure 1-1. The Systemwide Planning Area and State Plan of Flood Control

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2.0 The Importance of Ecological Flows and Floodplain Flooding

Floods that periodically inundate the floodplains adjacent to rivers provide widespread ecosystem benefits. They can dramatically alter riverine landscapes, and benefit fish communities, food webs, and biological productivity (Junk et al., 1989; Feyrer et al., 2006b).

2.1 Floodplains

Floodplains are important components of aquatic ecosystems. They can provide widespread benefits at multiple trophic levels, ranging from individual organisms to ecosystems (Junk et al., 1989; Sommer et al., 2008). Floodplain habitat is particularly important to fish populations, where access to floodplain habitat produces increases in fish production, abundance, species diversity, and growth (Feyrer et al., 2004, Jeffres et al., 2008). For example, the fish communities of Yolo and Sutter bypasses appear to be structured primarily by the underlying physical habitat characteristics of each floodplain and secondarily by flood flows (Feyrer et al., 2006b). Results from several studies suggest that salmonids benefit from floodplains (Feyrer et al., 2007) because juveniles that use floodplain habitats in the Yolo Bypass (Sommer et al., 2001) and the Cosumnes River (Jeffres et al., 2008) consume more prey and grow faster than those in mainstem habitats. Sommer et al. 2001 found that survival rates of juvenile salmon may have been better in the Yolo Bypass in 1998 when flows were of a higher duration and magnitude than in 1999. The possible improvement in wet-year survival of salmon may have been due to increased access to floodplain rearing habitat, reduced water temperature, reduced predation losses, and other factors (Sommer et al., 2001). Floodplains also benefit other native fishes and support lower trophic levels, including drift invertebrates, phytoplankton, and zooplankton.

Fish yield and production seem to be a function of accessible floodplain habitat (Junk et al., 1989). Feyrer et al. (2007) documented enhanced growth and production of age-0 Sacramento splittail (*Pogonichthys macrolepidotus*), a native floodplain-dependent minnow, in floodplain habitat. Feyrer et al. (2007) found evidence that food web pathways supporting age-0 splittail in riverine and floodplain habitats were affected by flows connecting the two habitats. This suggests that flow and connectivity have an important effect on trophic relationships in river-floodplain systems.

Connection between a river and its floodplain enhances production of lower trophic levels, such as in the floodplain of the Sacramento River, where drift insects (primarily chironomids) were one to two orders of magnitude more abundant than in the adjacent river channel during 1998 and 1999 flood events (Sommer et al., 2001). The increased productivity is likely to be a significant benefit to secondary consumers, including salmon (Sommer et al., 2004).

River-floodplain connectivity also provides increased amounts of foraging and spawning habitat for fish. Studies have shown that inundation of the Yolo Bypass creates one of the major rearing habitats for downstream migrating juvenile Chinook salmon (*Oncorhynchus tshawytscha*), which take advantage of rearing areas created by seasonally inundated vegetation and an enriched food web in the floodplain (Sommer et al., 2001, 2004, 2005, 2008). Significantly larger wild Chinook salmon are captured at the downstream end of the Yolo Bypass than at the upstream end, and juvenile salmon in the Yolo Bypass floodplain grow substantially faster than the adjacent Sacramento River, illustrating the importance of this habitat (Sommer et al., 2001, 2005).

National Oceanic and Atmospheric Administration (NOAA) Fisheries recognized the importance of floodplain habitat in the Biological and Conference Opinion for the Central Valley Project (CVP) and State Water Project (SWP) (NOAA Fisheries, 2009b). Action I.6.1 requires the U.S. Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR) to "restore floodplain rearing habitat for juvenile winter-run and spring-run Chinook salmon, and Central Valley steelhead (*Oncorhynchus mykiss*), in the lower Sacramento River Basin. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River."

The Yolo Bypass is also an adult anadromous fish migration corridor when inundated. Structures within the Yolo Bypass have been a documented source of migratory delay to, and loss of, adult salmon, steelhead and green sturgeon (Harrell 2003 et al., NOAA Fisheries 2009b). Better and more regular upstream passage is needed to make it a migration corridor without barriers that hinder the movement of fish.

Another phenomenon important for migrating adult Chinook salmon is hydrologic banding.[3] In the Yolo Bypass, salmon pass through the floodplain on their journey to spawn in the upstream channels of Putah Creek, and the Sacramento River and its tributaries (Harrell and Sommer, 2003). Sommer et al. (2008) found that photographs of hydrologic banding

[3] Hydrologic bands are plumes of water from different sources that do not mix.

in the Yolo Bypass provide clues as to the likely routes that salmon take as they rely on chemical cues to migrate upstream.

Floodplain habitat in California has frequently been lost through the channelization of rivers, including construction of levees and channel straightening, deepening, and lining (Mount, 1995). Impacts of hydraulic mining, especially in the Yuba and Feather rivers, caused changes in sediment deposition within channels and floodplains, loss of channel capacity, and aggradation of river courses (Mount, 1995). A variety of activities, including water storage, conveyance, flood management, and navigation enhancements, have contributed to river modification and impaired natural floodplain inundation. Recent modeling studies have indicated that these factors can also affect habitats integral to the floodplain as well as their fisheries (Feyrer, 2006b).

2.2 Flows

Two primary factors that affect the operations of large reservoirs are regulatory and environmental requirements.

2.2.1 Regulatory Requirements

Regulatory restrictions include flood management, water, and energy supply obligations; requirements of the Central Valley Project Improvement Act, the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, the Federal Endangered Species Act, California Fish and Game Code Section 5937[4], and terms and conditions of water right permits. In order to meet regulatory objectives, reservoir operations must be based on consideration of many factors, including current and anticipated hydrological conditions; water supply forecasts; demand for water and electricity; the location, movement, and condition of fish; water temperature; coldwater pool availability; and water quality conditions in the Sacramento-San Joaquin River Delta (Delta) (Surface Water Resources Inc., 2004).

2.2.2 Environmental Requirements

Flows released for environmental (ecological) considerations (Peak and Ecological Flow Technical Advisory Committee, 2010) are typically divided into three types:

[4] California Fish and Game Code 5937 requires that the owner of any dam shall allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, allow sufficient water to pass over, around or through the dam, to keep in good condition any fish that may be planted or exist below the dam.

1. Low-flow thresholds ("subsistence flows") that prevent direct mortality of aquatic species. Subsistence flows are often used as short-term emergency bypass flows needed to keep populations of aquatic species alive and avoid fish kills or other serious acute impacts due to poor water quality.

2. "Base flows" that provide minimal or optimal habitat for target aquatic species, including flows that occur outside of freshets and storm events. The biological objectives of base flows include providing adequate protection of habitat for aquatic species, and upstream/downstream and mainstream/tributary connectivity (such as fish passage flows). Base flows include minimum bypass flows, which are defined by the State Water Resources Control Board as the minimum instantaneous flow rate of water that is important for managing the protection of steelhead and salmon life history needs, such as: (1) maintaining natural abundance and availability of spawning habitat; (2) minimizing unnatural adult exposure, stress, vulnerability, and delay during adult spawning migration; and (3) sustaining high quality and abundant juvenile salmonid winter rearing habitat (State Water Resources Control Board, Division of Water Rights, 2010).

3. Elevated "channel and habitat maintenance flows" are needed to maintain and create instream and riparian/floodplain habitat. These flows have a significant effect on the habitat of listed anadromous fish within the Systemwide Planning Area. Elevated releases (i.e., flood releases) are essential to the maintenance of habitat both within the floodplain and in the stream channel. The timing, duration, and frequency of elevated flows influence the effectiveness of habitat maintenance. These flows serve many purposes, including:

    a. Moving cobbles and gravels that remove fine sediments (silt, sand, fine gravel), thereby improving fish spawning and rearing habitat and macroinvertebrate rearing habitat;

    b. Scouring and filling the stream channel to prevent the encroachment of riparian vegetation, allowing the stream to retain its bed form rather than losing conveyance capacity and stream habitat space;

    c. Retaining bed configuration that supports the formation and maintenance of riffles, pools and other channel habitats, and creating and maintaining off-channel habitat;

    d. Creating conditions for the replenishment of streamside vegetation such as cottonwoods (*Populus* spp.) to maintain long-term riparian functions; and,

e. Maintaining recruitment, movement, and functionality of large woody debris in the stream.

4. Elevated "biological triggering flows" that stimulate and facilitate important life stage behavior such as migration or spawning in target species.

Large pulse flows act as biological triggers for anadromous fish. Fish and other aquatic organisms tie important activities such as migration or spawning to changes in environmental conditions such as water temperature, turbidity, daily sunlight, or flow rate. Some known scenarios where variability in streamflow or elevated flows cause aquatic organisms to initiate important phases of their life cycle include:

- Increases in flows to initiate upstream or downstream migration of fish (Jager, et al., 2003);
- Elevated flows to initiate spawning activity;
- Elevated flow periods to allow for the use of off channel, floodplain, or side channel habitat on large and small rivers; and,
- Changes in flow that initiate different life stage activities in aquatic insects.

The environmental flows discussed above are all important for maintaining ecological processes in riverine corridors, and illustrate the interconnectedness of flow vs. life stages (spawning, rearing, and migration).

2.2.3 Example of Project to Restore Flows - San Joaquin River

The operation of Friant Dam is an important example of the necessity of providing adequate stream flows to the reaches downstream from a large dam. The San Joaquin River Restoration Program (SJRRP) is a direct result of a settlement reached in September 2006 on an 18-year lawsuit (NRDC, et al., vs. Kirk Rodgers, et al, 2006). The SJRRP is designed to implement this settlement and to restore flows and naturally reproducing and self-sustaining populations of salmon to the San Joaquin River between the Friant Dam and the Merced River.

Proposition 84 (the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006) provided $100 million to implement this court settlement. The funds are designated for channel and structural improvements and related research pursuant to the

court settlement. In collaboration with Reclamation, DWR's South Central Region Office has lead responsibility for the Department's involvement in the San Joaquin River Restoration Program.

The settlement establishes two goals:

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

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

The settlement also identifies Interim Flows, which were released and are to continue until full Restoration Flows begin. The intent of the Interim Flows is to collect relevant data on flows, temperatures, fish needs, seepage losses, and water recirculation, recapture, and reuse (San Joaquin River Restoration Program, 2009).

The ecological functionality intended for the actions to reoperate Friant Dam was provided through a review of expert testimony submitted to the U.S. Eastern District Court of California during litigation. Based on the expert testimony, the overall ecological intent of the flow schedules provided in Exhibit B of the settlement can be summarized as follows:

- Provide for salmon life history needs (spring-run Chinook, fall-run Chinook), including:
  - Adult migration
  - Adult holding (spring-run Chinook only)
  - Spawning and incubation
  - Juvenile rearing
  - Juvenile outmigration
- Support other native fish and warm-water game fish[5]

[5] While ecological flows for native fish are supported by fisheries groups, the proliferation of warm-water game fish has been an ongoing concern. Warm-water fish include predators of juvenile Chinook salmon that could potentially cluster near flood control structures and gravel pits. (Comments received from A. Leon Cardona, 2011).

These flow schedules for the protection of native fishes are an example of "base flows" as described above.

In addition, the flow schedules intend to provide channel and habitat maintenance flows that (1) maintain geomorphic processes (especially gravel mobility) and (2) support recruitment and maintenance of riparian vegetation (San Joaquin River Restoration Program, 2009).

Under the settlement, spring-run and fall-run Chinook salmon are to be reintroduced to the San Joaquin River between Friant Dam and the confluence with the Merced River by December 31, 2012. The implementing agencies are currently working to implement the Reintroduction Strategy (NRDC, et al., vs. Kirk Rodgers, et al, 2006; San Joaquin River Restoration Program, 2011b). Recently, the SJRRP has performed work to identify fish passage barriers on the San Joaquin River from Friant Dam to the Merced River. This work includes literature research, field visits, and evaluations (Pers. comm. Romero, 2011).

For more information about SJRRP, see
http://www.restoresjr.net/background.html)

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3.0 Listed Anadromous Fish Within the Systemwide Planning Area

This report focuses on three species of anadromous fish that use the Central Valley: Chinook salmon, steelhead, and green sturgeon (*Acipenser medirostris*). Table 3-1 lists these three species (and important runs) and provides comparative information about their life history stages and seasonality. Anadromous fish are fish species that hatch from eggs laid in freshwater streams, migrate as juveniles to saltwater, and after living and growing in ocean waters then return as adults to spawn in freshwater to complete their life cycle.

Table 3-1. Anadromous Fish in the Upper Sacramento River

Species	Adult Immigration	Adult Holding	Typical Spawning	Egg Incubation	Juvenile Rearing	Juvenile Emigration
Winter-run Chinook salmon	December – July	January – May	April – August	April – October	July – March	July – March
Spring-run Chinook salmon	April – July	May – September	August – October	August – December	October – April	October - May
Fall-run Chinook salmon	July – December	n/a	October – December	October - March	December – June	December – July
Late Fall-run Chinook salmon	October – April	n/a	January – April	January – June	April – November	April – December
CA Central Valley Steelhead	August – March	September – December	December – April	December – Jun	Year round	January – October
Green sturgeon	February – June	June – November	March – July	April – June	May – August	May – December

Source: NOAA Fisheries, 2009b.
Key:
n/a = not applicable

California Chinook salmon are similar in morphology and are distinguished mainly by genetic and life history traits (e.g., run timing) (Moyle et al., 2008). The distinct populations within the species generally referred to as "runs" or "stocks," are named after the season in which they begin their freshwater spawning migrations, and are genetically and geographically distinct. In California's Central Valley, there are four genetically distinct runs: fall, late-fall, winter, and spring (Table 3-1).

Steelhead in California occur in six populations[6] (Evolutionary Significant Units (ESU) and Distinct Population Segments (DPS)) recognized by NOAA Fisheries. The populations are morphologically identical to one another and are distinguished by genetic characteristics. California populations of steelhead have complex systematic relationships (Moyle, 2002), and while California's six populations have essentially discrete geographic boundaries, adjacent populations have some degree of genetic similarity. The DPS of steelhead that is distributed in the Central Valley and the Systemwide Planning Area is the California Central Valley Steelhead.

Sturgeon occur in temperate waters throughout the Northern Hemisphere. Twenty-five species are currently extant, of which eight species are found in North America, and only two occur in California: white sturgeon (*Acipenser transmontanus*) and green sturgeon (Moyle, 2002). On the basis of genetic analyses and evidence of spawning site fidelity, NOAA Fisheries determined that green sturgeon occur in at least two DPS (Adams et al., 2002): a "Northern DPS" consisting of populations from coastal watersheds northward of and including the Eel River, and a "Southern DPS" consisting of populations from Coastal California and Central Valley watersheds south of the Eel River (NOAA Fisheries, 2010a, 2010b).

Federal and State agencies have listed several populations of anadromous fish as Threatened or Endangered, or a Species of Concern under the federal Endangered Species Act and California Endangered Species Act, respectively:

- Sacramento River winter-run Chinook salmon are listed by the State and federal governments as "Endangered."
- Central Valley steelhead, Central Valley spring-run Chinook salmon, and the Southern DPS of North American green sturgeon are listed by the federal government as "Threatened." Central Valley spring-run Chinook salmon is also listed by the State as "Threatened."
- Central Valley fall-run and late-fall run Chinook salmon are listed by the federal government as "Species of Concern" and by the State as "Species of Special Concern."

[6] The Endangered Species Act (ESA) defines a "species" to include any distinct population segment of any species of vertebrate fish or wildlife. For Pacific salmon, NOAA Fisheries Service considers an evolutionarily significant unit (ESU) a "species" under the ESA. For Pacific steelhead, NOAA Fisheries Service has delineated distinct population segments (DPS) for consideration as "species" under the ESA (NOAA Fisheries 2009).

4.0 Historic and Current Populations of Listed Anadromous Fish in the Systemwide Planning Area

4.1 Chinook Salmon

4.1.1 Spring-Run Chinook Salmon

The basic life history of spring-run Chinook salmon is to migrate upstream in spring, hold through the summer in deep, cold water pools, and then spawn in early fall, with juveniles emigrating after either a few months or a year while rearing in fresh water (Table 3-1).

Lindley et al. (2004) identified 26 historical populations within the spring-run Chinook salmon ESU; 19 were independent[7] populations, and seven were dependent populations. Only three independent populations of spring-run Chinook that occurred historically are extant, in Deer, Mill, and Butte creeks (in Tehama and Butte counties). Extant dependent populations have increased to nine and occur in Battle, Antelope, Big Chico, Clear, Beegum, and Thomes creeks, as well as in the Yuba River, the Feather River downstream of Oroville Dam, and in the mainstem Sacramento River below Keswick Dam (NOAA Fisheries, 2009a) (Figure 4-1). Within these regions, Chinook distribution is determined by water temperature and accessibility of spawning, rearing, and holding habitats (Moyle et al., 2008).

[7] Lindley et al. (2004) used several characteristics, including distance from a basin to its nearest neighbor (at least 50 km), the basin size (generally at least 500 km^2), and significant environmental differences between basins inside of the distance criterion, as well as data on population genetics and dynamics to decide whether populations were independent or dependent.

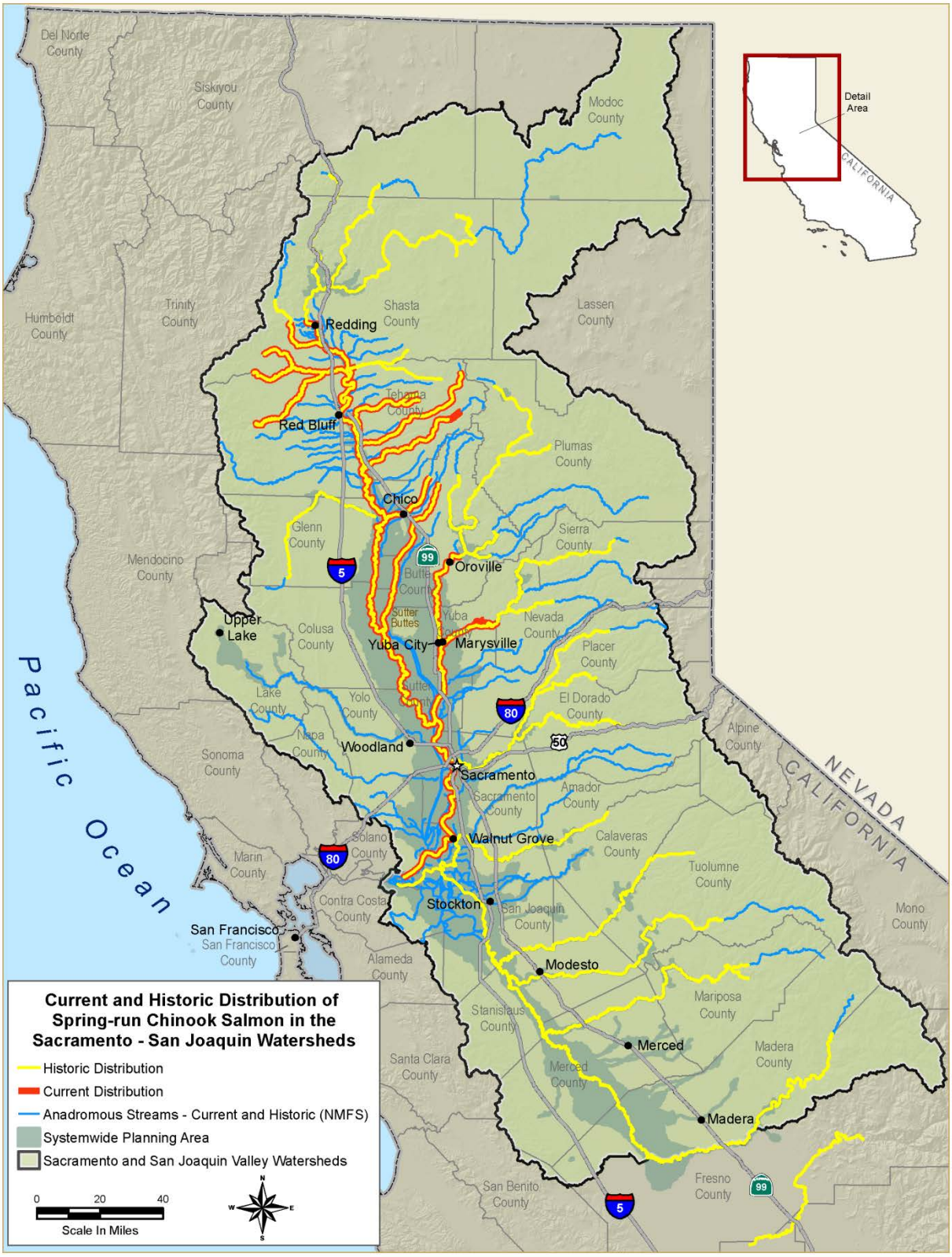


Figure 4-1. Current and Historic Spring-Run Chinook Salmon Distribution

Blockage of upstream summer holding habitat has created a greater potential for spring-run salmon to hybridize with other runs because the runs are no longer spatially and temporally separated (DWR, 2005). The Feather River population depends on Feather River Fish Hatchery production. Recent studies on this stock (Garza et al., 2008 as cited in NOAA Fisheries, 2011b; O'Malley et al., 2007) found subtle, but significant, differentiation between the Feather River Hatchery spring- and fall-run stocks. Genetic analysis (Garza et al., 2008 as cited in NOAA Fisheries, 2011b), suggests that the Feather River Hatchery spring-run population is a remnant of the ancestral Feather River spring-run that has been hybridized with fall-run Chinook.

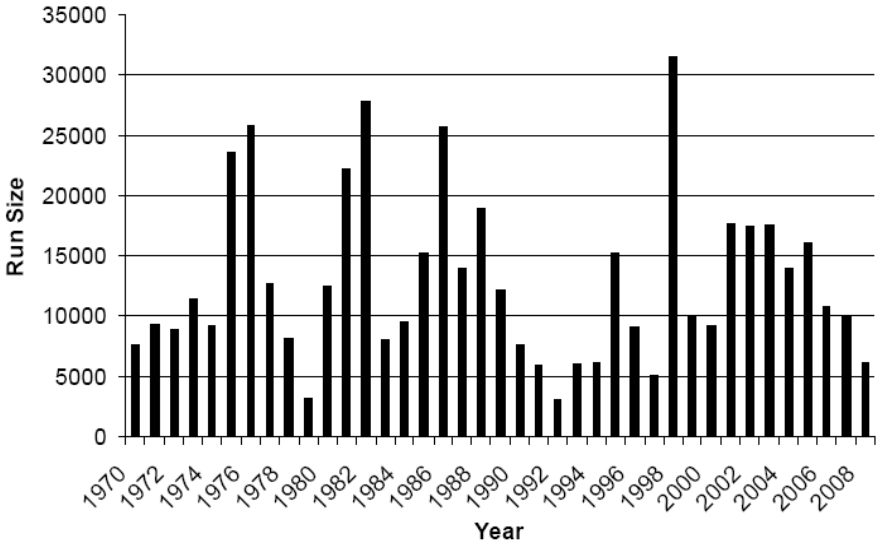
Current population estimates for spring-run Chinook salmon vary. However, the annual spawning run size of spring-run Chinook salmon on the Yuba River generally ranges from a few hundred to a few thousand fish with the annual trend closely following the annual abundance trend of the Feather River Hatchery spring-run Chinook salmon population (NOAA Fisheries, 2011b). The relatively recent installation of a Vaki Riverwatcher system at Daguerre Point Dam is providing more accurate estimates of spring-run Chinook population size in the lower Yuba River. The upper Sacramento River downstream of Keswick Dam may support a small spring-run Chinook salmon population, but that population is likely to be highly hybridized with fall-run Chinook salmon, and the status of that population is poorly documented (NOAA Fisheries, 2009a).

Since 1970, Central Valley spring-run Chinook salmon population levels have fluctuated significantly from highs near 30,000 fish to lows near 3,000. The 5-year average spring-run Chinook salmon abundance in the late 1990s was 8,500 fish, compared with 40,000 fish in the 1940s (NOAA Fisheries, 2008a.) (Figure 4-2).

4.1.2 Sacramento River Winter-Run Chinook Salmon

Sacramento River winter-run Chinook salmon have a life history that differs considerably in its timing from the other three Central Valley runs. Their spawning migration[8] lasts from December to July (NOAA Fisheries, 2009b), with runs peaking in mid-March (Moyle et al., 2008). They enter fresh water as sexually immature adults and migrate to the Sacramento River downstream from Keswick Dam, where they hold for several months until spawning from April through early August (Moyle et al., 2008).

[8] Descriptions of salmon run timing vary among published sources and are known to vary among years depending on environmental conditions.



Source: (NOAA Fisheries, 2009a)

Figure 4-2. Estimated Spring-Run Chinook Salmon Run Size (1970 – 2008)

Most winter-run fry migrate past Red Bluff Diversion Dam (RBDD) in summer or early fall (Moyle et al., 2008), but many rear in the river below Red Bluff for several months before they reach the Sacramento-San Joaquin (Delta) in early winter. Juveniles enter the Delta from November through March where they complete smoltification and migrate to the ocean (del Rosario et al., in review). Most juvenile winter-run Chinook salmon have migrated out of the Delta toward the ocean by the end of April (del Rosario et al., in review).

Historically, there were four independent populations of winter-run Chinook salmon: Little Sacramento River, Pit River-Fall River-Hat Creek, McCloud River, and Battle Creek (Figure 4-3). The first three of these areas are blocked by Shasta and Keswick dams (Lindley et al., 2004).

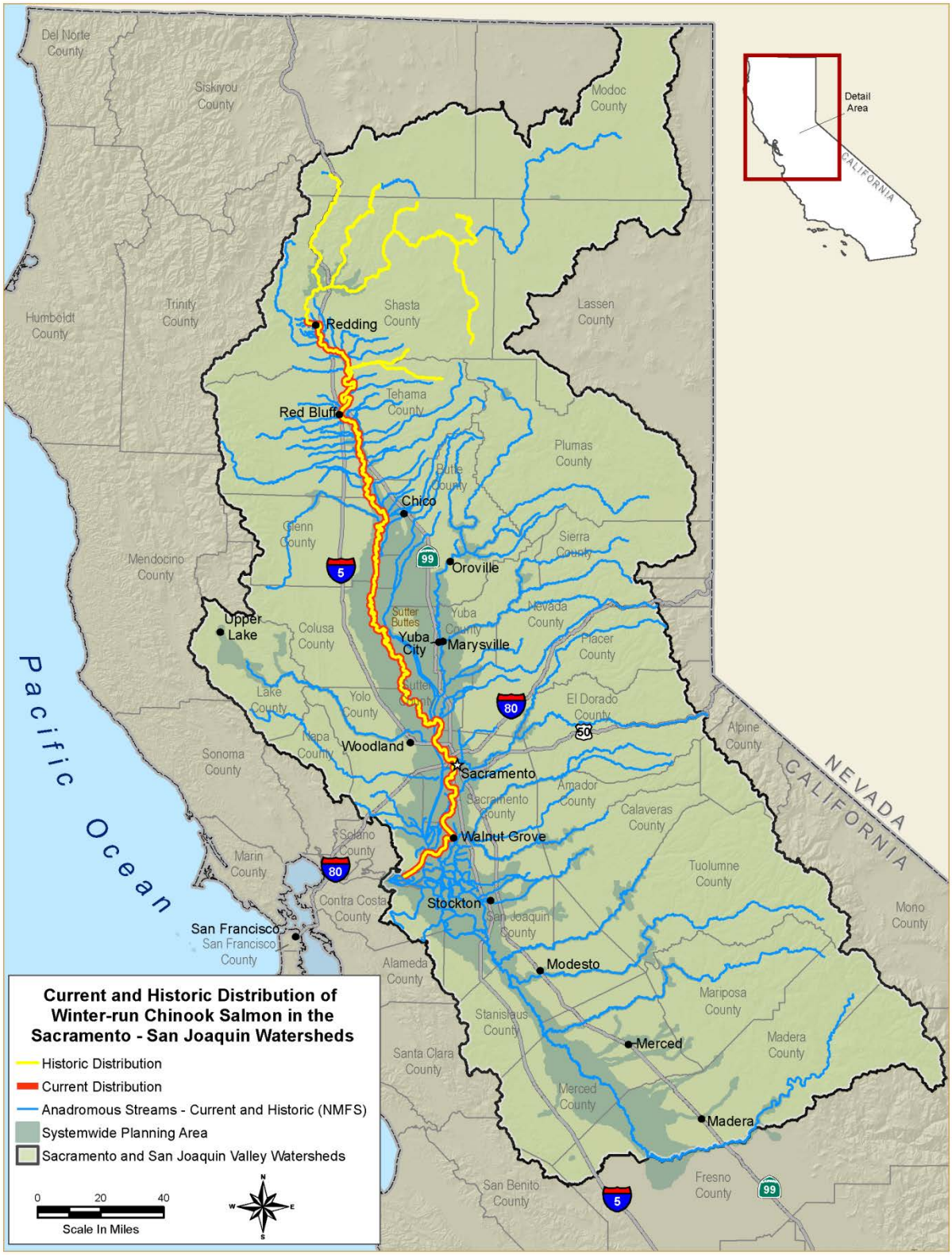


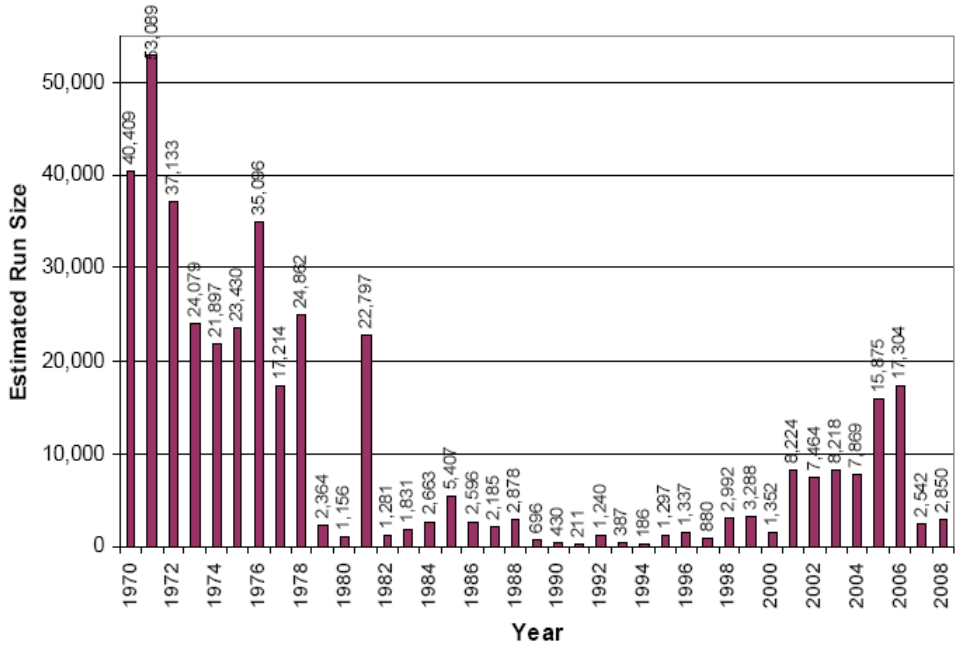
Figure 4-3. Current and Historic Winter-Run Chinook Salmon Distribution

Winter-run Chinook salmon no longer inhabit Battle Creek as a self-sustaining population, probably because hydropower operations make conditions for eggs and fry unsuitable (Lindley et al., 2007). In addition, access to much of the basin was blocked until recently by the Coleman National Fish Hatchery barrier weir (Lindley et al., 2007). However, a collaborative partnership (including state and federal resource agencies, Pacific Gas and Electric Company, public watershed groups, and other stakeholders) is implementing the Battle Creek Salmon and Steelhead Restoration Project. This restoration project will eventually remove five dams on Battle Creek, install fish screens and ladders on three dams, and end the diversion of water from the North Fork to the South Fork (NOAA Fisheries 2011c). Upon its completion, the project will re-establish approximately 42 miles of winter-run and spring-run Chinook salmon and steelhead habitat on Battle Creek, plus an additional six miles on its tributaries. For information, see: http://www.usbr.gov/mp/battlecreek/index.html (Reclamation, 2011).

Currently, there is one independent population of winter-run Chinook salmon inhabiting the area of cool water between Keswick Dam and Red Bluff, where cold-water releases from Shasta Reservoir, combined with artificial gravel additions, have created suitable habitat (Moyle et al., 2008). This area was not historically used by winter-run Chinook salmon for spawning (Lindley et al., 2004). Winter-run Chinook salmon have avoided hybridization with fall-run Chinook in this area, unlike spring-run Chinook salmon, due to their temporal isolation from the fall-run salmon.

The U.S. Fish and Wildlife Service (USFWS) manages a conservation hatchery program for winter-run Chinook salmon that is located at the Livingston Stone National Fish Hatchery. This hatchery program supplements the natural population according to strict guidelines developed in conjunction with NOAA Fisheries. Based on a review of available genetic and other information, this hatchery stock was considered part of the Sacramento River winter-run Chinook ESU and was listed in 2005 (NOAA Fisheries, 2011c).

The population of winter-run Chinook salmon that spawns below Keswick Dam increased in abundance from the mid-1990s through 2006, although the abundance remained well below historic levels. Since 2006, the increasing trend in winter-run Chinook salmon abundance has reversed during the more recent period of unfavorable ocean conditions (2005-06) and drought (2007-09).



Source: (NOAA Fisheries 2009a & c)

Figure 4-4. Estimated Sacramento Winter-Run Chinook Salmon Run Size (1970 – 2008)

4.1.3 Fall-Run Chinook Salmon

Central Valley fall-run Chinook salmon primarily migrate upstream in the fall as mature fish, although they have been recorded migrating from June through December, and a portion of the population returns as immature fish (Moyle et al., 2008). Peak spawning time is typically in October through November but can continue through December. Juveniles mostly emerge in December through March and rear in natal streams for one month to seven months, usually moving downstream into the main rivers within a few weeks after emerging and then enter the San Francisco Estuary as both fry and smolts (Moyle et al., 2008) (Table 3-1).

Using modern genetic techniques, late-fall-run Chinook salmon are distinguishable from the other runs, although late-fall-run Chinook were only recognized as a distinct run in 1966 after the construction of the RBDD (Williams, 2006). NOAA Fisheries manages late-fall-run Chinook as part of the Central Valley fall-run ESU because of their close relationship to it (Moyle et al., 2008).

Central Valley fall-run Chinook salmon historically spawned in all major rivers of the Central Valley, migrating as far south as the Kings River, and north to the upper Sacramento, McCloud, and Pit rivers (Figure 4-5). There were also small runs in smaller Central Valley streams and creeks (Moyle et al., 2008).

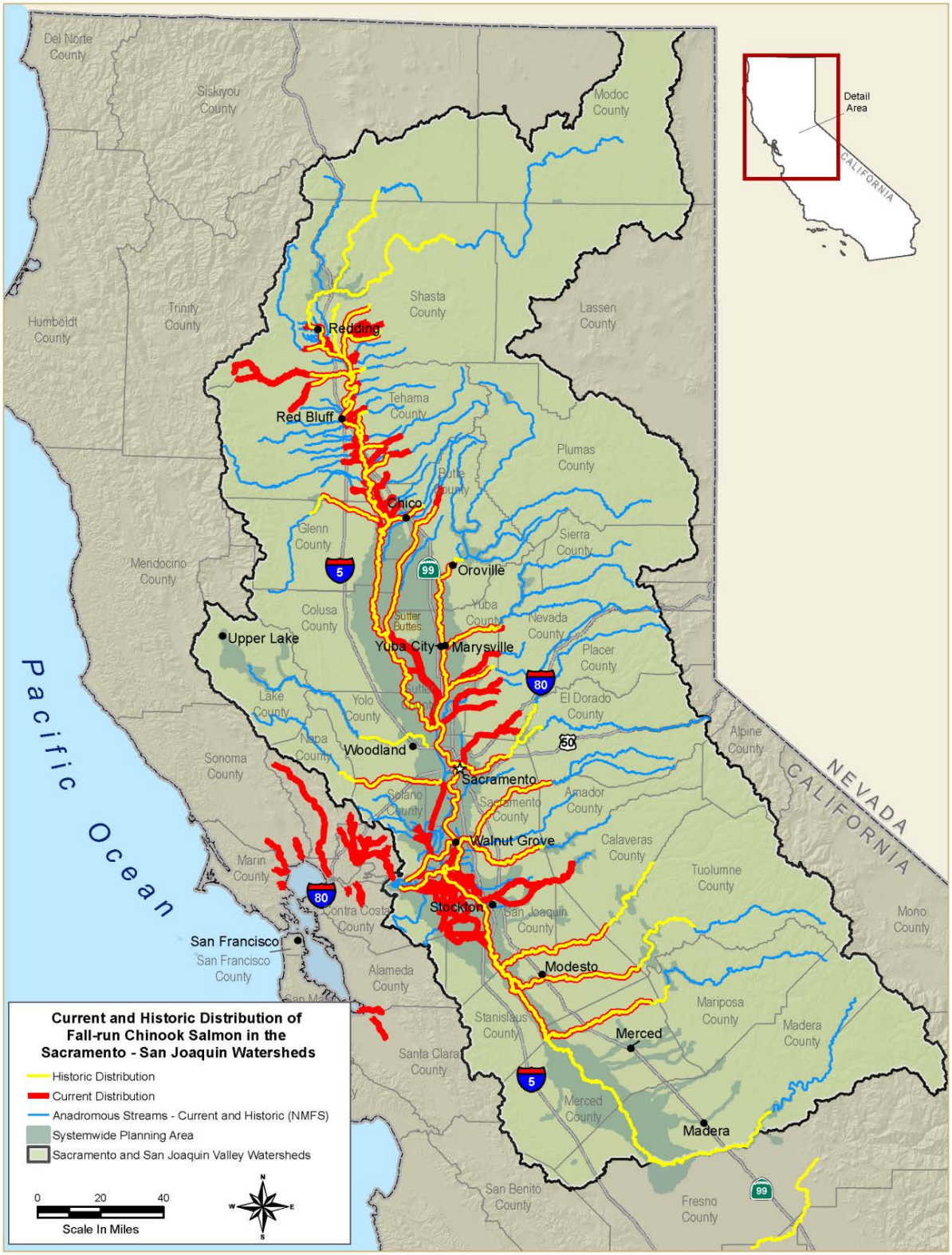


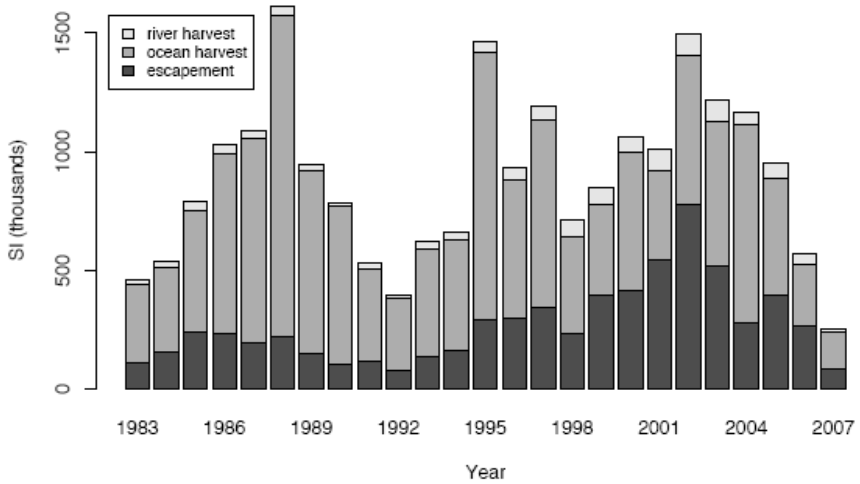
Figure 4-5. Current and Historic Fall-Run Chinook Salmon Distribution

A large portion of the fall-run Chinook salmon population contributing to ocean fisheries is raised in hatcheries, including Feather River Hatchery, Mokelumne River Hatchery, Coleman National Fish Hatchery on Battle Creek, and Nimbus Hatchery on the American River (Lindley et al., 2009).

Currently, fall-run Chinook salmon spawn upstream as far as the first impassible dam (e.g., Keswick Dam on the Sacramento River), although on the San Joaquin side of the Central Valley, they only reach the Merced River because Friant Dam has cut off all natural flows to the lower San Joaquin River (Moyle et al., 2008). Restoration in the San Joaquin River is ongoing (See section 2.2.1 of this report). In the upper Sacramento River, the relative proportions of fall-run spawning in the mainstem and in Battle Creek have approximately reversed over the last half-century, with more fish now spawning in Battle Creek than in the Sacramento River upstream of Red Bluff (Williams, 2006).

Spawning populations of late-fall-run Chinook salmon occur in several tributaries of the Sacramento River, including Battle, Cottonwood, Clear and Mill creeks, and in the Feather River (Stillwater Sciences, 2007). However, the sizes of these spawning populations are relatively small, with the exception of Battle Creek where late-fall-run Chinook are artificially propagated at the Coleman National Fish Hatchery (Stillwater Sciences, 2007). Incidental observations of late fall-run Chinook salmon have been reported to occur in the lower Yuba River (Lower Yuba River Accord Management Team Planning Group, 2010).

Fall-run Chinook have always been the most abundant salmon run in the Central Valley (Moyle, 2002). From the 1870s through early 1900s, annual in-river harvest in the Central Valley often totaled 4 million to 10 million pounds of Chinook, approaching or exceeding the total annual harvest by statewide ocean fisheries in recent decades. Maximum annual stock size (including harvest) of Central Valley Chinook salmon before the 20th century has been estimated conservatively at 1 million to 2 million spawners with fall-run salmon totals perhaps reaching 900,000 fish (Yoshiyama et al., 1998). Annual escapement of fall-run Chinook salmon has remained relatively stable from the 1960s through the 1990s, totaling between 100,000 and 350,000 adults per year. However, escapement began to fluctuate more erratically in the present decade, climbing to a peak of 775,000 in 2002 but then falling rapidly to near-record lows in 2007 (estimated spawning escapement of 88,000) (Figure 4-6) (Lindley et al., 2009).



Source: Lindley et al., 2009

Figure 4-6. Sacramento River Fall-Run Chinook Escapement, Ocean Harvest, and River Harvest (1983 – 2007)

4.2 Central Valley Steelhead

Steelhead and rainbow trout are the same species, with steelhead referring to the anadromous form of the species. Central Valley steelhead typically[9] begin their spawning migration in fall, winter, and spring, and spawn relatively soon after freshwater entry. Spawning occurs January through March, but can extend into spring and possibly early summer months (McEwan, 2001). Rearing takes place during the summer and juvenile steelhead emigrate from natal streams during fall, winter, and spring high flows (Table 3-1) (NOAA Fisheries, 2009b).

Historically, Central Valley steelhead were distributed throughout the Sacramento and San Joaquin rivers (McEwan, 2001). Steelhead were found from the upper Sacramento and Pit rivers (both now inaccessible due to Shasta and Keswick dams) south to the Kings River and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (NOAA Fisheries, 2009b).

Naturally spawning stocks of steelhead are known to occur in the Sacramento River and tributaries, Mill, Deer, Antelope, and Butte creeks, and the Feather, Yuba, American, Mokelumne, Calaveras, and Stanislaus rivers. Steelhead smolts have been found in Auburn Ravine, Dry Creek,

[9] Descriptions of salmon run timing vary among published sources and are known to vary among years depending on environmental conditions.

and have been monitored in the Stanislaus River since 2003 (Figure 4-7) (McEwan, 2001; FISHBIO Environmental, 2011; NOAA Fisheries, 2009a). Steelhead are also present in the Tuolumne River, Merced River, and Cow, Battle, Cottonwood, Clear, and Big Chico creeks (DWR, 2005; NOAA Fisheries, 2009a).

Naturally spawning populations may exist in many other streams but are undetected due to lack of monitoring programs (NOAA Fisheries, 2009b). According to Lindley et al. (2006), historically there were approximately 81 independent populations of steelhead in the Central Valley.

Four hatcheries raise steelhead in the Central Valley, producing an average of 1.5 million yearlings per year: Feather River Hatchery, Mokelumne River Hatchery, Coleman National Fish Hatchery on Battle Creek, and Nimbus Hatchery on the American River (Moyle et al., 2008).

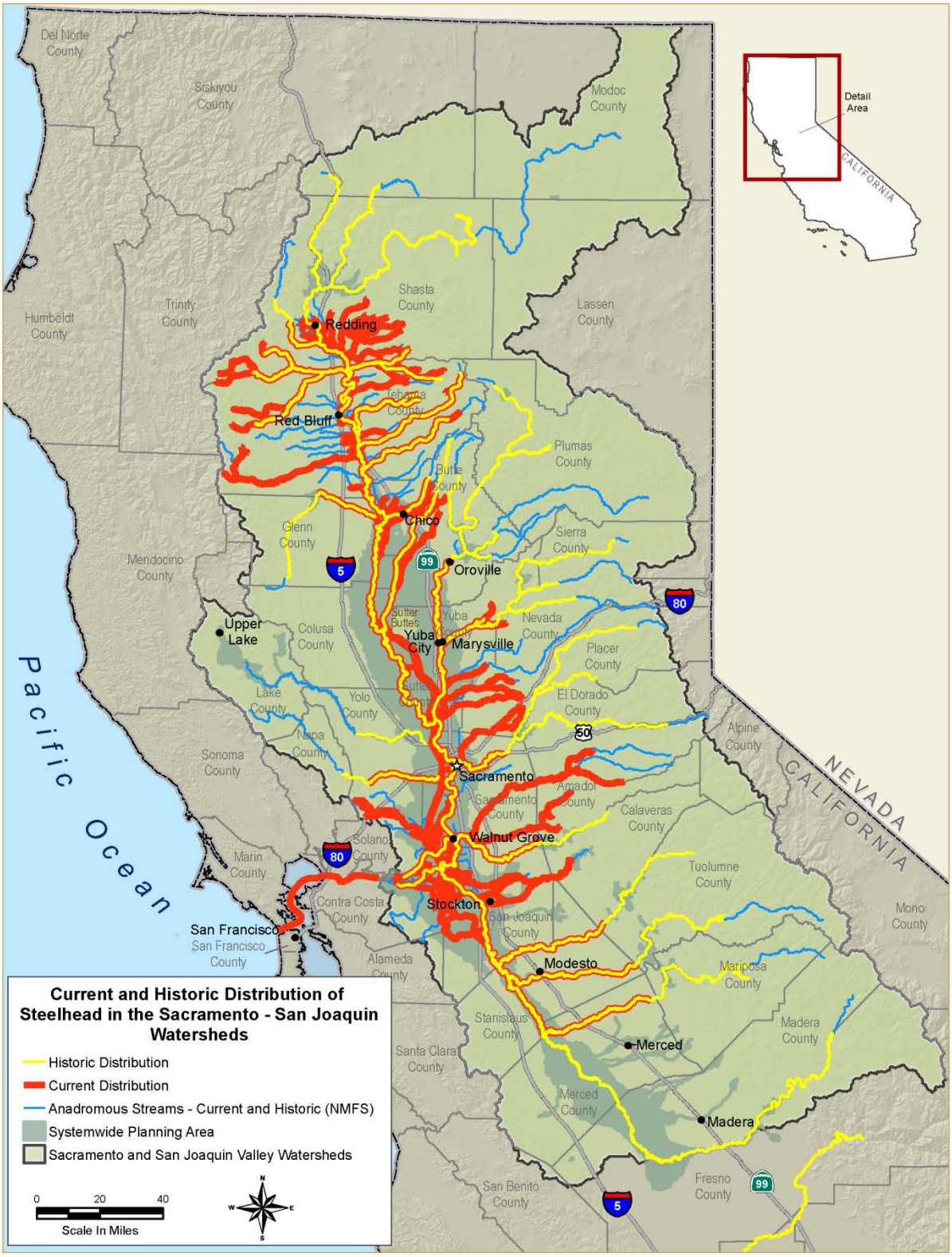


Figure 4-7. Current and Historic Central Valley Steelhead Distribution

From 1967 to 1993, steelhead counts at the RBDD on the Sacramento River provided an indicator of the magnitude of the decline of Central Valley hatchery and wild steelhead stocks. Steelhead counts declined from an average annual count of 11,187 adults for the 10-year period beginning in 1967, to 2,202 adults annually in the 1990s (McEwan, 2001). After 1993, the RBDD gates were raised during the winter to minimize adverse impacts on winter-run Chinook salmon. Because of this change in gate operations, adult steelhead could no longer be counted at RBDD during winter. Recnet trends in estimated natural steelhead spawning upstream from RBDD to 2005 are shown in Figure 4-8.

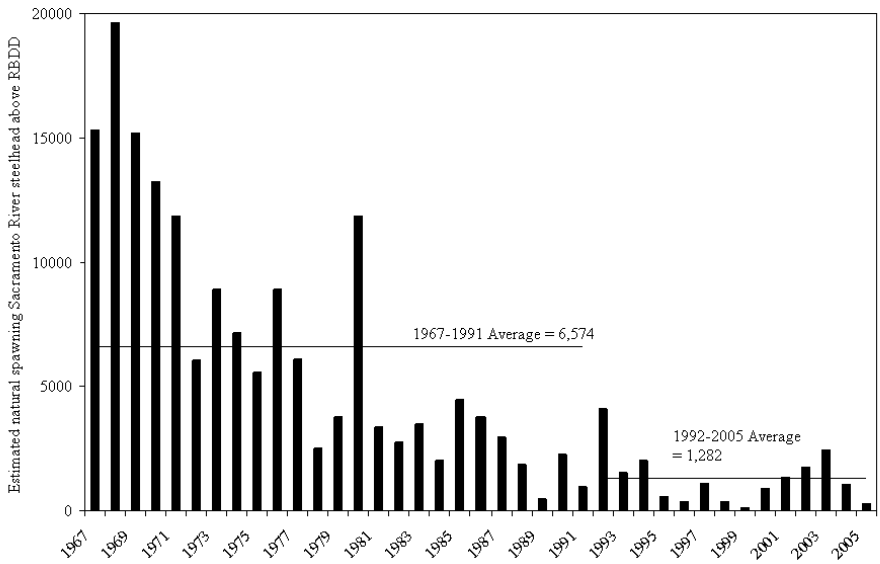


Figure 4-8. Steelhead Population Trends in the Sacramento River, Upstream from Red Bluff Diversion Dam from 1967 to 2005

4.3 Green Sturgeon

Little is known about the timing or location of spawning for green sturgeon, although recent studies have provided additional information (Poytress et al., 2010; Poytress et al. 2011). Heublein et al. (2009) describes the timing and movement patterns of migrating green sturgeon and identifies likely spawning reaches. Upstream migration of adult green sturgeon appears to begin in February and lasts until late July (Stillwater Sciences, 2007). Green sturgeon spawn between March and July in the mainstem Sacramento River as far upstream as Keswick Dam. Adult sturgeon are found in the Delta and the San Francisco Bay Estuary, including northern San Francisco, San Pablo, and Suisun bays, from

March, or earlier, through October (Kelly et al., 2007), with some individuals outmigrating from the Sacramento River in December and February (NOAA Fisheries, 2010a).

Green sturgeon larvae begin to emerge and move downstream in May, with peak passage occurring at RBDD in June and July (Stillwater Sciences, 2007). Green sturgeon juveniles rear in the Sacramento River and the Delta and bays for 1 year to 4 years before migrating out to sea as subadults (NOAA Fisheries, 2010a) (Table 3-1).

Spawning, rearing, feeding, and migratory habitat for all life stages of green sturgeon found within the Systemwide Planning Area include the following estuaries, bays, and freshwater rivers and streams within the Central Valley: the Delta; the San Francisco, San Pablo, and Suisun bays; the Sacramento River upstream to Keswick Dam; the lower Feather River upstream to Oroville Dam; and the lower Yuba River upstream to the Daguerre Point Dam (NOAA Fisheries 2010a). Designated Critical Habitat of green sturgeon is shown on Figure 4-9.

Population abundance information for green sturgeon is limited (Beamesderfer, 2002; Adams et al., 2002; NOAA Fisheries, 2005; Beamesderfer, 2007). In terms of overall annual relative abundance, it appears that green sturgeon populations declined from 1995 to 1999 and then remained relatively stable from 2002 to 2006 (Stillwater Sciences, 2007).

Above RBDD, Israel (2006) estimated a maximum spawning population of 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 (with an average of 71) (NOAA Fisheries, 2009b). Below RBDD, green sturgeon larvae were captured in rotary screw traps: 517 individuals in 1994 and 291 individuals were captured between 1996 and 2000 (Heublein et al., 2009).

Abundance information has also been collected at two DWR facilities, the John E. Skinner Fish Facility and the Harvey O. Banks Pumping Plant. Abundance data for green sturgeon were recorded at the John E. Skinner Fish Facility in Tracy between 1968 and 2001. The average number of green sturgeon entrained per year at the facility before 1986 was 732; from 1986 on, the average entrained per year was 47. At the Harvey O. Banks Pumping Plant, the average number of green sturgeon entrained per year before 1986 was 889; from 1986 to 2001, the average entrained per year was 32 (NOAA Fisheries, 2009b).

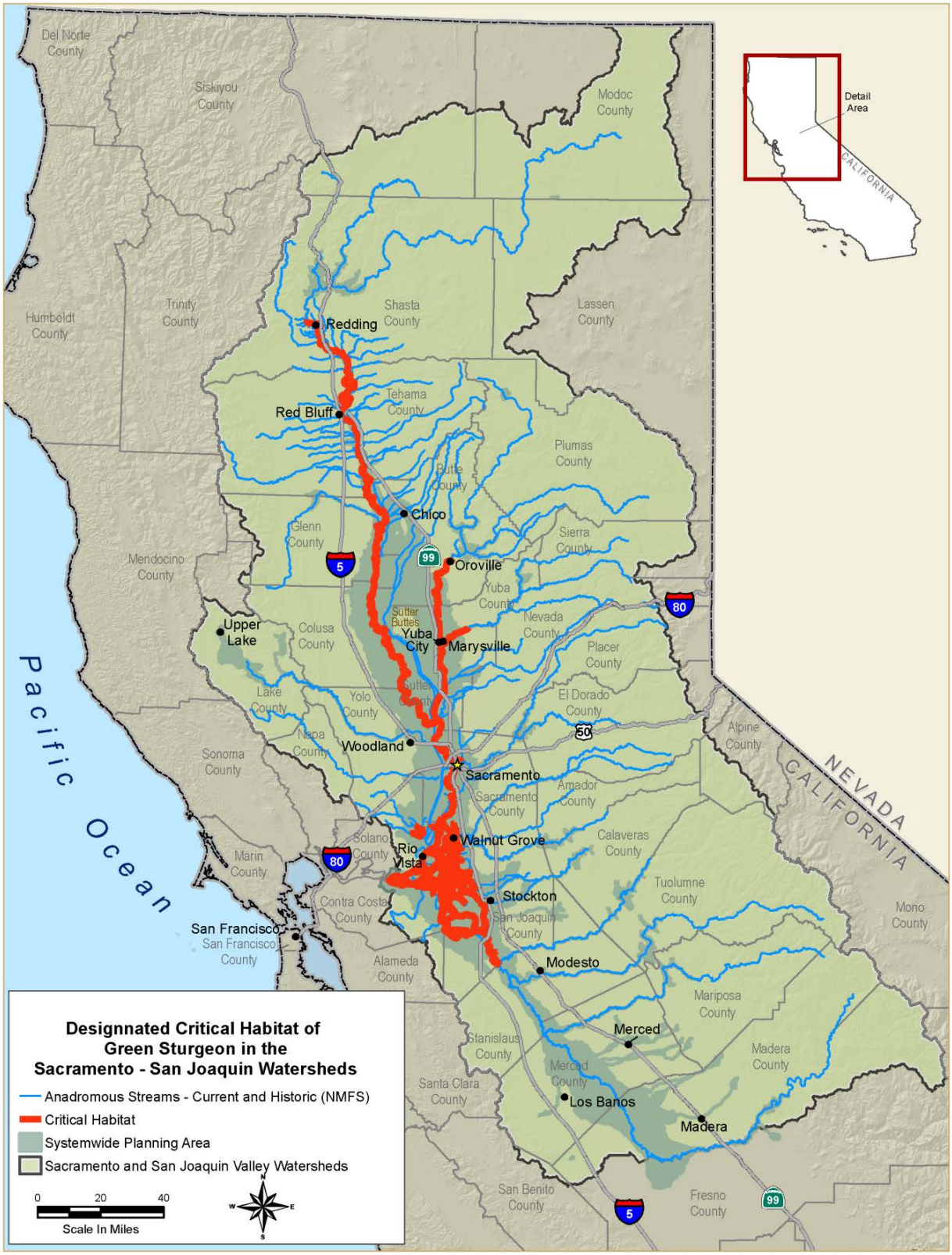


Figure 4-9. Critical Habitat for Green Sturgeon in the Central Valley

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5.0 Reasons for the Decline in Anadromous Fish Populations

Several factors have contributed to the decline of Chinook salmon, steelhead, and green sturgeon populations in the Central Valley. However, the single biggest cause has been the construction of massive dams and diversions on all major rivers (Moyle, 2002; NOAA Fisheries, 2005).

Other structures besides dams that block or delay migrating fish from accessing habitat include: road crossings, bridges, culverts, flood control channels, erosion control structures, canal and pipeline crossings, flow measurement weirs, pumping plants, borrow pits, and gravel mining pits (DWR, 2005; PSMFC, 2011).

In the Sacramento-San Joaquin system, dams have denied Chinook salmon access to more than half the stream reaches they once used and to more than 80 percent of their historical holding and spawning habitat (Moyle, 2002). Shasta and Keswick dams block winter-run Chinook salmon access to more than approximately 100 miles of historical habitat in the Little Sacramento River, Pit River-Fall River-Hat Creek, and McCloud River (Lindley et al., 2004).

Approximately 80 percent to 90 percent of spring-run Chinook spawning and rearing habitat has been lost due to water system developments in the Central Valley watersheds, and large rim dams (e.g., Shasta and Oroville dams) and hydropower development projects have prevented spring-run Chinook salmon from accessing significant areas of upstream summer holding and spawning habitat (DWR, 2005). Within the Systemwide Planning Area, NOAA Fisheries has identified several major dams that affect spring-run Chinook salmon migration, including: Englebright Dam, Oroville Dam, Keswick Dam, Shasta Dam, RBDD, and the Anderson Cottonwood Irrigation District diversion dam[10] (NOAA Fisheries, 2009a).

Barriers to spawning habitat are a major anthropogenic threat to fall-run Chinook salmon (Stillwater, 2007). Lindley et al. (2009) attributed the collapse of the fall-run population in 2007 and 2008 to a combination of unfavorable ocean conditions and anthropogenic effects such as the

[10] The Anderson Cottonwood Irrigation District diversion dam was improved in 2001 with the installation of new fish ladders and fish screens around the diversion. However, NOAA Fisheries indicates that diversion dam operations could still impact Chinook salmon (NOAA Fisheries 2009b).

presence of large dams and levees, which block access to spawning and rearing habitat.

Lindley et al. (2006) estimated that approximately 80 percent of stream habitat that was historically available to anadromous Central Valley steelhead is now behind impassable dams, and that 38 percent of the populations identified have lost their entire habitat. In addition, NOAA Fisheries (2009a) highlighted steelhead passage issues at the following structures within the Systemwide Planning Area: Friant Dam, La Grange Dam, Don Pedro Dam, Goodwin Dam, New Melones Dam, McSwain Dam, Crocker Huffman Dam, Camanche Dam, Pardee Dam, and Bellota Weir.

The principal threat to green sturgeon has been the loss of access to habitat for spawning and rearing, now upstream from impassable dams (NOAA Fisheries, 2005). The presence of Keswick Dam currently blocks sturgeon passage to upstream sites (Adams et al., 2002; NOAA Fisheries, 2010b). The RBDD gates have been known to delay migration, block the migratory corridor, and block access to 53 miles of the Sacramento River with suitable water quality conditions for green sturgeon spawning and rearing from May 15 through September 15 of each year (NOAA Fisheries, 2009b). Early gate closures before May 15 resulted in mortality of green sturgeon (NOAA Fisheries, 2009b). However, this should be eliminated with the implementation of the Red Bluff Fish Passage Improvement Project, which is expected to be completed in 2012. As part of the project, a screened pumping plant will be constructed that will allow the RBDD gates to be permanently placed in the open position for free migration of salmon and sturgeon (Reclamation 2011b). Passage to 5 miles of spawning habitat downstream from Keswick Dam is blocked by the Anderson Cottonwood Irrigation District Diversion Dam (installed April to November) (NOAA Fisheries 2009b). The continued presence of green sturgeon adults below Oroville Dam suggests that sturgeon are trying to migrate to upstream spawning areas now blocked by the dam.

In addition to fish passage barriers, sturgeon are susceptible to stranding within floodplains and bypasses (NOAA Fisheries, 2009b). Most channels and floodplains have irregular surfaces, and as flows recede, fish can become trapped in isolated pools, old channels, and in depressions formed as water flows around vegetation, large woody debris, or other features. The pools and depressions create areas in which the fish can become stranded. Unless water levels increase or the depressions are fed by subsurface flow, fish will desiccate or become easy prey for a variety of predators (Sullivan, and Chinnici, 2009).

In this report DWR defines stranding as occurrences when fish are trapped in areas that are inundated when flood flows move outside the active channel into bypasses, side channels, backwaters, floodplains, and then the flows recede. In particular, stranded fish are those trapped in scour holes that occur within bypasses, in abandoned gravel or mining pits that are adjacent to the active channel, or in side channels that become isolated from the main river channel.

NOAA Fisheries (2009b) identified stranding that occurs under two types of flow releases: releases made for flood control and those made to meet Delta water quality objectives and demands. Both types of releases can result in rapid flow increases for a period of time followed by rapid flow decreases. The abrupt decrease in flows can result in redd[11] dewatering and isolation, isolation of side channels and backwaters, and draining of floodplains. DWR did not include stranding that occurs within the active channel because of flow decreases in response to Delta water quality objectives or export demands in this analysis. In addition, people sometimes refer to situations where a fish cannot pass a manmade structure, like a weir, as stranding, but DWR defines that as a fish passage barrier, and addresses those situations in the barrier section of this report.

In addition to fish passage barriers blocking habitat and stranding identify other factors contribute to the decline of Chinook salmon, steelhead, and green sturgeon populations (Moyle 2002, Moyle et. al, 2008, NOAA Fisheries 2005, 2009b, and DFG 2011):

- Lack of in-stream flow (i.e., San Joaquin River restoration, Section 2.2.1)
- Altered flow regimes
- Fishing, both in the ocean and in streams
- Entrainment of juveniles in diversions
- Loss of floodplain and estuarine rearing habitat by diking and draining
- Predation
- Competition from hatchery reared juveniles
- Diseases, native and introduced
- Pollution and pesticides

[11] A redd is a nest dug by a female salmon in gravel in a creek, stream or river.

- Unsuitable water temperatures
- Loss of riparian forests
- Siltation of spawning areas
- Effects of introduced fish, invertebrates, and plants
- Periods of drought
- Extreme flooding events
- Unusual ocean conditions
- Climate change effects (see Section 6.0)

Although there are many factors that have contributed to the decline of salmonid and sturgeon populations in the Central Valley, this report focuses on fish passage barriers and stranding that occur within the Systemwide Planning Area.

6.0 Climate Change

Fish passage barriers and other impediments to migration (e.g., stranding) have contributed to the decline of anadromous fish in the Central Valley. Climate change will bring an additional level of variability to our water system and will compound the negative effect barriers have on anadromous fish populations. Successful long-term efforts to provide self-sustaining populations of anadromous fish need to plan for the potential impacts of climate change and to develop ways to accommodate those changes for anadromous fish. Current climate change models predict a range of impacts that should be considered in water supply and flood management systems.

Impacts that are likely to be particularly detrimental for salmonid species include:

- Sea-level rise, which leads to increased salinities in the Delta. Anadromous fish using Central Valley streams and rivers need to pass through the Delta on their way to and from the Pacific Ocean
- More frequent intense winter storms, high stream flow events, and floods
- Less snowpack and 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

Decreases in Sierra Nevada snowpack will have negative implications for anadromous fish. The Central Valley's largest source of fresh water is the Sierra Nevada snowpack. The snowpack melts slowly in the spring and in some years, even into the summer. There are 395 reservoirs with a capacity of at least 50 acre-feet that are fed by the Sierra Nevada snowpack. Their combined storage capacity is approximately 14 million acre-feet. The Sierra Nevada snowmelt provides an annual average 15 million acre-feet of water to those reservoirs. DWR (2008) projects a 25 percent to 40 percent reduction in the Sierra snowpack by 2050 because of warmer storms resulting in less snowfall.

As a result of a decrease in snow pack and earlier snowmelt, stream flows are expected to be lower during the summer months and extending into the fall. It is common for adult fish migrating to spawning grounds to

encounter obstacles that require high flow conditions in order to pass. If climate change results in reduced stream flows this could impede or halt their progress. A delay in the arrival to spawning grounds may decrease reproductive success and increase fish mortality (California Natural Resources Agency 2009). This decrease in summer flows will further limit access to available cold water habitat that salmonids require, particularly as temperatures in many stream and rivers increase (Moyle et al., 2008).For example, lower flows in the summer will affect spring-run Chinook salmon by reducing the size and frequency of deep pools used for holding, leading to crowding and increased mortality.

Reduced stream water depth and higher air temperatures will increase stream water temperatures to levels that are potentially unhealthy for coldwater fish. Salmonids are temperature-sensitive and rely on precipitation and snow melt. The projected changes in inland water temperatures with changing seasonal flows is projected to place additional stress on these species, contributing to the need for increased resources for monitoring and restoration efforts.

Lindley et al. (2007) examined the effects of climate warming on the availability of spring-run Chinook salmon over-summer habitat. Their analysis suggests that a 2-degree-Celsius increase in water temperatures might eliminate summer holding habitat for Butte Creek, where one of three viable populations of spring-run Chinook salmon in the Central Valley remain.Given the possible conditions that may exist in Central Valley streams as the climate warms, many researchers and agencies have recognized the need to evaluate opportunities to provide Central Valley salmonid species access to currently inaccessible habitat (DWR, 2007, 2008; NMFS, 2009b; and California Natural Resources Agency, 2009). In addition, to recover Central Valley salmonids, some populations will need to be established in areas now blocked by dams (Lindley et al. 2007). As temperatures increase, providing fish passage to areas upstream from reservoirs could eliminate or reduce the need for cold water releases and give water managers additional flexibility in meeting downstream water supply and flood protection needs.

7.0 Identification and Prioritization of Passage Barriers in the Systemwide Planning Area

Dams and other barriers have played an important role in the decline of salmon, steelhead, and green sturgeon in the Central Valley. The effects of climate change will compound the decline. Flood management structures, such as weirs, and flood operations have resulted in passage barriers, reductions in flows, and risk of mortality due to stranding. To achieve the environmental objectives of the Central Valley Flood Protection Act, DWR will need to work collaboratively with others to remove fish passage barriers and reduce stranding within the Systemwide Planning Area will be crucial.

To help inform such a collaborative effort, this section provides an assessment of existing barriers and stranding. It also shows the results of an interim process for identifying priority barriers. This process will be furthered refined by the interagency Fish Passage Forum (see Section 7.3)

7.1 Identification of Barriers

7.1.1 Methods

A Geographic Information System (GIS) analysis of existing spatial data sets was undertaken to determine the known and potential fish passage barriers and stranding areas in the Systemwide Planning Area. Geospatial data that describe anadromous fish passage barriers and anadromous fish distributions were obtained from official sources (e.g., CalFish Passage Assessment Database, NOAA Fisheries, California Department of Fish and Game (DFG)). These data sets and expert knowledge were used to identify stranding areas and to determine the number and distribution of known and potential barriers to anadromous fish passage within the Systemwide Planning Area on the basis of barrier location, barrier status, and barrier type. See Appendix A for a detailed description of methods.

Fish passage barriers can be total, temporal, or partial barriers for anadromous fish during migration (Table 7-1). Total barriers block all fish migration. Temporal and partial barriers may block fish passage for a certain life stage and/or only under certain flow conditions. For example, a

partial barrier may block juvenile spring-run and steelhead from migrating downstream.

Table 7-1. Definitions of Barrier Status

Barrier Status	Definition
Temporal	Impassable to all fish at certain flow conditions
Partial	Impassable to some fish during part or all life stages at all flows
Total	Impassable to all fish at all flows
Potential	The structure needs to be assessed or evaluated to determine if it is a temporal, partial or total barrier

Source: Adapted from Taylor and Love, 2003
Barriers can also be temporal and partial but for purposes of this report the barrier status categories are simplified.

7.1.2 Barrier Results

The GIS analysis, expert knowledge, and available written information identified 189 barriers in the Systemwide Planning Area (Figure 7-1 and Table 7-2). In addition, 45 DWR diversions were identified because of their impacts on fish entrainment.[12] Of the 189 barriers identified, 14 are components of the SPFC. Appendix B lists all 234 barriers and diversions.

Twenty-five total barriers were identified within the Systemwide Planning Area. These barriers block approximately 900 miles of salmonid habitat (Figure 7-2). The remaining partial, temporal, and potential barriers impair anadromous fish migration through approximately 3,000 miles of habitat.

Table 7-2. Number of Barriers and Diversions in the Systemwide Planning Area

Status	Number in the Systemwide Planning Area
Total	25
Partial[1]	23
Temporal[1]	46
Potential (needs assessment)	95
Screened and Unscreened Diversions	45
All Barriers and Diversions	234

[1] Barriers can also be temporal and partial but for purposes of this report the barrier status categories are simplified so that the numbers in Table 7-2 add up.

[12] The 44 DWR-owned diversions occur in the Delta and 1 outfall gate at Knights Landing Ridge Cut. NOAA (2009a) recommends any unscreened diversions in the Delta be evaluated for population level effects, and those diversions with substantial impacts be screened. DWR should implement that recommendation. Adult attraction and/or delay issues should be assessed and addressed as needed at the Knights Landing Ridge Cut Outfall Gates.

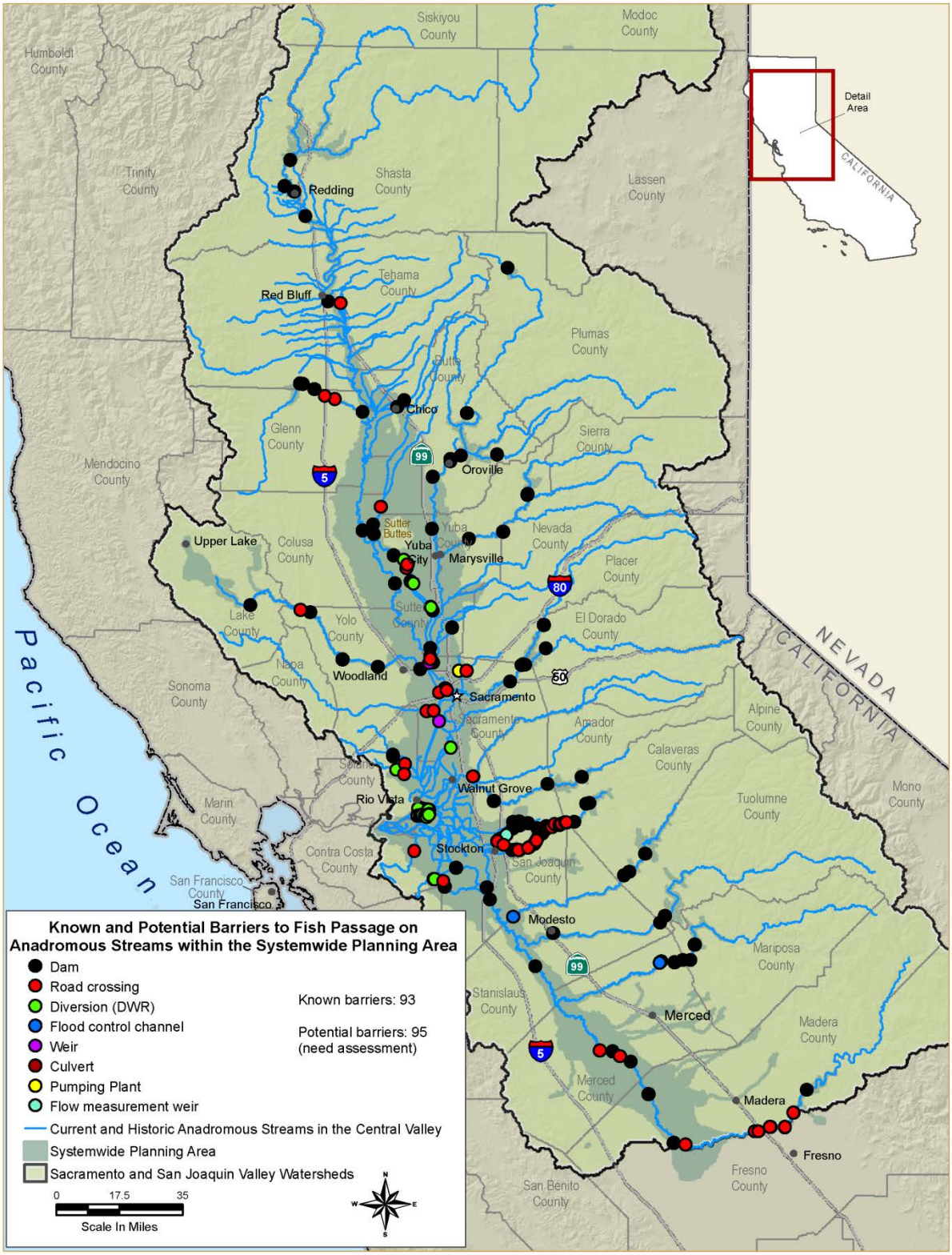
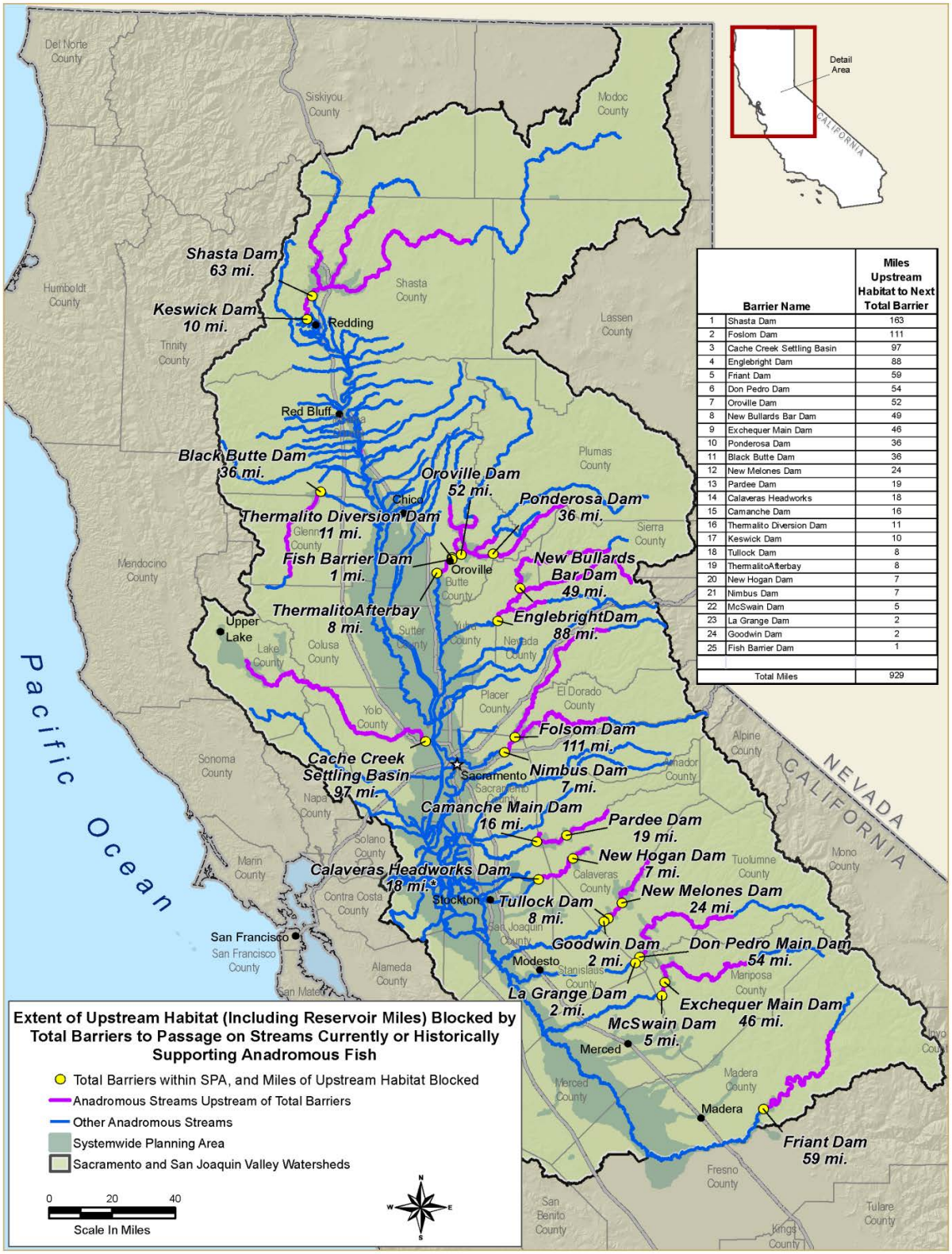


Figure 7-1. Known and Potential Barriers, Including DWR-Owned Diversions, in the Systemwide Planning Area



	Barrier Name	Miles Upstream Habitat to Next Total Barrier
1	Shasta Dam	163
2	Foslom Dam	111
3	Cache Creek Settling Basin	97
4	Englebright Dam	88
5	Friant Dam	59
6	Don Pedro Dam	54
7	Oroville Dam	52
8	New Bullards Bar Dam	49
9	Exchequer Main Dam	46
10	Ponderosa Dam	36
11	Black Butte Dam	36
12	New Melones Dam	24
13	Pardee Dam	19
14	Calaveras Headworks	18
15	Camanche Dam	16
16	Thermalito Diversion Dam	11
17	Keswick Dam	10
18	Tullock Dam	8
19	ThermalitoAfterbay	8
20	New Hogan Dam	7
21	Nimbus Dam	7
22	McSwain Dam	5
23	La Grange Dam	2
24	Goodwin Dam	2
25	Fish Barrier Dam	1
	Total Miles	929

Figure 7-2. Miles of Habitat Upstream from Total Barriers in the Systemwide Planning Area

About half of the 189 barriers in the Systemwide Planning Area have not been assessed to determine if they either block or impair fish migration. CVFPP fish passage surveys, following DFG (2003) protocols, should be done at all potential barriers within the Systemwide Planning Area to determine the passage status of the barriers. If barriers need remediation, fish passage solutions (repairs or new construction) that meet NOAA Fisheries and DFG standards should be implemented.

Many of the barriers within the Systemwide Planning Area are small dams, road culverts, or low-water road crossings. Most of these are temporal or partial barriers, but this does not minimize their impact. A temporal and partial barrier can delay or block listed species, resulting in take[13]. When population levels are low, such as with spring-run or winter-run Chinook salmon, saving an individual fish is important. The methods used to provide fish passage at small dams, road culverts, or low-water road crossings are well documented, and solutions can be implemented quickly at low cost to provide immediate benefit to anadromous fish populations. Since these projects can be implemented quickly, remediation of these structures can occur during the planning stages for fish passage at larger structures. Information on fish passage at large dams is provided in a subsequent section.

7.2 Stranding Risks

Stranding may be a problem associated with flood bypasses, in-stream gravel extraction, and rapid changes in flows.

7.2.1 Flood Bypasses

Conflicting information is available on whether stranding is a significant problem within the Central Valley flood bypasses. It may be a potential problem within the following flood bypasses (Figure 7-3):

- Yolo Bypass/Sacramento Bypass
- Colusa Bypass
- Butte Sink
- Sutter Bypass/Tisdale Bypass
- Chowchilla Canal Bypass/ Eastside Bypass/Mariposa Bypass system

[13] The term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (Endangered Species Act, Section 3 (19)).

Figure 7-3. Locations of Known Stranding Sites[14] Within the Systemwide Planning Area

[14] It is known that the San Joaquin River contains in-channel and captured pits that have the potential to strand salmon (Mussetter Engineering, Inc., 2005). However, DWR did not have enough information to delineate specific pits on Figure 7-3. Therefore, the entire San Joaquin River is marked as a potential stranding site.

Floodplain habitat carries the risk of stranding when water levels drop. Flood flows from the Sacramento River spill into the Yolo and Sutter bypasses and the Butte Overflow Basin. Sommer et al. (2005) described stranding rates on the Yolo Bypass floodplain as being relatively low. This finding is consistent with other studies that report juvenile salmonids are relatively mobile and that most avoid being stranded during moderate rates of stage change. However, other researchers reported that stranding occurs in scour holes, borrow pits, depressions, ponds, and sumps when flows recede within the Yolo Bypass, Butte Overflow Basin, and Sutter Bypass (Pers. comm. T. Cannon, T. Schroyer, J. Navicky, 2011). For example, DFG rescued salmon, steelhead and green sturgeon trapped in scour holes when flood flows receded in the Yolo Bypass in 2011 (Weiser, 2011). While some studies indicate that the impact of floodplain stranding on juvenile salmon is low, other biologists indicate that stranding may have a more significant impact on fish than previously thought; the scale and level of impacts due to stranding are often undocumented and unknown.

Federal and State efforts are being made to address stranding issues within the Yolo Bypass. The NOAA Fisheries' Recovery Plan (2009a) and the Bay-Delta Conservation Plan Working Draft (BDCPSC, 2010) include recommendations to eliminate stranding in the Yolo Bypass, including: modification of the Fremont Weir, modification of the Yolo Bypass by grading, removal of existing berms and other earthwork, and improvement of the Sacramento Weir and Tule Canal/Toe Drain. These actions would reduce stranding of covered fish species in isolated ponds (BDCPSC, 2010).

The Chowchilla Canal Bypass/ Eastside Bypass/Mariposa Bypass system reduces the magnitude of flood flows into the main channel of the San Joaquin River. If high flows are sent into the bypass system, fish, including juvenile salmon, are likely to be carried in with the water, with potential for stranding if flows are suddenly reduced. As noted above, studies have shown that in the Yolo Bypass, native fishes including juvenile salmon are very good at leaving the bypass as flows drop. Solutions to the stranding problem at the Chowchilla Bypass system may involve operation of the Chowchilla Bifurcation gates and releases from the dam (avoiding water shutoff and using secondary pulse flows to push fish out of the bypasses) (Moyle, 2005).

7.2.2 In-stream Gravel Extraction

The presence of gravel pits, with the potential for stranding, has been identified in the following areas:

- Sacramento Valley: American River, Cottonwood Creek, Thomes Creek, Stony Creek, and Yuba River

- San Joaquin Valley: Merced River, Tuolumne River, San Joaquin River, and Stanislaus River

Gravel pits can adversely affect salmon, steelhead, and other fishes as they move up or downstream. Stranding primarily occurs after the river stage rises and allows fish to move into newly inundated areas along channel margins. The likelihood and extent of entrapment effects associated with floodplain mining are directly related to the pit's proximity to the active stream channel, pit size relative to the stream, and the frequency of flood inundation (Packer et al., 2005).

With floodplain pit mining, the risk of fish entrapment is due to two processes: (1) floods overtopping the pit perimeter, and (2) natural migration of the channel into the excavated area. Ponded water isolated from the main channel may strand or entrap fish carried there during high-water events. Fish in these ponded areas could experience higher temperatures, lower dissolved oxygen, increased predation compared to fish in the main channel, an altered food web, desiccation if the area dries out, and freezing (Packer et. al., 2005).

Bar scalping (or "skimming") is the extraction of gravel from the surface of gravel bars. To avoid stranding fish in shallow holes after high flows inundate the bar and then recede, fish and wildlife agencies in California and Washington typically require that the bar, which originally would typically have a steep margin and relatively flat top, be left after scalping with a smooth slope upwards from the edge of the low water channel at a 2 percent gradient (Kondolf et al., 2002).

NOAA Fisheries recommends that gravel extraction sites be situated outside the active floodplain and that the gravel not be excavated from below the water table. In other words, dry-pit mining on upland outcrops, terraces, or the floodplain is preferable to any of the in-stream alternatives. Bar skimming is generally preferable to wet-pit mining (deep water dredging) within the active channels if no upland or floodplain sources are reasonably available (Packer et. al., 2005).

Significant channel and pit remediation has been conducted to restore salmon in the Tuolumne and Merced rivers (Mussetter Engineering, Inc., 2005). According to Dr. Michael Harvey (Mussetter Engineering, Inc., 2005), the San Joaquin River has about 1,300 acres of in-channel and captured pits, the Merced River has about 290 acres of pits, and the Tuolumne River has about 170 acres of pits. DWR (2002) prepared conceptual designs to restore several isolated ponds and captured mining pits within the Oakdale Recreation Area, located in the lower portion of the Stanislaus River.

7.2.3 Rapid Changes in Flows

Rapid reductions in flows in rivers can potentially strand fish. Downstream from Englebright Dam on the Yuba River, when flood waters rose high and then dropped quickly, fish, including young-of-the-year salmon, were stranded in side channels and side ponds (Pers. Comm., J. Nelson, 2011). Studies of potential stranding within the Yuba River are ongoing (Pers. Comm., J. Nelson, 2011). The USFWS has conducted investigations on the effects of flow fluctuations on anadromous salmonid redd dewatering and juvenile stranding in the Yuba River between Englebright Dam and the Feather River as part of a six-year effort that began in 2001 (USFWS, 2010).

In the lower American River, flow fluctuations have been documented to result in steelhead redd dewatering and isolation, fry stranding, and fry and juvenile isolation (NOAA Fisheries, 2009b). Redd dewatering can affect salmonid embryos and alevins by impairing development and causing direct mortality due to desiccation, insufficient oxygen levels, waste metabolite toxicity, and thermal stress (NOAA Fisheries, 2009b). Isolation of redds in side channels can result in direct mortalities due to these factors, as well as starvation and predation of emergent fry. NOAA Fisheries (2009b) limits the rate of flow reductions in Nimbus Dam releases, thereby reducing the risk of stranding and isolating steelhead.

7.2.4 Research Needs

There is no consensus among researchers on the extent and impact of stranding within Central Valley floodplains. Sommer et al. (2005) indicated that the stranding rate of juvenile salmonids in the Yolo Bypass is low. This was consistent with juvenile salmonid findings from other areas. However, the impact to sturgeon was not discussed in these studies, and the perception continues that floodplain and gravel pit stranding has an impact on fish. Consequently, individual CVFPP restoration projects should include an evaluation of the extent and impact of stranding in gravel pits and in areas where floodplain inundation is considered. A brief literature review should be completed to determine if the impacts of stranding differ for adult versus juvenile salmonids, and to confirm the need for green sturgeon stranding studies. The literature review will indicate if more research is needed to understand the effects of stranding on the population dynamics of juvenile and adult salmon, steelhead, and sturgeon in the regions where stranding is known to occur. Finally, results from existing and future stranding research should be more broadly disseminated to minimize perceptions that are not supported by research.

7.3 Prioritization of Fish Passage Barriers and Stranding Areas

DWR identified 189 fish passage barriers within the Systemwide Planning Area. If all these structures are made passable, more than 4,000 miles[15] of anadromous fish habitat from the western edge of the legal Delta to the headwaters will become fully accessible. Because funding and staffing often limit progress that can be made on addressing barriers, it is common practice to prioritize barriers for fixing. The Fish Passage Forum (Forum) is developing a prioritized list of fish passage barriers in California. The Forum is an association of public, private, and governmental organizations that promote collaboration among private landowners, community groups, and public agencies on fish passage restoration programs and activities that contribute to the protection and recovery of listed anadromous salmonid species throughout California. The Forum was formalized with the creation of a Memorandum of Understanding, which DWR signed in 2006. Other members of the Forum include California Resources Agency, DFG, California Department of Transportation, Coastal Conservancy, NOAA Fisheries, U.S. Forest Service, U.S. Fish and Wildlife Service, CalTrout, Southern California Steelhead Coalition, Five County Salmon Conservation Group, FishNet 4C, Friends of the River, Pacific States Marine Fisheries Commission, and U.S. Army Corps of Engineers (USACE).

The Forum began developing a method to rank fish passage barriers using biologically based criteria in 2010. The method will be a statewide first-cut ranking process that filters identified barriers based on objective and measurable attributes. The process includes an assumption that individual agencies, funding entities, and local groups will apply second-cut ranking criteria that are specific to their goals and allow them to further narrow down potential barrier treatment priorities. Once the Forum's prioritization method is developed it will have the support of 14 State, federal, and local agencies throughout California, providing a powerful tool in justifying funding, in strategic planning and design efforts, and gaining consensus for restoration efforts implemented through the CVFPP.

7.3.1 Interim Prioritization Process

Because the Forum's criteria and methodology are still in development and have not been adopted by the Forum, DWR developed an interim prioritization process to rank the 189 barriers within the Systemwide Planning Area. Once the Forum's ranking methodology is finalized, the ranking of barriers identified in this report should be revised using the

[15] See Attachment 9C.1 for a description of the methods used to calculate the total miles that would be fully accessible.

Forum's final ranking method and CVFPP second-cut criteria. These revised rankings can be valuable for informing the development of the Conservation Strategy and for updating the 2017 CVFPP.

For the purposes of this report, DWR's interim prioritization process uses the criteria of biological importance, linkage to SPFC facilities, geographical location, and urgency:

- **Biological importance** – this criterion is based on the NOAA Fisheries (2009a) ranking of recovery actions. NOAA's highest priority actions (Priority 1) are "those critical actions that must be taken to prevent extinction or to prevent the species from declining irreversibly." Priority 2 actions as those that "must be taken to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction."

- **Linkage to SPFC facilities** – Current funding from Proposition 1E for improving flood management requires that the funding be spent on improving SPFC facilities. Thus, those barriers that are SPFC facilities are considered higher priority than others that are not.

- **Geographical location** – Priority order is based on the NOAA

  Fisheries (2009a) order shown in Table 7-3.

Table 7-3. Geographic Priorities Identified by NOAA Fisheries

Priority	NOAA Fisheries Geographic Regions (NOAA Fisheries, 2009a)
1	Delta
2	Lower Sacramento River
3	Middle Sacramento River
4	Upper Sacramento River
5	Northern Sierra Nevada Diversity Group
6	Basalt and Porous Lava Diversity Group
7	Northwestern California Diversity Group
8	Southern Sierra Diversity Group

Source: NOAA Fisheries, 2009a
Key:
NOAA = National Oceanic and Atmospheric Administration

- **Urgency** is based on NOAA fisheries (2009a) regulatory guidelines. This interim process identifies the following three timeframes for urgency:

  - **Short term** – actions likely to be completed within five years, or required to be completed within five years by regulatory deadlines (NOAA Fisheries, 2009b).

  - **Moderate term** – actions that can be potentially accomplished by 2025, given additional funding from federal, State, and other sources, or required to completed by or before 2025 by regulatory deadlines (NOAA Fisheries, 2009b).

  - **Long term** – actions that are unlikely to be completed by 2025 due to their complexity, need for substantial funding, or lack of regulatory deadlines.

In summary, the highest priority actions recommended for the 2012 CVFPP planning process are those actions that are most biologically important (NOAA Priority 1), linked to SPFC facilities, and most urgent (NOAA short term followed by moderate term).

Assuming that Proposition 1E funding, with its SPFC constraints, suffices to fund additional fish passage improvements beyond Priority 1 actions, the next set of recommended priority actions would be NOAA Priority 2 actions, linked to SPFC facilities, and most urgent (NOAA moderate term followed by long term).

As for non-SPFC fish passage barriers, DWR has several programs (other than flood management) that are involve working with other agencies to address fish passage issues at major dams and other facilities. DWR flood managers need to be aware of these other priority actions to ensure good coordination and reduce potential conflicts. Efforts to improve passage at non-SPFC facilities may have the potential to benefit downstream flood management, providing opportunities to achieve SPFC flood management goals. Future flood management funding could be developed to direct some funding toward implementing non-SPFC projects that support flood management goals.

Attachment 9C.1 provides additional details on the GIS methods used in the *Interim Prioritization Process*.

7.3.2 Interim Prioritization Results – Short Term

Based on the interim process described above, short term priority fish passage actions include actions at two SPFC facilities and actions at several other non-SPFC facilities (Attachment 9C.2, Table 9C.2-2). These are actions of high biological importance (NOAA Priority 1) and of an urgent nature (within the next 5 years). As described above, current funding from Proposition 1E for improving flood management requires that this funding be spent on improving SPFC facilities, so flood managers will need to seek other funding sources to assist at non-SPFC facilities.

The two SPFC facilities are Sutter Bypass and Yolo Bypass. At the Sutter Bypass, actions include conducting assessments and making improvements at Willow Slough Weir and Weir No. 2 in the East Barrow Canal. Although not identified as specific SPFC facilities, the two facilities are contained within the Sutter Bypass. Construction of a new fish ladder at Willow Slough Weir was completed in 2010 but testing still needs to be done to confirm that the ladder is functioning to NOAA Fisheries and DFG standards. Construction of a new fish ladder at Weir No. 2 began in 2011 and should be completed in 2012.

In the Yolo Bypass, short term priority actions are at Fremont Weir, Lisbon Weir, Toe Drain and Tule Canal, and structures in the South Fork of Putah Creek. DWR will need to coordinate several funding sources to assist DFG in providing an interim solution for fish passage at the existing Fremont Weir fish ladder by 2012. The interim measure would provide passage through Fremont Weir (a SPFC facility) until a permanent solution is developed (see moderate-term actions below), as required by the SWP and CVP biological opinion. Priority short term fish passage actions at non-SPFC facilities are in the Stockton area and at Red Bluff Diversion Dam. In the Stockton area, DWR's Fish Passage Improvement Program has been working with Stockton East Water District, DFG, USFWS, and other stakeholders to implement fish passage improvements in the Calaveras River, Mormon Slough, and Stockton Diverting Canal. DWR's design of a rock ramp roughened channel for fish passage improvement at Budiselich Dam was constructed in September of 2011. DWR, in cooperation with Stockton East Water District, should complete fish passage designs at the Caprini low-flow road crossing and assist Stockton East Water District in implementing the improvements by December 2013.

At the Red Bluff Diversion Dam, Reclamation is implementing the Red Bluff Fish Passage Improvement Project, which is expected to be completed in 2012. This is in response to the biological opinion for the long-term operations of the CVP and SWP (NOAA Fisheries, 2009b) As part of the project, a screened pumping plant will be constructed that will

allow the RBDD gates to be permanently placed in the open position for free migration of salmon and sturgeon (Reclamation 2011b).

In addition to improving fish passage, the top five areas for evaluating and reducing fish stranding are the Yolo and Sacramento bypasses, American and Yuba river side channels, and the Stanislaus River gravel pits. A complete list of prioritized areas where stranding should be evaluated is in Attachment 9C.3, Table 9C.3-1.

7.3.3 Interim Prioritization Results – Moderate Term

Based on the interim process described above, moderate term priority fish passage actions include actions at two SPFC facilities (Yolo Bypass and Sacramento Weir) and actions at several other non-SPFC facilities (Attachment 9C.2, Table 9C.2-3). These include actions that are of a less urgent nature (within the next 10 years) than short term actions. As described above, current funding from Proposition 1E for improving flood management requires that the funding be spent on improving SPFC facilities, so flood managers will need to seek other funding sources to assist at non-SPFC facilities.

The only action at a SPFC facility of high biological importance (NOAA Priority 1) for this time frame is at the Yolo Bypass. Additional work is needed to build on the interim passage solution described above (under short-term priorities).

DWR and Reclamation are required by the SWP and CVP biological opinion (NOAA Fisheries, 2009b) to submit a plan by December 2011 for high-quality, reliable anadromous fish passage through the Yolo Bypass, (the permanent solution). The permanent solution should be a comprehensive fish passage plan that provides for fish passage at Fremont Weir, Lisbon Weir, other structures in the South Fork of Putah Creek, and within the Yolo Bypass (Toe Drain and Tule Canal), and addresses straying of anadromous fish upstream through the Knights Landing Ridge Cut and the impacts of the Knights Landing Outfall Gates. NOAA Fisheries (2009b) requires DWR to implement fish passage solutions at many of the structures within the bypass by 2015 but recognizes that actions at some structures require participation by willing partners. DWR will need to complete fish passage assessments at structures where passage status is unknown. Implementing fish passage solutions at all of the important Yolo Bypass structures will require use of multiple funding sources and participation of willing partners and/or owners.

Moderate term fish passage actions at non-SPFC facilities (but still of high biological importance – NOAA Priority 1) include addressing several major dams and multiple smaller obstructions. DWR's State Water Project

and Reclamation's Central Valley Project are leading efforts to improve fish passage at Keswick, Shasta, Folsom, Nimbus, New Melones, Tulloch and Goodwin dams. These two programs are responding to the biological opinion and conference opinion for the long-term operations of the CVP and SWP (NOAA Fisheries, 2009b), which requires Reclamation, with DWR's assistance, to determine the feasibility of providing fish passage at these dams by 2018. If it is determined to be feasible, Reclamation, with DWR's assistance, will construct fish passage facilities at those sites by 2020.

Other non-SPFC projects in the moderate term, high biologic importance category include providing fish passage at Webster Dam, Sack Dam, Englebright Dam, New Bullards Bar Dam, and numerous smaller barriers in the Calaveras River system.

In addition to the actions of high biological importance (NOAA Priority 1) above, five other passage improvements of moderate importance (NOAA Priority 2) also need to be worked on in the next 10 years. These improvements are at Tisdale Weir (SPFC facility) and at the following non SPFC facilities: One Mile Dam (Big Chico Creek), Daguerre Point Dam (Yuba River), Crocker Diversion Dam (Merced River), and Mendota Pool Dam and Diversion.

NOAA also identifies other passage improvements of lower biological importance (Priority 3) that could be worked on in the next 10 years. The four SPFC facilities are Colusa Weir, Big Chico Flood Control, Sand Slough Control Structure, and Cache Creek Settling Basin. Non-SPFC facilities include New Hogan Dam and over 100 other barriers in the Statewide Planning Area.

The full list of known and potential barriers that should be fixed and/or assessed within the Systemwide Planning Area in the next 10 years is in Attachment 9C.2, Table 9C.2-3.

7.3.4 Interim Prioritization Results – Long Term

Long term (more than 10 years) actions are to improve fish passage at thirteen other major dams in the Statewide Planning Area (Attachment 9C.2, Table 9C.2-4). Although they are not SPFC facilities, the dams of highest biological importance (NOAA Priority 1) are Camanche Main, Pardee, Don Pedro Main, and La Grange dams. Dams of moderate biological importance (Priority 2) for this time frame include three SPFC dams (Oroville Dam and Thermalito Diversion and Afterbay) and four non-SPFC dams (Black Butte, Exchequer, Friant, and McSwain dams).

Improving fish passage at these sites is a long-term goal because there are no regulatory deadlines tied to the actions, additional funding will be required to complete the work, and substantial stakeholder involvement and cooperation is needed to make the effort a success. To initiate these actions, DWR can seek opportunities to:

- Incorporate fish passage evaluations at SPFC structures in water supply planning studies
- Participate in interagency/stakeholder forums evaluating fish passage at these sites or on these rivers (Yuba River Multi-Part Forum, Calaveras River, etc.)
- Identify funding to support DWR staff and/or contracts to coordinate and carry out the evaluations
- Develop and implement a plan, with assistance from State and federal agencies and other stakeholders, for addressing feasibility of fish passage at these structures in a comprehensive and strategic manner.

8.0 Possible Solutions for Fish Passage at Large Dams

Numerous known fish passage barriers have been identified within the Systemwide Planning Area. More than 150 of these barriers are small dams, road culverts, or low-water road crossings, and the technologies used to provide fish passage at these types of barriers are well known. Providing fish passage at the 25 large dams identified in this report is more of a challenge. The technologies used at smaller structures, such as fishways, have been tried, often with mixed success. In addition, other technologies have been developed to handle passage over high structures, such as locks and lifts, but these have had limited success.

In the northwest United States, many large dams have fish passage for upstream and downstream migrants, and more will follow through the Federal Energy Regulatory Commission (FERC) relicensing process and NOAA Fisheries biological opinions. In California, all of the large dams, such as Shasta or Oroville, were constructed without upstream or downstream fish passage. Instead, hatcheries were built to compensate for lost habitat for salmonid species. In addition, since the dams at major reservoirs that ring the Central Valley did not provide passage, many of the hydropower facilities located at higher elevations were not provided with fish passage either (CEC, 2005). Providing fish passage at large dams would be a new effort within California, and it is further complicated by the disagreement among State and federal agencies on whether it is prudent or even possible to do so.

As an initial step, DWR's Fish Passage Improvement Program has developed a report investigating fish passage at large dams. The report, *Technologies for Passing Fish at Large Dams*, is divided into three major sections. The first section, Problems with Dams, gives the reader a basic understanding of the problems that dams create for migratory fish, especially salmon and steelhead. The second section, Types of Fish Passage Technologies, provides a general overview of fish passage technologies. The third section, Fish Passage Case Studies, describes specific fish passage technologies being used at large dams around the world.

The case studies describe in detail the upstream and downstream technologies used at specific dam projects throughout the world. They provide a general overview of the project, the history of fish passage at the

project, and the current upstream and downstream technologies being used. The dams were generally chosen because of the height that the technology overcomes, the uniqueness of the technology, the possible relevance to projects in California, or because the passage facility was recently constructed. Dams with fish passage facilities to be constructed are also included. The aim was to include all the various methods used for fish passage at large dams. In addition, case studies of large dams that have been or soon will be removed were included. All dam heights listed refer to hydraulic height unless otherwise noted.

For this document, short summaries of the case studies are provided. The summaries are grouped by passage direction, upstream or downstream, and further into volitional and non-volitional passage. Volitional fish passage, such as fishways for upstream migrants and fish bypasses for downstream migrants, is fish passage made continuously without collection and transport (NMFS, 2008). Therefore, these types of passage facilities let the fish choose when to move past a dam, as they provide a constant hydraulic connection from the reservoir upstream from the dam to the river downstream from the dam. Other technologies rely on humans or machines to provide assistance in the passing of fish. Examples of these technologies are lifts, locks, and trap and transport. These technologies do not have a constant hydraulic connection, and may take hours for one “load” of fish to be moved.

In general, NOAA Fisheries prefers volitional passage, as opposed to collection and transport, for all salmonid passage facilities. This is mainly due to the risks associated with handling and transporting migrating salmonids, and the long-term uncertainty of funding, maintenance, and operation of these types of programs. Further, collection and transport programs may not operate at the start and end of migration periods because there are only a few individual fish present. This practice is likely to have an adverse effect on salmon population diversity. In contrast, volitional passage facilities operate every day, year round. However, there may be locations where collection and transport may be the best option for fish passage, due to height of the dam, possible temperature issues with a long fishway, or passage being needed past multiple dams (NMFS, 2008).

8.1 Large Dams with Volitional Upstream Passage

8.1.1 Fishways

Fishways are the only method to volitionally pass fish over a dam. Styles of fishways are nature-like (made with rock and other natural materials), and baffle- and pool-type (fish ladders). There are not many dams with hydraulic heads above 100 feet that have fishways. Two hydroelectric projects with fishways to circumvent higher heads are in Oregon, the Pelton Round Butte Project (230 feet) on the Deschutes River and the North Fork Project (200 feet) on the Clackamas River. The North Fork Project also has a new fishway at River Mill Dam. The nine most downstream dams on the Columbia River and the four dams on the lower Snake River all have fishways. Finally, a fishway will be constructed at the Carmen-Smith Project's Trailbridge Dam on the McKenzie River in Oregon. Examples of fishways at projects outside of the United States are the Itaipu Hydroelectric Project in South America and the Tongland Hydroelectric Project in Scotland, which are described later in this section.

Pelton Round Butte Hydroelectric Project – Deschutes River, Oregon

Portland General Electric's (PGE) Pelton Round Butte Project consists of three dams (listed from downstream to upstream), 25-foot-high Reregulating Dam, 204-foot-high Pelton Dam, and 425-foot-high Round Butte Dam, on the Deschutes River (PGE and CTWSRO, 2004). The project's 2.84-mile-long pool and weir fishway were built in 1957 and passed fish from below the Reregulating Dam to above Pelton Dam, a hydraulic vertical gain of approximately 230 feet (Ratliff et al., 1999). The fishway was only partially successful at passing adult salmonids during the initial years of the project and is not currently being used for passage. The exact cause of fishway rejection is unknown, but it is thought that vegetative growth in the fishway during the late spring and summer (including the 0.5-mile-long canal section that develops emergent vegetation), not only changed the water chemistry, but also changed the odor fish encountered when entering the fishway. To the adult migrants that wanted to pass, the fishway smelled like a tributary to which they were not cued (Don Ratliff, personal communication, October 7, 2010). The lower 600 feet of the fishway is currently used in the project's collection and transport operation, and upper portions of the fishway are used for the rearing of hatchery produced salmonid fry (Ratliff and Schulz, 1999).

North Fork Hydroelectric Project – Clackamas River, Oregon

The North Fork Project's 1.7-mile-long pool and weir fishway passes Chinook and Coho salmon, and steelhead up about 200 vertical feet from below Faraday Dam to above North Fork Dam (Taylor, 1999). It is the

longest operating fishway in the world (PGE, 2011). Until 1998, fish could travel unimpeded up the entire length of the fishway to exit above North Fork Dam (PGE, 1999). Currently, all fish are trapped approximately 600 feet up the fishway and all wild salmonids are either returned to the fishway to continue upstream or trucked above North Fork Dam. All hatchery returns are recycled downriver or used for fishing opportunities (Bartlett, 2006). From 1988 through 1998, 66 percent of Chinook salmon entering the fishway passed its entire length and 34 percent volitionally entered the fish trap (PGE, 1999). Flows in the upper portion of the fishway are maintained at about 43 cubic feet per second (cfs), with provisions at the fishway entrance to increase flows to about 140 cfs to attract fish (Gunsolus and Eicher, 1970 in PGE, 1999). The fishway exit structure into North Fork Reservoir was designed to accommodate 19 feet of variation in the forebay.

The North Fork Project also has a newly constructed fishway at River Mill Dam, just a couple of miles downstream from Faraday Dam. The River Mill Dam fishway was completed in 2006 and is a Half Ice Harbor pool-and-weir-type, which passes fish over the 70-foot-high dam. Typical pools in the fishway measure 6 feet wide by 10 feet long by 6.5 feet deep. The fishway has two entrances, a primary entrance next to the powerhouse discharge and a secondary one adjacent to the spillway. The fishway has many 180 degree bends as it snakes its way up the right bank of the river. Flow in the fishway ranges from about 20 cfs to 24 cfs. Early observations of the fishway showed no concentrations of fish or unusual behavior, and fish appeared to pass the fishway with little effort (Bartlett and Cramer, 2006).

Carmen-Smith Hydroelectric Project – McKenzie River, Oregon

Eugene Water and Electric Board is designing a fishway for the Carmen Smith Project's Trailbridge Dam on the McKenzie River. The fishway will be a Half Ice Harbor-type and will aid the passage of spring-run Chinook salmon, bull trout, coastal cutthroat trout, and Pacific lamprey. The fishway entrance will be on the right bank of the river just downstream from a new tailrace barrier. The fishway will consist of pools and transport channels, and is designed to overcome a maximum of 86 feet of water surface differential between the reservoir at full pool and the river downstream from the new tailrace barrier. It has 9-inch steps between each pool to accommodate non-anadromous (resident) fish. The number and configuration of the pools is still to be determined, but the types of pools that will be used have been determined. The majority of the pools (approximately 113) will be standard size (8 feet wide by 9 feet long), but some may be replaced by long pools (8 feet wide by 11 feet long) to reduce the total length of transport channel. In addition, there may be some resting pools (8 feet wide by 13.5 feet long) to break up long lengths of transport

channel. There will be 16 exit pools, to handle the 12 feet of reservoir fluctuation, which are designed with 45-degree beveled gates that exit into the reservoir. Within the fishway there will also be several hundred feet of transport channel, constructed of concrete in a rectangular cross section (3 feet wide by 4.33 feet deep). The velocity in the transport channels will be 2 feet per second and the design flow for the fishway is 26 cfs. (Andrew Talabere, Personal Communications, August 24, 2010, and October 20, 2010).

Columbia and Lower Snake Rivers – Washington/Oregon

All of the nine Columbia River dams downstream of the Chief Joseph Dam (River Mile 545) and the four lower Snake River dams have fishways. Hydraulic head at the dams ranges from 40 feet to 105 feet. All but Lower Granite Dam and Little Goose Dam, the uppermost dams on the lower Snake River, have multiple fishways, mainly of the pool-and-weir type with orifices. The fishways are generally arranged with one near each bank of the river. The fishway passage success rate for adult salmonids is generally about 95 percent (USACE, 1997).

Itaipu Hydroelectric Project – Parana River, Brazil/Paraguay

The approximately 6.2-mile-long fishway at Itaipu Dam is the longest of its kind in the world. The fishway is composed of multiple sections, including a nature-like fishway using an existing river channel, fish ladders, and artificial pools. The elevation gain from the bottom to the top of the fishway is 394 feet and the mean flow through the fishway is 424 cfs. There are 11 gates that are used to control water discharge through the fishway system. From the opening of the fishway in December 2002 to January 2010, there have been 135 species of fish found throughout the fishway; this includes about 40 species of long- and medium-migratory-distance fish (Fernandez, 2010). Studies have shown, however, that the number of species found in the uppermost reaches of the canal decreased significantly compared to the lowest reach, which suggests that many species are not able to navigate all reaches of the fishway system (Makrakis et al., 2007).

Tongland Hydroelectric Project – River Dee, Scotland

The pool-type fishway at Tongland Dam was constructed during the time of dam construction and was completed in 1934. The total elevation gain provided by the fishway is approximately 69 feet. In 1960, improvements to the fishway were made to convert the access between pools from orifices to overflow weirs in most locations. Some orifices are still in use in the fishway. In 1999, baffles were installed in the upper pools of the fishway to make it easier for Atlantic salmon to pass. The total flow released through the fishway is approximately 9 cfs year-round, with an additional 28 cfs released from the dam during the period of salmon migration. A

Vaki Riverwatcher fish counter is installed in one of the resting pools to record adult salmon ascending the fishway.

From 2006 to 2008, a Passive Integrated Transponder (PIT) tag study was done by Galloway Fisheries Trust, Dee District Salmon Fishery Board, and Marine Scotland Science, to identify any problems with the fishway. Fish were tagged downstream from the fishway in a fish trap adjacent to Tongland Power Station and PIT detectors were located throughout the fishway. Of the 44 fish that were tagged, 35 percent were recorded at the lowest PIT detector at the fishway. It was found that fish moved through the fishway exclusively during daylight hours. Data analysis also showed that salmon that entered the fishway moved through it within 2 days. Some tagged fish were not recorded at the fishway, so further study needs to be done to determine the cause of this (Galloway Fisheries Trust and The Carnie Consultancy, 2010).

8.2 Large Dams with Non-Volitional Upstream Passage

Non-volitional upstream passage at large dams can be achieved by several methods, including lifts, locks, and collection and transport. These methods are used where vertical passage heights are excessive or when passage is needed for species that do not readily use fishways (CEC, 2005).

Fish lifts move fish over a barrier by mechanical means. Fish locks are devices that raise fish over dams, similar to the way boats are raised in a navigation lock. In North America, fish lifts have been preferably used over fish locks to pass fish over high dams (Clay, 1995). At Keswick Dam on the Sacramento River, a fish lift is used as part of a collection and transport facility. Locks built at dams on the Columbia River (Bonneville, The Dalles, and McNary) and at other locations in the United States were abandoned in favor of pool-type fishways. Likewise, most locks in France are considered to be unsuccessful and some have been replaced by pool-type fishways (Larinier, 2000).

Collection and transport operations have been used successfully for moving adults upstream from long reservoirs or multiple reservoirs. This technology has also been used for interim passage until construction of other fish passage technologies, such as fishways or lifts, is completed. At high-head dams, collecting and transporting adult migrants may be the only feasible passage method. A potential benefit of this type of system is that it needs much less flow than pool-type ladders, which may make it the most feasible fish passage option for drought periods in California (CC, 2005).

In the Pacific Northwest, most projects at high-head dams (greater than 100 feet) are or will be using the collection-and-transport method to move adult migrating salmonids upstream from a dam or multiple dams. Examples include the Baker River, Cowlitz River, Lewis River, Pelton-Round Butte, Cougar, Cle Elum, and Cushman projects.

8.2.1 Lifts

Touvedo Dam – Lima River, Portugal

At 140-foot-high Touvedo Dam on the Lima River, a fish lift is used for passing Atlantic salmon, sea trout, and other fish species. No other fish passage technologies were considered during the development of the project. There are three entrances to the lift located within the tailrace of the powerhouse. A maximum attraction flow of 159 cfs is evenly distributed among the three entrances; velocities in the entrances range from 5.5 feet per second to 8.2 feet per second. More detailed information about the fish lift was not available.

A study in the late 1990s found that cyprinids (Iberian nase, Iberian barbell, Iberian dace, Iberian red roach), salmonids (brown trout and Atlantic salmon), and European eel used the fish lift to pass upstream (Santos et al., 2002). Velocities within the entrance channel were within the ranges of critical swimming speeds for fish (Larinier, 1992, as cited in Santos et al., 2002). Cyprinids used the lift more often at night, while trout and eels passed during the day.

Keswick Dam – Sacramento River, California

At 118-foot-high Keswick Dam, the fish trapping facilities are located in the center of the dam, between the powerhouse and the spillway. The facilities consist of a pool-type fishway, a brail lift, and a 1,000-gallon elevator. After fish ascend the fishway, they pass through a fyke weir and are contained in a large fiberglass brail enclosure. The brail is raised and trapped fish are directed into a 1,000-gallon fish tank elevator that transports them up the face of the dam. At the top of the dam, the tank is dumped into a fish transport truck.

8.2.2 Locks

Ardnacrusha Hydroelectric Project – River Shannon, Ireland

In 1959, a Borland-MacDonald fish lock was constructed at Ardnacrusha Dam to provide upstream passage of adult Atlantic salmon. The average working head is approximately 94 feet. The lock at Ardnacrusha is different from the typical Borland lock because it has a vertical cylindrical chamber as opposed to the typical sloping chamber. Fish enter the base of the 15-foot-diameter cylinder, the downstream gate shuts, and water fills

the cylinder until the fish are raised to the forebay level. Attraction flow is provided by a 27-inch-diameter pipe that has two branches, one dispersing water at the base of the cylinder and the other discharging through nozzles outside of the gate entrance.

Baker River Hydroelectric Project – Washington

See Section 8.2.3 Collection and Transport for a description of the lock used at Puget Sound Energy's (PSE) adult fish collection facility on the Baker River.

8.2.3 Collection and Transport

Baker River Hydroelectric Project – Washington

In 2010, PSE completed construction of an adult fish collection facility downstream from Lower Baker Dam near the town of Concrete, Washington. The facility replaces the original trap that was built in 1958. The new fish trap is highly automated. Fish enter a fish lock seven feet in diameter and 60 feet tall, which raises fish from the river level to the facilities on the river bank. There is a programmable control system and operator's booth for sorting fish by species and separating them into six holding pools. From the holding pools, fish are transferred to trucks via automated systems with minimal handling of fish. (PSE, 2010)

Cle Elum Dam Project – Yakima River, Washington

At 124-foot-high Cle Elum Dam on the Yakima River in Washington, Reclamation is planning to build a collection-and-transport system. A fishway will lead adult migrants into a collection facility where they will be held for truck transport to locations in and upstream from the reservoir. Flows in the fishway will be less than 10 cfs and will come from the stilling basin downstream from the dam. The target species for passage are sockeye, Coho, and Chinook salmon, steelhead, and bull trout (Reclamation, 2010).

Cougar Dam Project – South Fork McKenzie River, Oregon

Cougar Dam is a 467-foot-high structure on the South Fork McKenzie River in Oregon. USACE completed a $10.4 million adult fish collection facility in 2010 as part of their collection-and-transport system. The facility uses a Half Ice Harbor fishway to get fish to the collection facility. Water pumped from the tailrace of the power plant is used at the facility and in the fishway. At the facility, spring-run Chinook salmon, bull trout, and resident fish species are sorted and then loaded onto trucks for transport to locations above Cougar Reservoir. Rather than crowding fish mechanically, the facility was designed to let fish make their own way up the fishway and into the truck tank with as little impediment as possible. The goal is to get at least 1,000 adult spring-run Chinook salmon into the upper watershed

each year (Palmer, 2010). That goal has not been reached as of yet, but the USACE has passed several hundred spring-run Chinook salmon as well as hundreds of resident species. Aside from a few minor issues, the facility is working well (Greg Taylor, Personal Communication, November 7, 2011).

Cowlitz River Hydroelectric Project – Washington

Tacoma Power uses the Cowlitz River Hydroelectric Project to generate power, and provide flood protection, water supply, and recreational opportunities. It includes two large dams (listed from downstream to upstream), 230-foot-high Mayfield Dam and 529-foot-high Mossyrock Dam, located on the Cowlitz River in Washington State. A third large dam on the river, just upstream from Riffe Lake (Mossyrock Dam's reservoir) is Lewis County Public Utility District's 120-foot-high Cowlitz Falls Dam (FERC, 2002), the only dam in its Cowlitz Falls Project. Tacoma Power uses a collection-and-transport system to pass spring- and fall-run Chinook salmon, coho salmon, and steelhead past the dams and reservoirs. Migrating adults are collected at the Cowlitz Salmon Hatchery and Cowlitz Trout Hatchery downstream from Mayfield Dam and sorted by species and destination. Hatchery fish are kept at the hatchery to produce the next generation of salmon or trucked upstream. Wild salmon are transported to sites on the Tilton, Cowlitz, and Cispus rivers to continue their upstream migration (Tacoma Power, 2010a). The number of adults (Chinook salmon, coho salmon, steelhead trout, and cutthroat trout) annually transported upstream in the last eight years ranges from 18,000 to 112,000 (Tacoma Power, 2004, 2006, 2008, 2009, 2010b).

Cushman Hydroelectric Project – Skokomish River, Washington

Tacoma Power's Cushman Hydroelectric Project is located on the Skokomish River in Washington. It consists of two dams (listed from downstream to upstream), 215-foot-high Cushman No. 2 and 250-foot-high Cushman No. 1. Through Federal Energy Regulatory Commission (FERC) relicensing, Tacoma Power developed an Upstream Fish Passage Plan in 2010. From the plan, a fish collection trap will be constructed at the base of Cushman No. 2 Dam. Flows between 70 cfs and 280 cfs will pass through the new North Fork Powerhouse at the base of Cushman No. 2 Dam and into the trap, providing holding water and attraction flows at the trap entrance. Fish will be attracted or crowded into a hopper and then lifted to the top of the dam via a railed tramway. At the top of the dam, fish will be sorted and loaded onto trucks to be transported to hatcheries or Lake Cushman upstream from Cushman Dam No. 1 (Tacoma Power, 2010c).

Lewis River Hydroelectric Project – Washington

PacifiCorp's Lewis River Project consists of three main dams (listed from downstream to upstream), 230-foot-high Merwin Dam, 309-foot-high Yale Dam, and 400-foot-high Swift No. 1 Dam, on the Lewis River in

southwestern Washington (NMFS, 2006). Through FERC relicensing and their 2004 Settlement Agreement, PacifiCorp will provide upstream and downstream passage at project dams. Adult spring-run Chinook and Coho salmon, and winter-run steelhead will be trapped below Merwin Dam and transported by trucks upstream from Swift No. 1 Reservoir. Hatchery fish will be initially used to kick-start the reintroduction program and over time, and as naturally produced fish increase in number, hatchery supplementation will be tapered off (PacifiCorp, 2004). The fish collection facility will consist of new fish trap entrances with increased attraction flow, a new fish lift, and holding, sorting, marking, sampling, and truck-loading areas that will use water-to-water fish transfer protocols. The final design for the facility is completed, and construction is planned to begin in 2012 (R2, 2011).

Pelton Round Butte Hydroelectric Project-Deschutes River, Oregon

PGE's Pelton Round Butte Project consists of three dams (listed from downstream to upstream), 25-foot-high Reregulating Dam, 204-foot-high Pelton Dam, and 425-foot-high Round Butte Dam, on the Deschutes River (PGE and CTWSRO, 2004). The project has a fish trap built in 1956 and located below the Reregulating Dam, which was originally constructed to collect fish for passage around the construction activities at the Reregulating and Pelton dams. It has been used since 1972 for collecting upstream migrants for transport to the Round Butte Hatchery at the base of Round Butte Dam (Ratliff et al., 1999; ODFW, 2010).

Since 2007, steelhead and spring-run Chinook fry from the hatchery have been annually released upstream from Lake Billy Chinook, the reservoir formed by Round Butte Dam. Fry will be released every year until adults start being transported to the upper watershed. PGE completed a downstream migrant collection facility in December 2009, and, as of September 2010, had collected and transported nearly 100,000 juvenile fish (PGE, 2010).

Upstream passage for adult migrating salmonids has not begun yet, but is tentatively scheduled to start in 2012. That is when adults that originated in the upper watershed from the fry releases should return (Don Ratliff, personal communication, October 7, 2010). The returning adults will be collected at the Pelton Fish Trap and trucked to Lake Billy Chinook. To get ready for their release into Lake Billy Chinook, a facility, consisting of a concrete fish release vault positioned near the shore with a truck access point, was constructed in 2010 (PGE and CTWSRO, 2009; Don Ratliff, personal communication, October 7, 2010).

8.3 Large Dams with Volitional Downstream Passage

Typically, downstream migrants can pass a dam by three methods: turbines, spillways, or bypass systems (USACE, 2002). In addition, juvenile migrants can pass dams by using the fishways or navigation locks, but, since the percentage of fish passed by these methods is very small, DWR did not discuss them in the report.

8.3.1 Turbine Passage

One of the goals of downstream fish passage is to keep fish from passing through turbines. Studies of juvenile salmon have shown that fish reluctantly, after delays in the forebay, enter the turbine intakes. Even then, these fish seek refuge in the gatewells, slots used for inserting solid barriers that keep water from entering the turbines during maintenance (Coutant et al., 2006). Fish that do pass through turbines can become injured or die by a number of mechanisms. These include rapid and large pressure changes, shear stresses, cavitation, turbulence, collision with turbine parts, and squeezing through narrow openings between moving and fixed parts (Cada, 2001).

The survival of fish during turbine passage is influenced by the size and type of turbine, speed of revolution, hydraulic head, and mode of operation, as well as the characteristics of the fish, such as species, size, life stage, and condition (CEC, 2005).

Two types of turbines are generally used at large dams, Francis and Kaplan. The mortality rate for juvenile salmonids passing through Francis and Kaplan turbines varies greatly, from under 5 percent to more than 90 percent in Francis turbines, and from under 5 percent to approximately 20 percent in Kaplan turbines (FAO, 2001). The large Kaplan turbines at the mainstem Columbia and Snake River dams have an average survival rate (including both direct and indirect effects) of about 88 percent (Cada, 2001). Studies show that a correlation exists between peripheral turbine blade velocity and fish mortality for the Francis design but not the Kaplan design (EPRI, 1987). Fish size also affects mortality rate, as larger fish have a greater chance of colliding with turbine parts (OTA, 1995).

At California's large dams, Francis turbines are commonly used. For example, the Shasta and Keswick (Sacramento River), Folsom (American River), Narrows 2 (Englebright Dam on the Yuba River), New Melones (Stanislaus River), and Hyatt (Oroville Dam on the Feather River) power plants all have Francis-type turbines (Reclamation, 2011).

8.3.2 Spillway Passage

One way to keep fish out of turbine intakes is to pass them at a spillway. Since their reservoir capacities are small, spillways are often used to pass excess water at the Colombia and lower Snake River dams. These dams can also be operated to use their spillways to pass fish by not passing as much water through their power plants. But since large hydropower generation, flood management, water storage dams in California do not use their spillways except to pass excess water when their reservoirs are full, fish passage at these types of spillways is not a viable option.

8.3.3 Bypass Systems

The final type of volitional downstream passage is the bypass system. These are constructed exclusively for fish passage, but can be modifications of other structures such as an ice-and-trash chute, and generally consist of a barrier to guide the fish over to a pipe or flume in which the fish and water flow to an outfall point downstream from the dam.

Some of the Columbia River dams, such as Rocky Reach and Bonneville, have bypass systems that pass fish to the river below the dam. In addition, some larger flood control, water storage projects, such as the Cowlitz River and North Fork projects, also use bypasses leading directly to the river downstream.

Rocky Reach Hydroelectric Project – Columbia River, Washington
The permanent surface collection system at Rocky Reach Dam was completed in 2003. It includes 29 pumps to create a strong attraction flow into the collector. There are two entrances into the surface collector with 3,000 cfs of flow per entrance. After entering one of the two surface collector channels, flow is dewatered through fine screening from 3,000 cfs down to 120 cfs. The flow from the collector channels enters into the bypass pipe. Vertical barrier intake screens in two of the turbine units also deliver 120 cfs of flow and fish into the bypass pipe. The water and fish are transported in the bypass pipe several hundred yards downstream from the dam where they are released into the river. The total design, engineering, and construction costs for the system were $107 million (Hemstrom, 2010a).

The bypass efficiency (proportion of smolts using the bypass compared to turbines and spillway) is 50 percent to 70 percent for steelhead, 40 percent to 50 percent for sockeye, and 40 percent to 47 percent for Chinook. Smolt survival studies have shown that smolts are averaging 99.9 percent survival through the bypass system (Hemstrom, 2010b).

Bonneville Hydroelectric Project – Columbia River, Washington/Oregon

The second powerhouse at Bonneville Dam has a juvenile bypass system. Fish are screened within the powerhouse and are diverted into a 48-inch transport pipe that transports fish downstream from the dam. In 2004, a corner collector was built at the second powerhouse to augment the juvenile bypass system. The corner collector was designed to operate over flows of 3,375 to 6,570 cfs. Roughly 30 percent of all downstream migrants that pass through Bonneville Dam go through the corner collector (BPA, 2006). The corner collector was created by modifying the existing ice-and-trash chute intake area and adding a concrete channel to transport fish downstream from the powerhouse. The non-turbine routes are estimated to pass about 90 percent of all juvenile fish at the Second Powerhouse with an estimated survival rate exceeding 95 percent (Salmonrecovery.gov, 2004). In 2008, a prototype Behavioral Guidance System (BGS), 700 feet long and 10 feet deep, was installed in the forebay of the second powerhouse. The purpose of the BGS was to increase the passage of juvenile salmon into the corner collector. Studies were implemented to evaluate the effectiveness of the prototype BGS.

North Fork Hydroelectric Project – Clackamas River, Oregon

Portland General Electric uses a fishway and a bypass pipe to pass downstream migrants past all three of its dams. Smolts migrating downstream from the upper Clackamas River encounter North Fork Dam, the uppermost dam for the Project, and enter a collection system that passes them into the project's 1.7-mile-long pool and weir fishway. The juvenile fish travel about 1.5 miles down the fishway to a separator, which diverts them into a holding tank where they are identified and counted. Fish are then released into a 20 inch pipe that carries them downstream about five miles where they are released into the river below River Mill Dam (PGE, 2011).

Cowlitz River Hydroelectric Project – Washington

At Tacoma Power's Cowlitz River Project, a downstream migrant bypass facility passes fish around 230-foot-high Mayfield Dam. The facility was constructed in the early 1960s and consists of two vertical louver intake structures that funnel fish into a bypass channel. The bypass channel then directs the fish to a secondary separator, where they are guided through the dam to a holding and counting facility, then emptied into the river below the powerhouse using a pipe and chute (NOAA Fisheries, 2004). The bypass annually passes an estimated 25,000 to 250,000 salmonid smolts (Zapel et al., 2002).

8.4 Large Dams with Non-Volitional Downstream Passage

8.4.1 Collection and Transport

Collection and transport is the method for non-volitional downstream passage at large dams. At the dams on the Columbia and lower Snake rivers, downstream migrants are sometimes collected and transported downstream from the lowest dam on the Columbia River. At high flood control, water storage dams, collection and transport is becoming the main method for downstream passage. At some dams, downstream migrants are collected at a screening facility attached to the intake of the power plant. At other locations, the floating surface collector (FSC) has emerged as a preferred method to pass downstream migrants. PSE completed its FSC at Upper Baker Dam in 2008, and since then, many other entities have followed in its footsteps. Tacoma Power is currently designing an FSC for its Cushman Hydroelectric Project on the Skokomish River and will most likely do the same to improve downstream passage on the Cowlitz River. In addition, PacifiCorp is currently designing an FSC for its Lewis River Hydroelectric Project. Finally, USACE is looking at a FSC as an alternative for downstream passage at Cougar Dam on the South Fork McKenzie River.

Lower Granite Dam – Snake River, Washington

For downstream passage at 100-foot-high Lower Granite Dam on the Snake River, one of the methods used is a collection-and-transport system. Fish enter a bypass system through one of 18 bulkhead slot orifices located at the upstream powerhouse intake. Fish pass into a collection channel, move down the collection channel and pass through a downwell into a 42-inch pipe that transports them 1,700 feet downstream to a holding and loading facility. At the facility, fish are separated and can be loaded onto a truck or barge to be transported approximately 285 river miles downstream to be released below Bonneville Dam, the furthest downstream dam in the system (USACE, 2010).

Pelton Round Butte Hydroelectric Project – Deschutes River, Oregon

PGE's Pelton Round Butte Project consists of three dams (listed from downstream to upstream), 25-foot-high Reregulating Dam, 204-foot-high Pelton Dam, and 425-foot-high Round Butte Dam, on the Deschutes River (PGE and CTWSRO, 2004). In December 2009, the construction of a Selective Water Withdrawal Tower and its associated fish collection facility was completed at a cost of $108 million. The fish collection facility sits at the top of the tower and captures downstream migrant salmonids attempting to emigrate from Lake Billy Chinook, the reservoir created by Round Butte Dam. Through the primary downstream migration period

(February to June), nearly all the water used for generation at the Round Butte Powerhouse will be withdrawn from the surface of the reservoir through the fish screening facility. The facility uses large v-shaped screens for primary screening. The fish are captured, separated into four size categories, and distributed into separate holding, processing, and release or loading facilities. Most of the collected fish are transported by truck about 10 river miles downstream for release below Reregulating Dam (Ratliff et al., 2009).

Baker River Hydroelectric Project – Washington

Baker River Hydroelectric Project's $50 million FSC was completed in the spring of 2008. It is the primary facility for downstream passage of outmigrating juvenile salmonids from Baker Lake to the Skagit River. The FSC is a 130-foot-by-60-foot barge located upstream from Upper Baker Dam, and is outfitted with conventional v-screens within a floating channel with attraction flow created by pumps. The FSC has the capacity for 1,000 cfs attraction flow, but currently only provides 500 cfs. Guide nets that help funnel fish into the FSC are located on both sides of the collector and extend from the FSC to the opposing lake shores. The FSC also includes fish holding tanks and a sampling facility. Fish are transported by barge from the FSC to loading facilities on the dam, where they are loaded onto flatbed trucks or trailers for transport downstream from Upper Baker and Lower Baker dams. Since the FSC has been in operation, record numbers of juvenile sockeye salmon have been collected, with an efficiency estimated at 90 percent to 95 percent, and transported downstream.

8.5 Dam Removals

The best method to provide fish passage at a dam is to remove it. While allowing unimpeded fish passage, dam removal also offers the restoration of natural processes, such as sediment, woody debris, and nutrient transport, and reestablishes watershed connectivity. However, it is possible that removing a dam can have negative effects on a watershed, such as removing a reliable source of cold water and allowing fish passage for undesirable species that were formerly blocked by the dam.

8.5.1 Removed Dams

Marmot Dam – Sandy River, Oregon

Marmot Dam was located on the Sandy River about 30 miles southeast of Portland before its removal in 2007. Marmot Dam was 47 feet high (structural height) and a part of the Bull Run Hydroelectric Project, which generated up to 22 megawatts of power (Major et al., 2008). The dam originally had a fishway for passage that was frequently damaged in flood

events and required repairs and maintenance throughout its life (Taylor, 1998). Through the FERC relicensing process, PGE decided that the costs of upgrading and maintaining the fish passage facilities outweighed the power revenue that the hydroelectric project generated. Marmot Dam is one of the largest dams (in terms of height and volume of stored sediment) to have been removed in the western United States. The reservoir behind the dam stored approximately 1,000,000 cubic yards of sediment, and its management was one of the main issues to be solved during the dam removal process. PGE chose the informally termed "blow and go" option, in which the dam is removed as quickly as possible with minimal prior removal of stored sediment. The earthen coffer dam protecting the dam removal site was breached on October 19, 2007, and by mid- January 2008, about 400,000 cubic yards of the stored sediment was eroded by the river (Major et al., 2008).

Saeltzer Dam – Clear Creek, California

Saeltzer Dam was located on Clear Creek about six miles upstream of the confluence with the Sacramento River before its removal in 2000. Saeltzer Dam was approximately 15 feet high (structural height) and 200 feet long. It was constructed in 1903 to divert water for agriculture and cattle ranching (Boyle Engineering Corp 1986). A pool and weir fishway was constructed in 1958 to replace the original ladder but spring-run Chinook salmon and steelhead were never observed using the ladder or in upstream areas. Since the ladders did not appear to pass spring-run Chinook salmon and steelhead, the dam blocked access to 10 miles of cold water habitat available upstream for these species. Ten solutions for fish passage problems at Saeltzer Dam were evaluated for feasibility and cost (Rectenwald 2000). An interagency and stakeholder group ultimately focused on three: 1) rehabilitating the dam and installing a fish screen and ladder, 2) removing the existing dam and constructing a new dam with a ladder and screen at a new location, and 3) removing the dam and transferring the water rights to diversion points outside the watershed (Rectenwald 2000). The group selected option 3. About 13,000 cubic yards of sediment were excavated from behind the dam before the dam was removed in 2000 (Rectenwald 2000). By 2005, about 50,000 cubic yards of stored sediment were eroded by Clear Creek (Clayton-Niederman & Gilbreath 2005). Since 2001, the highest steelhead redd densities have been seen in the reaches upstream of where Saeltzer Dam was located (USFWS 2007, as cited in NMFS 2009a).

8.5.2 Dams to be Removed

Condit Dam – White Salmon River, Washington

Condit Dam is a 125-foot-high (structural height) barrier to fish passage on the White Salmon River, a tributary to the Columbia River, which was

removed beginning in October 2011 (Frank Shrier, Personal Communication, September 9, 2010). The hydroelectric project is owned by PacifiCorp and has a power generating capacity of 14.7 megawatts. The reservoir, Northwestern Lake, contains approximately 2.3 million cubic yards of captured sediment. Fish ladders were part of Condit's original design, but these facilities washed out twice during floods in the dam's early years. After the facilities washed out for the second time, the Washington State Fisheries Department required the former owner, Northwestern Electric, to contribute to construction of a state fish hatchery rather than rebuild the fish ladders (PacifiCorp, 2005).

In 1996, as part of the relicensing of the hydroelectric project, FERC issued a Final Environmental Impact Statement, which dictated required conditions for continued use of Condit Dam. Some of the conditions included installation of fish passage facilities and higher in-stream flows. With the new conditions, continuing hydroelectric operations at Condit Dam would have been uneconomical for PacifiCorp and its customers. PacifiCorp entered into a settlement process, where it was decided that it would shut down power generation and remove Condit Dam (PacifiCorp, 2005). Removing the dam will open up as much as 33 miles of spawning and rearing habitat for anadromous salmonids (NMFS, 2006).

Elwha River Dams – Elwha River, Washington

Removal of Elwha and Glines Canyon dams, located on the Elwha River in Olympic National Park, began in fall 2011 (USDOI NPS, 2011). Elwha Dam is 98 feet high and is located about five miles upstream from the mouth of the Elwha River at the Strait of Juan de Fuca. Glines Canyon Dam is 200 feet high and is approximately eight miles upstream from Elwha Dam. Elwha Dam produces up to 14.8 megawatts of power and Glines Canyon dam produces as much as 13.3 megawatts (American Rivers, 2010). Sediment management is a significant issue in the removal of the dams, as Elwha Dam's reservoir contains roughly 5 million cubic yards of sediment and the reservoir for Glines Canyon Dam contains approximately 13 million cubic yards. Much of the sediment will be slowly released to reduce impacts on downstream habitat (USDOI NPS, 2011).

Since the construction of the Elwha River dams, anadromous fish population and habitat has declined dramatically. With no fish passage facilities, these dams restrict fish from entering 90 percent of the watershed. Extensive environmental review in the early 1990s determined that removal of the dams was the only way to restore native anadromous fish stocks and the river's ecosystem. Removal of the dams will restore the river to its natural state, allowing all five species of Pacific salmon (Chinook, Coho, chum, pink, and sockeye) and other anadromous fish to reach their historic spawning and rearing habitat (USDOI NPS, 2011).

The Elwha River Ecosystem and Fisheries Restoration Act of 1992 stated that water quality on the Elwha River must be protected before dam deconstruction can commence. The completion of a $25.5 million water treatment plant in Port Angeles has initiated the beginning phases of dam removal (Bodilly, 2010). Needed flood protection levee improvements and construction of a new fish hatchery are also currently underway (USDOI NPS, 2011).

8.6 Conclusions

As the case studies indicate, fish passage is provided at many large dams throughout the world. In the northwest United States, many large dams have fish passage and many more will follow in the next few years. Fish passage is provided at the lower nine Columbia River dams and the four Lower Snake River dams, with hydraulic heights ranging from 40 feet to 105 feet. At the higher flood control, water storage dams in the northwest, not all the large dams have fish passage, but many do or will in the near future.

In Washington, 27 dams have hydraulic heads greater than 150 feet. Of these, four include Grand Coulee Dam (no fish passage mainly due to its 15-mile-long reservoir upstream) and those under the influence of the Grand Coulee Dam. Almost all of the others are multipurpose dams, used for flood control, water storage, power generation, and recreation, among other things. Of these 23 dams, eight are at or above a historical natural barrier to fish passage, leaving 15 dams where fish passage could be a viable option. Of these, eight dams currently have fish passage, including 277-foot Lower Baker Dam and 304-foot Upper Baker Dam on the Baker River and 230-foot Mayfield Dam and 529-foot Mossyrock Dam on the Cowlitz River. Of the remaining seven dams, five dams have fish passage projects in design and one is scheduled for removal starting in 2011, leaving only one dam without an active fish passage project. Collection and transport is the only method used (or to be used for those in design) for upstream passage at these large dams. Downstream passage is accomplished by fish bypass or collection-and-transport facilities.

In Oregon, fewer large multipurpose dams have fish passage. The Pelton-Round Butte Project (with 204-foot Pelton Dam and 425-foot Round Butte Dam) on the Deschutes River and the North Fork Project (145-foot North Fork Dam, 56-foot Faraday Dam, and 70-foot River Mill Dam) on the Clackamas River, are the only projects with constructed facilities for both upstream and downstream passage. Of the eight dams in the Willamette River watershed with hydraulic heights greater than 150 feet, only 467-foot Cougar Dam on the South Fork McKenzie River and 181-foot Fall Creek

Dam have fish passage. Both dams have a collection-and-transport operation for upstream passage but no downstream passage facilities. A downstream passage facility for Cougar Dam is in the planning stages and should be operational in the next couple of years. Through the National Marine Fisheries Service (NMFS) Biological Opinion for the Willamette Projects, upstream fish passage will be implemented in the next few years for those dams blocking access to the upper reaches of the watershed. Downstream passage will be implemented more slowly, as Cougar Dam's downstream facility will be the test case for the watershed.

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9.0 Recommendations and Conclusions

This report focuses on fish passage actions that, if implemented, could contribute to the recovery of anadromous fish in the Central Valley. DWR identified 189 known and potential fish passage barriers in the Systemwide Planning Area, 14 of them components of the SPFC. If all the barriers are removed and/or repaired, approximately 1,500 miles[16] of anadromous fish habitat from western edge of the legal Delta to the headwaters will become fully accessible for migration, spawning, and rearing. This should greatly increase and improve habitat connectivity and promote the recovery of anadromous fish populations in the Sacramento-San Joaquin River Flood Management System.

9.1 Recommended Priorities for Removing Fish Passage Barriers

This report identified fish passage barriers in the CVFPP Systemwide Planning Area and used an interim prioritization process to rank them. The interim ranking was conducted to meet the needs and scheduling of the 2012 CVFPP. The Forum, a statewide interagency collaboration, is developing a more robust and broadly supported ranking system, but that system is not ready for use at this time. Once that prioritization is complete, the barriers identified in this report should be re-ranked using the Forum's prioritization method. This will ensure that barriers within the Flood System are addressed in a manner consistent with the rest of the State and should provide interagency buy-in for CVFPP fish passage actions.

A summary of the interim priorities for improving fish passage, especially at SPFC structures, is in Table 9-1. The table is divided into three main sections: structures that NOAA Fisheries identified as being Priority 1 and Priority 2 actions in the Central Valley salmonid recovery plan (NOAA Fisheries, 2009a), and those that were not included in the recovery plan. The priority is based on the geographic location and the potential for providing the greatest benefit for the greatest number of anadromous species. Structures are divided into two columns: those that are part of SPFC and those that are not. The time frames are based on time frames associated with the CVFPP investment strategy, deadlines set by the 2009

[16] See Attachment 9C.1 for a description of the methods used to calculate the total miles that would be fully accessible.

Biological Opinion for the long-term operations of the CVP and SWP (NOAA Fisheries, 2009b & 2011a), and direction from the Central Valley salmonid recovery plan (NOAA Fisheries, 2009a).

The Biological Opinion requires:

- DWR and Reclamation to submit a plan for fish passage at Fremont Weir by December 2011, with implementation of the plan starting by June 2012.
- DWR and Reclamation to evaluate the feasibility of providing fish passage at Shasta, Folsom, Nimbus, Keswick, New Melones, Tulloch and Goodwin dams by December 2018.
- Reclamation to operate RBDD with gates out all year to allow unimpeded passage for listed anadromous fish no later than May 15, 2012.

The Central Valley salmonid recovery plan (NOAA Fisheries, 2009a) recommends that the State evaluate the feasibility of providing fish passage at Oroville (a SPFC structure), Black Butte, Exchequer Main, and Friant dams[17]. Providing fish passage at these structures is necessary "to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction."

DWR's investments in improving both the Central Valley flood management system and its associated ecosystem will be initially constrained by funding from Proposition 1E, which requires a link to the SPFC. Thus, Proposition 1E funding decisions will focus on those barriers in the SPFC column, as compared to non-SPFC barriers. By focusing on just SPFC structures, the DWR flood management programs will contribute toward improvements for anadromous fish at those facilities, but not toward improvements at other important non-SPFC barriers. If choices need to be made between Priority 1 and Priority 2 barriers, managers should select Priority 1 structures since improvements at those structures will benefit the most anadromous species.

[17] New Hogan Dam was originally included as a Priority 2 action in the Central Valley salmonid recovery plan (NOAA Fisheries, 2009a). Because the Calaveras River downstream of New Hogan Dam already has the potential (with passage and flow improvements) to support a viable steelhead population, passage upstream of New Hogan Dam is currently not a high priority for NOAA Fisheries (pers.com. B. Ellrott 2011).

Table 9-1. State Plan of Flood Control Fish Passages Priorities

Biological Importance – Priority	Time Frame	SPFC	Non-SPFC
1	Within the next 5 years	• Fremont Weir planning and implementation[1] • Willow Slough Weir (Sutter Bypass - East Borrow Canal) • Weir No. 2 (Sutter Bypass – East Borrow Canal)	• Planning and implementation for 15 Yolo Bypass barriers Budiselich Dam and Caprini Low-Flow (Stockton Diverting Canal and Mormon Slough) • Red Bluff Diversion Dam[2]
	Within the next 10 years	• Fremont Weir implementation Sacramento Weir	• Implementation fish passage solutions at 15 Yolo Bypass barriers • Keswick Dam[3] • Shasta Dam • Folsom Dam (American River) • New Melones and Tulloch dams (Stanislaus River) • 39 Calaveras River/Mormon Slough/ Stockton Diverting Canal barriers • Webster Dam (Mosher Slough near Stockton) • Sack Dam • Goodwin Dam • Harry L. Englebright Dam (Yuba River) • New Bullards Bar Dam (N. Yuba River)
	More than 10 years		• La Grange Dam (Tuolumne River) • Camanche and Pardee dams (Mokelumne River) • Don Pedro Dam (Tuolumne River)
2	Within the next 10 years	• Tisdale Weir	• One Mile Dam With Pool Fish Ladder (Big Chico Creek) • Daguerre Point Dam (Yuba River) • Crocker Diversion Dam (Snelling) (Merced River) • Mendota Pool Dam And Diversion
	More than 10 years	• Oroville Dam (Feather River)[4] • Fish Barrier Dam (Feather River) • Thermalito Diversion Dam and Afterbay	• Black Butte Dam (Stony Creek) • Exchequer Main Dam (Merced River) • Friant Dam • McSwain Dam (Merced River)

Table 9-1. State Plan of Flood Control Fish Passages Priorities (contd.)

Biological Importance – Priority	Time Frame	SPFC	Non-SPFC
3	Within the next 10 years	• Colusa Weir • Big Chico Flood Control • Sand Slough Control Structure • Cache Creek Settling Basin	• New Hogan Dam[5] • More than 100 structures (not included earlier in this table) throughout the Systemwide Planning Area

Notes:

[1] The biological opinion for the long-term operations of the CVP and SWP (NOAA Fisheries, 2009b & 2011a) requires DWR and Reclamation to submit a plan for fish passage at Fremont Weir by December 2011. The biological opinion requires the agencies, to the maximum extent of their authorities, and in cooperation with other agencies, begin implementation of the plan by June 2012.

[2] Reasonable and Prudent Alternative I.3.1 of the biological opinion for the long-term operations of the CVP and SWP (NOAA Fisheries, 2009b) states "No later than May 15, 2012, Reclamation shall operate RBDD with gates out all year to allow unimpeded passage for listed anadromous fish." Because of this regulatory deadline, Red Bluff Diversion Dam was moved up to the "Within the next 5 years" time frame.

[3] The biological opinion for the long-term operations of the CVP and SWP (NOAA Fisheries, 2009b) requires DWR to participate in the fish passage steering committee that is evaluating the feasibility of providing fish passage at Shasta, Keswick, Nimbus, Folsom, New Melones, Tulloch and Goodwin dams.

[4] The Central Valley salmonid recovery plan (NOAA Fisheries, 2009a) recommends that the State evaluate the feasibility of providing fish passage at Oroville, Black Butte, New Hogan, Exchequer Main, and Friant dams. Providing fish passage at these structures is necessary "to prevent a significant decline in species population/habitat quality or in some other significant negative impact short of extinction."

[5] Because the Calaveras River downstream of New Hogan Dam already has the potential (with passage and flow improvements) to support a viable steelhead population, passage upstream of New Hogan Dam is currently not a high priority for NOAA Fisheries (pers.com. B. Ellrott 2011).

Key:

SPFC = State Plan of Flood Control

As opportunities arise to use or leverage other funding that is not constrained to SPFC facilities, DWR should collaborate with others to address non-SPFC barriers. This approach will achieve the most biological benefit since DWR and willing partners will address all fish passage barriers in the Systemwide Planning Area.

Thus, recommended priorities for CVFPP implementation would follow this sequence:

- SPFC-related barriers of Priority 1 Biological Importance
    - Provide an interim passage solution at Fremont Weir (SPFC structure) (in cooperation with DFG and USACE) until a permanent passage solution is constructed
    - Develop and begin implementation (in cooperation with DFG, Reclamation, and USACE) of a Yolo Bypass fish passage plan, including Fremont Weir (SPFC structure) in 2012, as required by the biological opinion for the SWP and CVP (NOAA Fisheries, 2009b & 2011a)
    - Complete installation of a new fish ladder, and evaluate the ladder to confirm it operates to NOAA Fisheries and DFG standards, at Willow Slough Weir (SPFC structure)
    - Secondarily, pursue opportunities to collaborate with other DWR programs, Reclamation and other organizations to provide fish passage at other Priority 1 barriers with longer time frames. DWR should:
        - Complete fish passage modifications at Fremont Weir as part of the comprehensive Yolo Bypass fish passage effort
        - Evaluate the fish passage delay at Sacramento Weir and construct a fish passage solution, if needed
- Non SPFC-related barriers of Priority 1 Biological Importance
    - Pursue opportunities to use new funding to collaborate with others to fix non-SPCF barriers, with an initial focus on those barriers that can be addressed within five years. These include 15 Yolo Bypass barriers, Weir No. 2, Budiselich Dam, Red Bluff Diversion Dam, and Caprini low-flow road crossing.
    - Evaluate, in cooperation with Reclamation, the feasibility of providing fish passage at Shasta, Keswick, Nimbus, Folsom, New

Melones, and Tulloch dams by December 2018. If determined to be feasible, work with Reclamation to construct fish passage facilities at these dams by 2020 (NOAA Fisheries, 2009b)

  – Collaborate with others to evaluate fish passage opportunities at Englebright, La Grange, Camanche, Pardee, New Bullards Bar and Don Pedro dams, as recommended in the Central Valley salmonid recovery plan (NOAA Fisheries, 2009a)

- SPFC-related barriers of Priority 2 Biological Importance
  - Improve fish passage at Tisdale Weir
  - Collaborate with others to evaluate fish passage opportunities at Oroville Dam and its related facilities as recommended in the Central Valley salmonid recovery plan (NOAA Fisheries, 2009a).
- Non-SPFC-related barriers of Priority 2 Biological Importance
  - To achieve the most ecological benefit within the next 10 years or more, DWR, in cooperation with willing partners, should also make significant headway assessing potential non-SPFC barriers and fixing known fish passage barriers throughout the Systemwide Planning Area.

9.2 Improve Fisheries Habitat

In addition to removing fish passage barriers, restoration programs, such as the San Joaquin River Restoration Program, are vital to the restoration and maintenance of fish populations, including Chinook salmon and steelhead. DWR, with the cooperation of both private parties and public agencies, should continue to implement restoration projects to improve fisheries habitat and to ensure adequate in-stream flows to restore fish populations and habitat within the Systemwide Planning Area.

As part of this habitat restoration effort, DWR should take steps to increase the extent, quality, and inundation of floodplain habitats through setback levees, and restoration and enhancement of existing floodplain habitats. Floodplains are critical components of aquatic ecosystems, and access to floodplain habitat increases fish productivity, abundance, and growth.

DWR should work with reservoir operators to provide ecologically sustainable river flows that maintain natural channel and floodplain

characteristics. River-floodplain connectivity and condition is closely tied with reservoir operations and seasonal flows.

9.3 Improve Scientific Understanding of Stranding Effects

Stranding has been identified in 10 locations of the Systemwide Planning Area. Research in the Yolo Bypass indicates that the impact of stranding on juvenile salmon is low, but a perception remains that stranding has an impact on listed anadromous species. As DWR investigates options to increase floodplain inundation, DWR should collaborate with DFG, Reclamation, USFWS, and other agencies to:

- Evaluate the extent and impact of stranding on listed anadromous species, especially green sturgeon, in any floodplain inundation projects. but especially in flood control bypasses.
- Evaluate the extent of stranding in the Stanislaus River gravel pits and other locations.
- See, through outreach, that results from the stranding studies are broadly disseminated to the biological community.

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10.0 References

Adams, P.B., et al., 2002, *Status Review for the North American Green Sturgeon*, NOAA, National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California, June. Available at http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/greensturgeon.pdf.

Bartlett, James. 2006. Adult Salmon and Steelhead Counts at the North Fork Fish Ladder 2004 and 2005.

Bartlett, James, and Doug Cramer. 2006. River Mill Dam Adult Fish Ladder and Spillway Post-construction Monitoring Plan.

Bay Delta Conservation Plan Steering Committee (BDCPSC). 2010. Bay Delta Conservation Plan Working Draft. November 18. Available online at: *http://www.resources.ca.gov/bdcp/*. Last accessed June 3, 2011.

BDCPSC. *See* Bay Delta Conservation Plan Steering Committee

Beamesderfer, R.C.P., and M.A.H. Webb. 2002. Green sturgeon status review information. Report by S.P. Cramer and Associates to the State Water Contractors, Sacramento, California.

Beamesderfer, R.C.P., M.L. Simpson, and G.J. Kopp. 2007. Use of life history information in a population model for Sacramento green sturgeon. Environmental Biology of Fishes. 79 (3-4): 315-337.

Bonneville Power Administration (BPA). 2006. Managing the Columbia River System to Help Fish. Available at: http://www.bpa.gov/corporate/pubs/backgrounder/06/bg120106.pdf

Boyle Engineering Corporation. 1986. Evaluation of the Benefits and Costs of Improving the Anadromous Fishery of Clear Creek, California. U.S. Bureau of Reclamation. Available at: http://www.sacriver.org/documents/watershed/lowerclearcreek/restfish/CentralValley_FishWildlife_ManagementStudy_ClearCreek_Apr86.pdf Accessed on August 18.2011.

BPA. *See* Bonneville Power Administration

Cada, Glenn F. 2001. The Development of Advanced Hydroelectric Turbines to Improve Fish Passage Survival. Fisheries. Volume 26, Issue 9. Pages 14-23.

California Department of Fish and Game (DFG). 2003. Part IX Fish Passage Evaluation at Stream Crossings. California Salmonid Stream Habitat Restoration Manual. Available at http://www.dfg.ca.gov/fish/resources/habitatmanual.asp

_____. 2011. Comments submitted on the Draft 2012 Central Valley Flood Protection Plan Conservation Framework – Attachment 3: Fish Passage Assessment. September 21, 2011.

California Department of Water Resources (DWR), San Joaquin District, River Management Section. 2002. Stanislaus River Oakdale Recreation Area Restoration Project Summary of Conceptual Designs.

_____. 2005. Fish Passage Improvement, Bulletin 250. Sacramento, California.

_____. 2008. Managing an Uncertain Future. Climate Change Adaptation Strategies for California's Water. Sacramento, California.

_____. 2011. Central Valley Flood Protection Plan Progress Report. January. Available at http://www.cvfpb.ca.gov/. Accessed on March 2. 2011.

California Energy Commission (CEC). 2005. Roadmap for Pier Research on Fish Passage at California Hydropower Facilities, Staff Report CEC-500-2005-137.

California Natural Resources Agency. 2009 California Climate Adaptation Strategy. Sacramento CA. 200 pages. Available at http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF. Accessed September 8, 2010.

Cannon, Tom (of The Fishery Foundation). 2011. Personal communication. April 18.

CEC. *See* California Energy Commission

Clay, Charles H. 1995. Design of Fishways and Other Fish Facilities. Second Edition. Boca Raton, Florida. CRC Press.

Clayton-Niederman Z., and A. Gilbreath. 2005. Distribution of Bed Sediment on Clear Creek after Removal of Saeltzer Dam. Available at http://escholarship.org/uc/item/08144286. Accessed August 23. 2011.

Congress of the United States, Office of Technology Assessment (OTA). 1995. Fish Passage Technologies: Protection at Hydropower Facilities. OTA-ENV-641. Washington, D.C.

Coutant, Charles C., Roger Mann, and Michael J. Sale. 2006. Reduced Spill at Hydropower Dams: Opportunities for More Generation and Increased Fish Protection. United States Department of Energy, Office of Energy Efficiency and Renewable Energy.

Del Rosario, RB, YJ Redler, K Newman, P Brandes, T Sommer, K Reece, and R Vincik. In review. Migration patterns of juvenile winter-run size Chinook salmon (*Oncorhynchus tshawytscha*) through the Sacramento – San Joaquin Delta.

DFG. *See* California Department of Fish and Game

DWR. *See* California Department of Water Resources

Eicher Associates, Inc.. 1987. Turbine Related Fish Mortality: Review and Evaluation of Studies. Electric Power Research Institute. AP-5480, Research Project 2694-4.

Electric Supply Board (ESB). 2006. ESB Fisheries Conservation Annual Report, Year ending December 2006.

Ellrott, Brian (NOAA Fisheries). 2011. Personal communication. August 25.

FAO. *See* Food and Agriculture Organization of the United Nations

Federal Energy Regulatory Commission (FERC). 2002. Order Approving Settlement and Issuing New License for Cowlitz River Project.

FERC. *See* Federal Energy Regulatory Commission

Fernandez, Domingo Rodriguez. 2010. Itaipu Binacional. Personal Communication. Email. 28 January 2010.

Feyrer, F., T.R Sommer, S.C. Zeug, G. O'Leary, and W. Harrell. 2004. Fish assemblages of perennial floodplain ponds of the Sacramento River, California (USA), with implications for the conservation of native fishes. Fisheries Management and Ecology 11:335-344.

Feyrer, F., T. Sommer, and W. Harrell. 2006a. Managing floodplain inundation for native fish: production dynamics of age-0 splittail in California's Yolo Bypass. Hydrobiologia 573:213–226.

Feyrer, F, T. Sommer, and W. Harrell. 2006b. Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California. North American Journal of Fisheries Management 26:408-417.

Feyrer, F., T. Sommer, and J. Hobbs, 2007. Living in a dynamic environment: variability in life history traits of age-0 splittail in tributaries of San Francisco Bay. Transactions of the American Fisheries Society 136:1393-1405.

FISHBIO Environmental, Inc. 2011. San Joaquin Basin – Stanislaus River (Webpage) http://www.sanjoaquinbasin.com/stanislaus-river.html. Accessed August 24, 2011.

Flosi, G., Taylor, R., Love, M., Weaver, B., Hagans, D., Weppner, E., and K. Bates. 2003. California Stream Habitat Restoration Manual. Volume Two. Fourth Edition. Department of Fish and Game. Available at http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp. Accessed on 3/2/11.

Food and Agriculture Organization of the United Nations (FAO). 2001. Dams, fish and fisheries, opportunities, challenges and conflict resolution. FAO Fisheries Technical Paper. No. 419. Rome, FAO. 2001. 166p.

Galloway Fisheries Trust and The Carnie Consultancy. 2010. Dee (Kirkcudbright) District Salmon Fishery Board, Galloway Fisheries Trust and Galloway Hydros (Scottish Power) Salmon Fishery Management Plan. Updated 2010 (Version 2). 84 pages.

Garza, J .C., S. M. Blankenship, C. Lemaire, and G. Charrier. 2008. Genetic population structure of Chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Final report, CalFed Research Project.

Garza, J.C. and D.E. Pearse. 2008. Population genetic structure of *Oncorhynchus mykiss* in the California Central Valley. Final report for California Department of Fish and Game Contract # PO485303.

Harrell, W.C., and T.R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. Pages 88-93 in P.M. Faber, editor. California riparian systems: Processes and floodplain management, ecology, and restoration. 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, California.

Hemstrom, Steven. 2010a. Chelan County Public Utility District. Personal Communication. Email. February 18, 2010.

Hemstrom, Steven. 2010b. Chelan County Public Utility District. Personal Communication. Email. August 4, 2010.

Heublein, J.C., J.T. Kelly, C.E. Crocker, A.P. Klimley, and S.T. Lindley. 2009. Migration of green sturgeon, Acipenser medirostris, in the Sacramento River. Environmental Biology of Fish 84:245-258.

Israel, J. 2006. Determining spawning population estimates for green sturgeon with microsatellite DNA. Presentation at the 2006 CALFED Science Conference. Sacramento, California. October 23, 2006.

Jager, H., Rose K. 2003. Designing optimal flow patterns for fall Chinook salmon in a Central Valley, California river. North American Journal of Fisheries Management 23: 1–21.

Jeffres C.J., J.J. Opperman, and P.B. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83(4): 449-458.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river–floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences 106:110–127

Kelly, J.T., A.P. Klimley, and C.E. Crocker. 2007. Movements of green sturgeon, *Acipenser mediostris*, in the San Francisco Estuary, California. Environmental Biology of Fishes, 29: 281-195.

Kondolf, G.M., M. Smeltzer, and L. Kimball. 2002. Freshwater gravel mining and dredging issues. White paper prepared for: Washington Departments of Fish and Wildlife, Ecology, and Transportation, 122 pp.

Larinier, Michel. 2000. Environmental Issues, Dams and Fish Migration. Gerd Marmulla editor. Dams Fish and Fisheries, Opportunities, challenges and conflict resolution. *FAO, Fisheries Technical Paper No. 419.* Rome, FAO. 2001. 166p. Available at: ftp://ftp.fao.org/docrep/fao/004/Y2785E/y2785e.pdf

Leon Cardona, Abimael (of DWR). 2011. Comments received on July 2011 Draft of the 2012 Central Valley Flood Protection Plan Appendix D: Attachment 3D – Fish Passage Assessment.

Lester, Aric (of DWR). 2011. Personal communication. August 24.

Lindley, S.T., R. Schick, B.P. May, J.J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2004. Population structure of threatened and endangered Chinook salmon ESU in California's Central Valley basin. NMFS Southwest Science Center NOAA-TM-NMFS-SWFSC-360. Santa Cruz, California.

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. http://repositories.cdlib.org/jmie/sfews/vol4/iss1/art3

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.

Lindley, S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, L.W. Botsford, D.L. Bottom, C.A. Busack, T.K. Collier, J. Ferguson, J.C. Garza, A. M. Grover, D.G. Hankin, R.G. Kope, P.W. Lawson, A. Low, R.B. MacFarlane, K. Moore, M. Palmer-

Zwahlen, F.B. Schwing, J. Smith, C. Tracy, R. Webb, B.K. Wells, T.H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? Pre-publication report to the Pacific Fishery Management Council.

Lower Yuba River Accord River Management Team Planning Group. 2010. Lower Yuba River Water Temperature Objectives Technical Memorandum. November 2010.

Makrakis, Sergio, et al. 2007. The Canal da Piracema at Itaipu Dam as a fish pass system. Neotropical Ichthyology. 5(2): 185-195.

McEwan, D. 2001. Central Valley Steelhead in Contributions to the biology of Central Valley salmonids. R.L.Brown (ed.), CDFG, 1-43. http://www.dfg.ca.gov/fish/Resources/Reports/Bulletin179_V1.asp

Mount, Jeffrey F. 1995. *California Rivers and Streams: The Conflict Between Fluvial Process and Land Use*, University of California Press.

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

Moyle, P.B. 2005. Expert Report of Dr. Peter Moyle, Friant Cases (E.D. Cal.), Exhibit AR-13. August 14, 2005

Moyle, P.B., J.A. Israel, and S.E. Purdy. 2008. Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna. Report for California Trout, 316pp.

Mussetter Engineering, Inc. 2005. Supplemental Expert Report of Dr. Michael D. Harvey Regarding Geomorphic Requirements for Restoration of an Anadromous Fishery in the Upper San Joaquin River, California, Case No. S-88-1658-LKK/GGH. September 15, 2005.

Natural Resources Defense Council, et al. v. Kirk Rodgers, as Regional Director of the United States Bureau of Reclamation, et al. (2006). United States District Court, Eastern District of California. CIV NO. S-88-LKK/GGH.

Navicky, James (of California Department of Fish and Game). 2011. Personal communication. April 20.

Nelson, Jonathan. (of California Department of Fish and Game). 2011. Personal communication. April 19.

NMFS. *See* National Marine Fisheries Service

NOAA Fisheries. *See* National Oceanic and Atmospheric Administration's National Marine Fisheries Service

National Oceanic and Atmospheric Administration's National Marine Fisheries Service Fisheries (NOAA Fisheries). 2004. Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Consultation, Operation of the Cowlitz River Hydroelectric Project.

NOAA Fisheries 2005. Green Sturgeon (*Acipenser medirostris*) Status Review Update. February. Santa Cruz Laboratory Southwest Fisheries Science Center.

NOAA Fisheries. 2006. Modified Fishway Prescriptions for the Lewis River Hydroelectric Project.

NOAA Fisheries. 2008. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.

NOAA Fisheries. 2008a. Fact Sheet West Coast Chinook Salmon. April 2008. http://www.swr.noaa.gov/psd/99chinfs.htm. Accessed November 7, 2011.

NOAA Fisheries. 2009. Snapshot of Salmon and Steelhead ESA status. www.nwr.noaa.gov/ESA-Salmon-Listings/upload/snapshot-7-09.pdf Updated July 1, 20-09. Accessed June 7, 2011.

NOAA Fisheries. 2009a. Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Sacramento Protected Resources Division. October 2009.

NOAA Fisheries. 2009b. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. Protected Resources Division. Sacramento California. Available at http://swr.nmfs.noaa.gov/ocap.htm.

NOAA Fisheries. 2010a. Environmental Assessment for the Proposed Application of Protective Regulations Under Section 4(D) of the Endangered Species Act for the Threatened Southern Distinct

Population Segment of North American Green Sturgeon. Prepared by the Department of Commerce National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Region. Long Beach, California. March 2010.

NOAA Fisheries. 2010b. Endangered and Threatened Wildlife and Plants: Final Rulemaking To Establish Take Prohibitions for the Threatened Southern Distinct Population Segment of North American Green Sturgeon. Federal Register. Vol. 75, No. 105.

NOAA Fisheries, 2011. Central Valley Recovery Domain 5-Year Review: Summary and Evaluation of Sacramento Winter-run Chinook Salmon ESU. Southwest Region. Long Beach, California.

NOAA Fisheries, 2011a. Enclosure 2: Clean Version of the 2009 Reasonable and Prudent Alternative Revised to Include the 2011 Amendments. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. Protected Resources Division. Sacramento California.

NOAA Fisheries, 2011b. Central Valley Recovery Domain 5-Year Review: Summary and Evaluation of Central Valley Spring-run Chinook Salmon ESU. Southwest Region. Long Beach, California.

ODFW. *See* Oregon Department of Fish and Wildlife

O'Malley K., Camara M., Banks M. 2007. Candidate loci reveal genetic differentiation between temporally divergent migratory runs of Chinook salmon (*Oncorhynchus tshawytscha*). Molecular Ecology 16:4930–4941.

Oregon Department of Fish and Wildlife (ODFW). 2010. Round Butte Hatchery Operations Plan 2010.

PacifiCorp, 2004. Press release obtained from PacifiCorp website: (http://www.pacificpower.net/Article/Article45782.html)

Pacific States Marine Fisheries Commission (PSFMC). 2010. California Fish Passage Assessment Database Project. Methodology and Documentation. Prepared by Martina Koller. September 2010. Available at www.calfish.org.

Packer, D.B., K. Griffin, and K.E. McGlynn. 2005. National Marine Fisheries Service National Gravel Extraction Guidance. U.S.

Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-70, 27p.

Palmer, Susan. 2010. Helping Fish Find Their Way. The Register Guard. Page B1. August 20, 2010.

Peak and Ecological Flow Technical Advisory Committee. Oregon Water Resources Department. 2010. White Paper: Peak and Ecological Flows; a Scientific Framework for Implementing Oregon HB 3369

PGE. *See* Portland General Electric Company

PGE and CTWSRO. Portland General Electric Company and Confederated Tribes of the Warm Springs Reservation of Oregon

Portland General Electric Company (PGE). 1999. The Effect of Project Operations on Upstream Passage of Anadromous Fish as well as Effectiveness of Existing Fishways.

Portland General Electric Company and Confederated Tribes of the Warm Springs Reservation of Oregon (PGE and CTWSRO). 2004. Pelton Round Butte Project (FERC 2030) Offer of Settlement, Joint Explanatory Statement In Support of Settlement Agreement, and Request for Technical Conference.

Portland General Electric Company and Confederated Tribes of the Warm Springs Reservation of Oregon (PGE and CTWSRO). 2009. Pelton Round Butte Project (FERC 2030) Test and Verification Study: Upstream Trap and Haul and Round Butte Adult Release Facility.

Portland General Electric Company (PGE). 2010. Deschutes Passage. Accessed September 16, 2010. Available at: http://www.deschutespassage.com/index.html.

Portland General Electric. 2011. Clackamas Hydro Plants and Fish Passage Website. Accessed March 1, 2011. Available at http://www.portlandgeneral.com/community_environment/initiatives/protecting_fish/clackamas_river/hydro_plants_fish_passage.aspx=

Poytress, W.R., J.J. Gruber, and J.P. Van Eenennaam. 2010. 2009 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, California.

Poytress, W.R., J.J. Gruber, and J.P. Van Eenennaam. 2011. 2010 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval

Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, California.

PSE. *See* Puget Sound Energy

Puget Sound Energy (PSE). 2010b. Fish Enhancement fact sheet. July 2010 edition. Available at: http://www.pse.com/SiteCollectionDocuments/mediaKit/001_Baker_River_Fact_Sheet.pdf

R2. *See* R2 Resource Consultants, Inc.

R2 Resource Consultants, Inc. (R2). 2010. Merwin Upstream Fish Passage Facility Design and Fish Behavior Studies.

Ratliff, Don (of Portland General Electric). 2010. Personal Communication, October 7, 2010

Ratliff, Don, James Bartlett, and Chad Croft. 2009. Pelton Round Butte Project Downstream Fish Passage Facilities, Operations and Maintenance Plan; Appendix A. Description of Downstream Fish Facilities by System. Portland General Electric Company. Portland, Oregon.

Ratliff, Don, Colleen Fagan, Mike Riehle, Mark Powell, Scott Carlon, Peter Lickwar, Amy Stuart, Paul DeVito, Mike Gauvin, and Jim Eisner. 1999. Alternatives for Renewing Fish Passage at the Pelton Round Butte Hydroelectric Project, Madras, Oregon. Portland General Electric Company. Portland, Oregon.

Ratliff and Schulz. 1999. Fisheries Program at the Pelton Round Butte Hydroelectric Project (Oregon) 1956 – 1995. Portland General Electric Company. Portland, Oregon.

Reclamation. *See* U.S. Department of the Interior, Bureau of Reclamation

Rectenwald H. 2000. Making a Good Run…A Watershed Approach to Restoration of Clear Creek. Department of Fish and Game. Available at http://www.st.nmfs.noaa.gov/st5/abstracts/Salmon_Habitat_Restoration_Cost_Workshop_2000.htm. Accessed August 18.2011.

Romero, Paul (of California Department of Water Resources). 2011. Personal communication. August 24.

Salmonrecovery.gov. 2004. Surface Passage Systems and Removable Spillway Weirs, Lower Columbia and Snake River Dams. Available at: http://www.salmonrecovery.gov/Files/ResearchReportsPublications/RSW.pdf

San Joaquin River Restoration Program. 2009. Final Environmental Assessment/Initial Study. Water Year 2010 Interim Flows Project. September 2009. Available online at: http://www.restoresjr.net/

San Joaquin River Restoration Program. 2011a. http://www.restoresjr.net/background.html Accessed July 7, 2011.

San Joaquin River Restoration Program. 2011b. Reintroduction Strategy for Spring Run Chinook Salmon. February 2011. Available online at: http://www.restoresjr.net/

Santos, J.M. M.T. Ferreira, F.N. Godinho, and J. Bochechas. 2002. Performance of fish lift recently built at the Touvedo Dam on the Lima River, Portugal. Journal of Applied Ichthyology. Volume 18. Pages 118-123.

Santos, Jose Maria, Godinho, Francisco, Ferreira, Maria Teresa, and Rui Cortes. 2004. The Organisation of Fish Assemblages in the Regulated Lima Basin, Northern Portugal. Limnologica. Volume 34. Pages 224-235.

Schroyer, Tom (of California Department of Fish and Game). 2011. Personal communication. April 18.

Shaw, R., Cameron, D., Morris, B., Bratman, G., Bachelet, D., Klausmeyer, K., MacKenzie, J., Conklin, D., Lenihan, J., Haunreiter, E., and C. Daly. 2009a. The impact of climate change on California's ecosystem services. California Energy Commission, PIER. CEC-500-2009-025. As cited in California Natural Resources Agency 2009 available at http://www.climatechange.ca.gov/adaptation/index.html

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

Sommer, T.R., W.C. Harrell, A. Mueller-Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California,

USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14:247-261.

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

Sommer, T., W.C. Harrell, and T.R. Swift. 2008. Extreme hydrologic banding in a large-river Floodplain, California, U.S.A. Hydrobiologia 598:409--415.

State Water Resources Control Board, Division of Water Rights. 2010. Policy for Maintaining Instream Flows in Northern California Coastal Streams. September 28, 2010.

Stillwater. *See* Stillwater Sciences

Stillwater Sciences. 2006. Sacramento River ecological flows study. State of the System Report for The Nature Conservancy prepared by Stillwater Sciences.

Stillwater Sciences. 2007. Linking biological responses to river processes: Implications for conservation and management of the Sacramento River—a focal species approach. Final Report. Prepared by Stillwater Sciences, Berkeley for The Nature Conservancy, Chico, California.

Sullivan, K. and S. Chinnici. 2009. Biological Assessment of Gravel Bar Mining on the Middle Reach of the Eel River from Howe Creek to Sonoma Creek. Report for Humboldt Redwood Company.

Surface Water Resources, Inc. 2004. Draft Policy Document Lower American River Flow Management Standard. Prepared for The Water Forum.

Tacoma Power. 2004. Upstream Fish Passage: Barrier, Mayfield, and Mossyrock - Report Results.

Tacoma Power. 2006. Upstream Fish Passage Study Report – 2006 Annual Report.

Tacoma Power. 2008. Upstream Fish Passage Study Report – 2008 Annual Report.

Tacoma Power. 2009. Upstream Fish Passage Study Report – 2009 Annual Report.

Tacoma Power. 2010a. Cowlitz River Project-Salmon Hatchery Website. Accessed December 17, 2010. http://www.mytpu.org/tacomapower/parks-rec/fish-wildlife/cowlitz-river-project/fisheries-programs/salmon-hatchery.htm

Tacoma Power. 2010b. Upstream Fish Passage Study Report – 2010 Annual Report.

Tacoma Power. 2010c. Cushman Hydroelectric Project Upstream Fish Passage Plan.

Talabere, Andrew (of Eugene Water & Electric Board). 2010. Personal Communications, August 24, 2010, and October 20, 2010.

Taylor, Barbara. 1999. Salmon and Steelhead Runs and Related Events of the Clackamas River Basin – A Historical Perspective.

Taylor, Greg (of the U.S. Army Corps of Engineers). 2011. Personal Communication. November 7, 2011.

Taylor, R., Love, M. Grey, T., and A. Knoche. 2002. Final Report: Trinity County Culvert Inventory and Fish Passage Evaluation. Ross Taylor and Associates. McKinleyville California.

Taylor, Ross, and Mike Love. 2003. Part IX Fish Passage Evaluation at Stream Crossings. Salmonid Stream Habitat Restoration Manual. DFG. 3rd Edition. Available at http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

U.S. Army Corps of Engineers (USACE). 1997. To Save the Salmon. Portland District. Available at http://www.nwp.usace.army.mil/pa/docs/pubs/salmon.pdf

_____. 2002. Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement.

_____. 2010. Lower Granite Lock and Dam, Snake River, Juvenile Fish Facility Upgrade, Final Draft March 2010, Engineering Design Report.

U.S. Department of the Interior, Bureau of Reclamation. 2010. Cle Elum Dam Fish Passage Facilities and Fish Reintroduction Project – Draft Environmental Impact Statement, Yakima Project, Washington. Boise, Idaho. Bureau of Reclamation, Pacific Northwest Region. 299 pages. January 2010. Available at:

http://www.usbr.gov/pn/programs/eis/cle-elum/cle-elum-draft-eis.pdf

_____. 2011. Bureau of Reclamation Powerplants (Web page). February 17, 2011. Available at: http://www.usbr.gov/projects/powerplants.jsp?SortBy=4

_____. 2011a Bureau of Reclamation. Battle Creek Salmon and Steelhead Restoration Project. August 24, 2011. Available at http://www.usbr.gov/mp/battlecreek/index.html.

_____. 2011b Bureau of Reclamation. Red Bluff Fish Passage Improvement Project. August 24, 2011. Available at http://www.usbr.gov/mp/2010_accomp_rpt/accomp/red_bluff/index.html

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), Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch. 2010. Yuba River Redd Dewatering and Juvenile Stranding Report. September 15, 2010.

USACE. *See* U.S. Army Corps of Engineers

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

Weiser, Matt. 2011. Fish rescue included endangered salmon. The Sacramento Bee. April 18. Available at http://www.sacbee.com/2011/04/18/3561050/fish-rescue-included-endangered.html

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

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

Yoshiyama, R.M., Gerstung, E.R., Fisher, F.W., and Moyle, P.B. 2000. Chinook salmon in the California Central Valley: an assessment. Fisheries (Bethesda), 25(2): 6-20.

Zapel et al. 2002. Cowlitz River Project, Mayfield Dam, Fish Guidance Louver Evaluations.

11.0 Acronyms and Abbreviations

BGS ..... Behavioral Guidance System

cfs ..... cubic feet per second

CVFPP ..... Central Valley Flood Protection Plan

Delta..... Sacramento-San Joaquin River Delta

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

DPS..... Distinct Population Segment

DWR ..... California Department of Water Resources

ESU..... Evolutionarily Significant Unit

FERC ..... Federal Energy Regulatory Commission

Forum..... The Fish Passage Forum

FSC..... floating surface collector

GIS..... Geographic Information System

NOAA Fisheries..... National Oceanic and Atmospheric Administration's National Marine Fisheries Service

PAD..... Passage Assessment Database

PGE ..... Portland General Electric

PIT ..... Passive Integrated Transponder

PSE..... Puget Sound Energy

RBDD..... Red Bluff Diversion Dam

Reclamation ..... U.S. Department of the Interior, Bureau of Reclamation

RM ..... River Miles

SPFC ..... State Plan of Flood Control

USACE..... U.S. Army Corps of Engineers

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

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Attachment 9C.1. Methods Used in Geographic Information System Analysis of Known and Potential Fish Passage Barriers in the Systemwide Planning Area

A GIS analysis was undertaken to determine the known and potential fish passage barriers in the Systemwide Planning Area, using existing spatial data sets, obtained from official sources that describe anadromous fish passage barriers and anadromous fish distributions. These data sets were used to determine the number and distribution of known barriers to anadromous fish passage within the Systemwide Planning Area.

The geographic data sets used in this analysis, and their sources (Table 9C.1-1), are:

- Current and historic distributions of anadromous fish (fall-run, spring-run, winter-run Chinook; steelhead; green sturgeon) in the Central Valley watersheds

- Streams in the Central valley watersheds that are currently or historically used by anadromous fish

  - Source: Central Valley Recovery Coordinator, National Marine Fisheries Service, Protected Resources Division

  - Layer is based on (matched to) the cdfg_100k_2003_6 shapefile, a widely used, medium-resolution GIS dataset representing stream hydrology in California, produced by California Department of Fish and Game (metadata link: http://www.calfish.org/Portals/0/DataMaps/DataDownLoad/cdfg_100k_2003_6.htm; last updated 2003)

- Passage Assessment Database (PAD), the most comprehensive available dataset identifying known and potential barriers to anadromous fish passage

  - Source: Calfish: http://www.calfish.org

  - September 2010 release

- Components of State Plan of Flood Control (SPFC)
  - Source: California Department of Water Resources (DWR) Division of Flood Management, Central Valley Flood Planning Office

- Systemwide Planning Area
  - Source: DWR Division of Flood Management, Central Valley Flood Planning Office

The first level of analysis focused on barriers on anadromous streams that are listed in the CalFish PAD within the Systemwide Planning Area, and determining which components of the SPFC were fish passage barriers. This was defined in the following steps:

- All historic and current anadromous streams that intersect Systemwide Planning Area were identified, and the segments that actually fell inside the Systemwide Planning Area were cut ('clipped') at the Systemwide Planning Area boundary to identify only reaches within the Systemwide Planning Area.

- All entries in the PAD that occur on anadromous stream reaches within the Systemwide Planning Area were identified
  - PAD points within 300 meters of an anadromous stream reach within the Systemwide Planning Area were included in the analysis
    - The different layers used in the analysis have different degrees of positional accuracy; therefore, a "buffer" is required to select the points that should be located on an anadromous stream
    - A 300-meter buffer was determined by trial and error to be an appropriate, and conservative, distance

- PAD entries that were not relevant to the analysis were excluded on the basis of attributes in the PAD data
  - Diversions not owned by DWR or were not identified as part of the SPFC were excluded
    - Barriers with 'site type' = 'diversion' AND 'structure owner' <> 'DWR', whose names did not indicate they were part of the SPFC

- Nonstructural (i.e., natural) barriers
  - ‘SITETYPE’ = ‘nonstructural’
- Barriers that are in database but are no longer barriers
  - ‘BARSTATUS’ = ‘not a barrier’ OR TRTSTATUS ‘ ‘Completed’

Barrier status within the PAD defines how much of a barrier the structure is for fish. Within the PAD, the barrier status options include total, partial, temporal, and others. Table 9C.1-2 defines the barrier status options. If barrier status of a PAD structure was unknown, DWR designated the structure as a potential barrier needing to be assessed for fish passage status.

Table 9C.1-1. Sources of Geographic Data Used in this Analysis

Population	Time frame	Source
Fall-run Chinook	current	California Central Valley Chinook data taken from Sari Sommarstrom dataset. Sommarstrom dataset originally prepared for defining Central Valley Essential Fish Habitat.
Fall-run Chinook	historic	The lines in this file represent the estimated historical distribution of fall run Chinook salmon in selected rivers/streams in the Central Valley of California. The data used to produce this file were derived from a DFG Contributions to the Biology of Central Valley Salmonids 2001 paper by Yoshiyama et al. entitled "Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California.”
Spring-run Chinook	current	The lines in this file represent the estimated present distribution of spring-run Chinook salmon in selected rivers/streams in the Central Valley of California. The data used to produce this file were derived from a DFG Contributions to the Biology of Central Valley Salmonids 2001 paper by Yoshiyama et al. entitled "Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California.”
Spring-run Chinook	historic	The lines in this file represent the estimated historical distribution of spring-run Chinook salmon in selected rivers/streams in the Central Valley of California. The data used to produce this file were derived from a DFG Contributions to the Biology of Central Valley Salmonids 2001 paper by Yoshiyama et al. entitled "Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California.”
Central Valley Steelhead	current	CCV_Steelhead_Distribution_06_2005' depicts steelhead presence as well as habitat type and quality in the California Central Valley ESU. The data was compiled by the NOAA Fisheries SWR in an effort to designate Critical Habitat for steelhead in California. The linework for this layer is based on the DFG and PSMFC 1:100,000 scale stream-based routed hydrography. SWR biologists divided the routed hydrography into stream segments using the best available information to represent local steelhead distribution and habitat. As a result, each segment has its own unique identifier (GIS_Link) and related presence and habitat information. The data set is in shapefile format and can be included as a map layer in a GIS. This data set is an update of 'CCV_Steelhead_Draft_2004

Table 9C.1-1. Sources of Geographic Data Used in this Analysis (cont.)

Population	Timeframe	Source
Central Valley Steelhead	historic	The lines in this file represent the estimated historical distribution of steelhead in selected rivers/streams in the Central Valley of California. The data used to produce this file were derived from a DFG Contributions to the Biology of Central Valley Salmonids 2001 paper by Yoshiyama et al. entitled "Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California."
Winter-run Chinook	current	The lines in this file represent the estimated historical distribution of steelhead in selected rivers/streams in the Central Valley of California. The data used to produce this file were derived from a DFG Contributions to the Biology of Central Valley Salmonids 2001 paper by Yoshiyama et al. entitled "Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California."
Winter-run Chinook	historic	The lines in this file represent the estimated historical distribution of steelhead in selected rivers/streams in the Central Valley of California. The data used to produce this file were derived from a DFG Contributions to the Biology of Central Valley Salmonids 2001 paper by Yoshiyama et al. entitled "Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California."
Green Sturgeon	current	The data was created by extracting stream lines from NHD medium resolution shapefile that represented Green Sturgeon Critical Habitat. This dataset's features were modified to better match up to the corresponding Estuaries and were cut at locations where the NMFS CHRT determined green sturgeon have been observed or where Head of Tide was determined. The attributes were also scaled down to reduce size of the database.

Key:
CHRT = Critical Habitat Review Team
DFG = California Department of Fish and Game
ESU = Evolutionary Significant Unit
NHD = National Hydrography Dataset
NOAA Fisheries = National Marine Fisheries Service
PSMFC = Pacific States Marine Fisheries Commission
SWR = Southwest Regional Office

Table 9C.1-2. Definitions of Barrier Status from the Passage Assessment Database

Total	A complete barrier to fish passage for all anadromous species at all life stages at all times of year
Partial	Only a barrier to certain species or life stages.
Temporal	Only a barrier at certain times of year.
Temporal and Partial	Only a barrier to certain species or life stages and only at certain times of year.
Temporal and Total	Total barrier only at certain times of year.
Not a Barrier	Structure/site has been determined not to be a barrier to any species or life stages, and is passable year-round.
Structure may not be in existence	Data were obtained from an old dataset, and are likely to have been removed or washed away.
Unknown	Dataset had no information about barrier status.

- Components of the SPFC that are known or potential barriers, but that are not included in the PAD, were identified and added to the barrier dataset
  - Geographic data files describing components of the SPFC were obtained from DWR Division of Flood Management, Central Valley Flood Planning Office
  - SPFC components that were already entered in the PAD were identified, and their barrier status was determined from the PAD entry
  - All SPFC components not in the PAD were added to the dataset
  - Available information and expert knowledge was used to assign barrier status to SPFC components; if no information was available a status of "No information" was assigned

To gather the expert knowledge mentioned above, DWR held two meetings of biologists familiar with fish passage issues in the Central Valley. DWR presented maps showing the barriers identified using the PAD and reports. The biologists updated and added to the barrier information DWR had.

Calculation of Habitat Extent Upstream from Barriers

The length of potential habitat that would opened up by removal of total barriers to fish passage was calculated as a means of quantifying the potential benefit to anadromous fish of its removal. Each barrier entry in the PAD that is identified as a total barrier to fish passage, which is also on an anadromous stream and is within the Systemwide Planning Area, was selected, and the amount of upstream channel it blocks was calculated.

- Total barriers were selected from the set of barriers identified in the previous step
  - Barriers on anadromous streams (within 300 meters) within the Systemwide Planning Area
  - Select only the total barriers (BARSTATUS – 'Total')
- All other total barriers on those streams were selected, regardless of whether the barrier was within the Systemwide Planning Area, which

identified all total barriers upstream from those within the Systemwide Planning Area

- Anadromous streams that had those total barriers were identified, and each steam was 'clipped' at the barrier locations
- Sums of stream segment lengths between each barrier and the watershed headwaters were calculated (in miles) to provide an estimate of the miles of stream that could be accessible to anadromous fish if that barrier was removed.

Ranking of Barriers

All barriers identified in this analysis were ranked on the basis of (1) what, if any, action priority they were assigned in the National Oceanic and Atmospheric Administration (NOAA) Fisheries Central Valley Recovery Plan (NOAA 2009a), (2) whether they were an actual component of the SPFC and (3) what geographic priority they are assigned on the basis of the Central Valley Recovery Plan's ranking of geographic areas (Table 9C.1-3). Results of this ranking are in Attachment 9C.2.

Table 9C.1-3. Geographic Priorities Identified by NOAA Fisheries

Priority	Geographic Region (as defined by NOAA Fisheries (2009) Within the State Plan of Flood Control
1	Delta
2	Lower Sacramento River
3	Middle Sacramento River
4	Upper Sacramento River
5	Northern Sierra Nevada Diversity Group
6	Basalt and Porous Lava Diversity Group
7	Northwestern California Diversity Group
8	Southern Sierra Diversity Group

Source: 2009a
Key:
NOAA = National Oceanic and Atmospheric Administration

Attachment 9C.2. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR Owned Diversions in the Systemwide Planning Area

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
1	East Borrow Canal	Willow Slough Weir[1]	Sutter	Dam	Temporal	1	X	2 - Lower Sacramento River	737025
1	Sacramento River	Fremont Weir[2]	Yolo	Dam	Temporal	1	X	2 - Lower Sacramento River	704343
1	Sacramento River	Sacramento Weir	Yolo	Dam	Needs assessment	1	X	2 - Lower Sacramento River	700222
2	Old River	State Water Project-Clifton Court	Contra Costa	Diversion	Screened	1		1 - Delta	700212
2	S.F. Putah Creek	DFG (Yolo)	Yolo	Road crossing	Needs assessment	1		1 - Delta	704788
2	S.F. Putah Creek	DFG (Yolo)	Yolo	Road crossing	Needs assessment	1		1 - Delta	704789
2	S.F. Putah Creek	Weir	Yolo	Dam	Needs assessment	1		1 - Delta	704775
2	S.F. Putah Creek Side Chan	DFG (Yolo)	Yolo	Road crossing	Needs assessment	1		1 - Delta	704794
2	S.F. Putah Creek Side Chan	DFG (Yolo)	Yolo	Road crossing	Needs assessment	1		1 - Delta	704795
2	Toe Drain	Culvert	Yolo	Road crossing	Needs assessment	1		1 - Delta	704451
2	Toe Drain	Culvert	Yolo	Road crossing	Needs assessment	1		1 - Delta	704448

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
2	Toe Drain	Culvert	Yolo	Road crossing	Needs assessment	1		1 - Delta	704338
2	Toe Drain	Culvert	Yolo	Road crossing	Needs assessment	1		1 - Delta	704452
2	Toe Drain	Culvert	Yolo	Road crossing	Needs assessment	1		1 - Delta	704342
2	Toe Drain	Culvert/Flashboard	Yolo	Road crossing	Needs assessment	1		1 - Delta	704449
2	Toe Drain	Culvert/Flashboard	Yolo	Road crossing	Needs assessment	1		1 - Delta	704450
2	Toe Drain	Lisbon Weir[3]	Yolo	Dam	Partial	1		1 - Delta	
2	Tule Canal	Culvert	Yolo		Temporal	1		1 - Delta	
2	Tule Canal	Wallace Weir	Yolo	Dam	Temporal	1		1 - Delta	
3	East Borrow Canal	Weir No. 2[4]	Sutter	Dam	Partial	1		2 - Lower Sacramento River	703964
4	Sacramento River	Keswick Dam	Shasta	Dam	Total	1		4 - Upper Sacramento River	718711
4	Sacramento River	Red Bluff Diversion Dam	Tehama	Dam	Partial	1		4 - Upper Sacramento River	718713

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
4	Sacramento River	Shasta Dam	Shasta	Dam	Total	1		4 - Upper Sacramento River	718710
5	American River	Folsom Dam	Sacramento	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718795
5	Mokelumne River	Camanche Main Dam	San Joaquin	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718812
5	Mokelumne River	Pardee Dam	Calaveras	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718827
5	North Yuba River	New Bullards Bar Dam	Yuba	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718761
5	Yuba River	Harry L. Englebright Dam	Nevada	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718765
6	Calaveras River	Calaveras Headworks	San Joaquin	Dam	Total	1		8 - Southern Sierra Diversity Group	735098
6	Calaveras River	Cherryland Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735090
6	Calaveras River	Dam	Calaveras	Dam	Partial	1		8 - Southern Sierra Diversity Group	704310
6	Calaveras River	Deteriorated Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735104
6	Calaveras River	Eight Mile Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735094

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	Calaveras River	Gotelli #1 Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735097
6	Calaveras River	Gotelli Low-Flow Road Crossing (River Mile 35.3)	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735105
6	Calaveras River	Gotelli Low-Flow Road Crossing (River Mile 6.2)	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735088
6	Calaveras River	Gravel Pit Pond	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735100
6	Calaveras River	McAllen Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735089
6	Calaveras River	McGurk Earth Dam	San Joaquin	Dam	Temporal & Partial	1		8 - Southern Sierra Diversity Group	737024
6	Calaveras River	McGurk Low-Flow Road Crossing	San Joaquin	Road crossing	Partial	1		8 - Southern Sierra Diversity Group	735099
6	Calaveras River	Murphy Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735093
6	Calaveras River	New Hogan Dam Road Bridge	Calaveras	Dam	Partial	1		8 - Southern Sierra Diversity Group	704323
6	Calaveras River	Old Dog Ranch Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735102
6	Calaveras River	Old DWR Stream Gauge Weir	San Joaquin	Flow measurement weir	Temporal	1		8 - Southern Sierra Diversity Group	737023

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	Calaveras River	Old Wooden Bridge	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735087
6	Calaveras River	Pezzi Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735092
6	Calaveras River	Rubble Dam Upstream from Bellota Weir	Stanislaus	Dam	Temporal	1		8 - Southern Sierra Diversity Group	704320
6	Calaveras River	Solari Ranch Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735091
6	Calaveras River	Tully Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735095
6	Calaveras River	Williams Crossing	San Joaquin	Road crossing	Needs assessment	1		8 - Southern Sierra Diversity Group	735103
6	Calaveras River	Wilson's Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735101
6	Mormon Slough	Avansino Street Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735121
6	Mormon Slough	Bellota Weir	San Joaquin	Dam	Partial	1		8 - Southern Sierra Diversity Group	703864
6	Mormon Slough	Bonomo Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735118
6	Mormon Slough	Caprini Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735110

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	Mormon Slough	Fine Road Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735122
6	Mormon Slough	Fujinaka Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735114
6	Mormon Slough	Highway 26 Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735123
6	Mormon Slough	Hosie Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735120
6	Mormon Slough	Hosie Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735119
6	Mormon Slough	Lavaggi Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735111
6	Mormon Slough	Main Street Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735108
6	Mormon Slough	Panella Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735109
6	Mormon Slough	Piazza Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735117
6	Mormon Slough	Prato Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735115
6	Mosher Slough	Webster Dam	San Joaquin	Dam	Partial	1		8 - Southern Sierra Diversity Group	704472

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	San Joaquin River	Sack Dam	Fresno	Dam	Partial	1		8 - Southern Sierra Diversity Group	704635
6	Stanislaus River	Goodwin Dam	Calaveras	Dam	Total	1		8 - Southern Sierra Diversity Group	718977
6	Stanislaus River	New Melones Dam	Tuolumne	Dam	Total	1		8 - Southern Sierra Diversity Group	718821
6	Stanislaus River	Tulloch Dam	Tuolumne	Dam	Total	1		8 - Southern Sierra Diversity Group	718976
6	Stockton Diversion Canal	Central Traction Railroad crossing	San Joaquin	Bridge	Partial	1		8 - Southern Sierra Diversity Group	
6	Stockton Diverting Canal	Budiselich Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735107
6	Tuolumne River	Don Pedro Main Dam	Tuolumne	Dam	Total	1		8 - Southern Sierra Diversity Group	718978
6	Tuolumne River	La Grange Dam	Stanislaus	Dam	Total	1		8 - Southern Sierra Diversity Group	718979
7	Sacramento River	Tisdale Weir	Sutter	Dam	Temporal	2	X	2 - Lower Sacramento River	720308
8	Feather River	Fish Barrier Dam	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	718748

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
8	Feather River	Oroville Dam	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	718746
8	Feather River	Thermalito Diversion Dam	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	718747
8	Unnamed Tributary	Thermalito Afterbay	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	719986
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700810
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700807
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700811
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700808
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700809
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700814
9	San Joaquin River	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700813
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700804
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700801

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700796
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700797
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700799
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700805
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700798
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700795
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700794
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700792
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700793
9	Sevenmile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700800
9	Threemile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700803
9	Threemile Slough	Twitchell Island	Sacramento	Diversion	Unscreened	2		1 - Delta	700806
10	Dry Creek	Culvert	Sacramento	Road crossing	Needs assessment	2		2 - Lower Sacramento River	717226

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
11	Big Chico Creek	One Mile Dam With Pool Fish Ladder	Butte	Dam	Temporal	2		5 - Northern Sierra Nevada Diversity Group	704198
11	Yuba River	Daguerre Point Dam	Yuba	Dam	Partial	2		5 - Northern Sierra Nevada Diversity Group	720147
12	Stony Creek	Black Butte Dam	Tehama	Dam	Total	2		7 - Northwestern California Diversity Group	718715
13	Calaveras River	New Hogan Dam[5]	Calaveras	Dam	Total	2		8 - Southern Sierra Diversity Group	718828
13	Merced River	Crocker Diversion Dam (Snelling)	Merced	Dam	Temporal	2		8 - Southern Sierra Diversity Group	718981
13	Merced River	Exchequer Main Dam	Mariposa	Dam	Total	2		8 - Southern Sierra Diversity Group	718975
13	Merced River	McSwain Dam	Mariposa	Dam	Total	2		8 - Southern Sierra Diversity Group	718983
13	San Joaquin River	Friant Dam	Fresno	Dam	Total	2		8 - Southern Sierra Diversity Group	718954
13	San Joaquin River	Mendota Pool Dam And Diversion	Madera	Dam	Partial	2		8 - Southern Sierra Diversity Group	718840
14	Colusa Basin Drain	Knights Landing Ridge Cut Outfall Gates	Yolo	Diversion	Unscreened		X	2 - Lower Sacramento River	
14	Sacramento River	Colusa Weir	Colusa	Dam	Needs assessment		X	2 - Lower Sacramento River	720139

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
15	Big Chico Creek	Big Chico Flood Control	Butte	Dam	Partial		X	5 - Northern Sierra Nevada Diversity Group	704194
15	Feather River, N Fork	Chester Diversion Dam	Plumas	Dam	Partial		X	5 - Northern Sierra Nevada Diversity Group	718744
16	San Joaquin River	Sand Slough Control Structure	Merced	Dam	Partial		X	8 - Southern Sierra Diversity Group	704663
17	Cache Creek	Cache Creek Settling Basin	Yolo	Dam	Total		X	--	719846
18	Barker Slough	North Bay Aqueduct Pumping Plant	Solano	Diversion	Screened			1 - Delta	702946
18	Cache Slough	Culvert	Solano	Road crossing	Needs assessment			1 - Delta	702936
18	Grizzly Slough	Culvert	Sacramento	Road crossing	Needs assessment			1 - Delta	703342
18	Grizzly Slough	Siphon	Sacramento	Diversion	Unscreened			1 - Delta	703381
18	Italian Slough	Clifton Court	Contra Costa	Diversion	Unscreened			1 - Delta	702313
18	Italian Slough	DWR	Contra Costa	Diversion	Unscreened			1 - Delta	702289
18	Italian Slough	DWR	Contra Costa	Diversion	Unscreened			1 - Delta	702290
18	Italian Slough	DWR	Contra Costa	Diversion	Unscreened			1 - Delta	702291

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
18	Lindsey Slough	Harry Petersen	Solano	Road crossing	Needs assessment			1 - Delta	702950
18	Marsh Creek	Private Ford	Contra Costa	Road crossing	Needs assessment			1 - Delta	713452
18	Middle River	Temporary Rock Barrier – Middle River	San Joaquin	Dam	Temporal			1 - Delta	712740
18	Old River	Coney Island	San Joaquin	Road crossing	Needs assessment			1 - Delta	702115
18	Old River	Head Of Old River Barrier	San Joaquin	Dam	Temporal			1 - Delta	712739
18	Old River	Temporary Rock Barrier – Old River At Tracy	San Joaquin	Dam	Temporal			1 - Delta	712741
18	Paradise Cut	Paradise Dam	San Joaquin	Dam	Needs assessment			1 - Delta	720251
18	Sacramento River	DWR Pump Stand (Hood)	Sacramento	Diversion	Unscreened			1 - Delta	700389
18	Sacramento River	DWR Test Facility Intake Pipe (Hood)	Sacramento	Diversion	Unscreened			1 - Delta	700390
18	Ulatis Creek	Maine Prairie Water District	Solano	Dam	Temporal			1 - Delta	703002
18	Unnamed Tributary	Clifton Court Forebay	Contra Costa	Dam	Needs assessment			1 - Delta	719749
18	Unnamed Tributary	Maine Prairie [3]	Solano	Dam	Needs assessment			1 - Delta	719341

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
19	Cross-Canal	Coppin Dam	Sutter	Dam	Temporal			2 - Lower Sacramento River	704926
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703978
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703976
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703975
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703977
19	East Borrow Canal	DWR #3 Old	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704176
19	East Borrow Canal	DWR #3 Old	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704177
19	East Borrow Canal	DWR Pumping Station #1 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704187
19	East Borrow Canal	DWR Pumping Station #2 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704179
19	East Borrow Canal	DWR Pumping Station #2 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704180
19	East Borrow Canal	DWR Pumping Station #2 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704183

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
19	East Borrow Canal	DWR Pumping Station #2 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704178
19	East Borrow Canal	DWR Pumping Station #3 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704173
19	East Borrow Canal	DWR Pumping Station #3 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704174
19	East Borrow Canal	DWR Pumping Station #3 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704175
19	East Borrow Canal	DWR Pumping Station #3 New	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704172
19	East Borrow Canal	DWR Station #1 Old	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704186
19	East Borrow Canal	DWR Station #1 Old	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704185
19	East Borrow Canal	DWR Station #2 Old	Sutter	Diversion	Unscreened			2 - Lower Sacramento River	704184
19	Sacramento River	Elkhorn Weir (Historical)	Yolo	Dam	Structure may not be in existence			2 - Lower Sacramento River	720163
19	Sacramento River	Sac 80 HOV California Department of Transportation Fish Passage Project	Sacramento	Road crossing	Needs assessment			2 - Lower Sacramento River	735370

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
19	West Borrow Canal	Butte Slough Irrigation Co., Weir 5	Sutter	Dam	Needs assessment			2 - Lower Sacramento River	703954
19	West Borrow Canal	Frank Guisti, Weir	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703956
19	West Borrow Canal	Frank Guisti, Weir	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703957
19	West Borrow Canal	Weir 1	Sutter	Dam	Needs assessment			2 - Lower Sacramento River	703959
20	Craig Creek	Hwy 99 Fish Passage Project	Tehama	Road crossing	Needs assessment			3 - Middle Sacramento River	737012
20	Stony Creek	Culvert	Glenn	Road crossing	Needs assessment			3 - Middle Sacramento River	717652
21	Sacramento River	Anderson Cottonwood Dam (ACID)	Shasta	Dam	Partial			4 - Upper Sacramento River	718712
21	Sacramento River	Middle Stake Fish Weir (Historical)	Shasta	Dam	Structure may not be in existence			4 - Upper Sacramento River	720231
22	American River	Folsom Left Wing	Sacramento	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	719927
22	American River	Folsom Prison	Sacramento	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	716173
22	American River	Nimbus Dam	Sacramento	Dam	Total			5 - Northern Sierra Nevada Diversity Group	718794

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
22	Butte Creek	Driver Cut Weir	Sutter	Dam	Partial			5 - Northern Sierra Nevada Diversity Group	703757
22	Butte Creek	RD 833	Sutter	Dam	Partial			5 - Northern Sierra Nevada Diversity Group	703756
22	Feather River	Fthrrv_D1_38.485_09	Sutter	Dam	Temporal			5 - Northern Sierra Nevada Diversity Group	717632
22	Mallard Slough	White Mallard Duck Club	Colusa	Road crossing	Needs assessment			5 - Northern Sierra Nevada Diversity Group	703776
22	Mallard Slough	White Mallard Duck Club	Colusa	Road crossing	Needs assessment			5 - Northern Sierra Nevada Diversity Group	703778
22	Natomas East Main Drainage Canal	Pumping Plant	Sacramento		Needs assessment			5 - Northern Sierra Nevada Diversity Group	
22	North Fork American River	Diversion	Placer	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	716129
22	North Fork Feather River	Big Bend Dam	Butte	Dam	Temporal			5 - Northern Sierra Nevada Diversity Group	715750
22	North Yuba River	Colgate Head	Yuba	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	716398
22	South Fork American River	Natomas Diversion	El Dorado	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	715794
22	South Fork Feather River	Ponderosa Dam	Butte	Dam	Total			5 - Northern Sierra Nevada Diversity Group	737345

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
23	Stony Creek	Dam	Glenn	Dam	Needs assessment			7 - Northwestern California Diversity Group	717644
23	Stony Creek	Dam	Tehama	Dam	Needs assessment			7 - Northwestern California Diversity Group	717641
23	Stony Creek	Stony Creek Gravel Dam	Glenn	Dam	Needs assessment			7 - Northwestern California Diversity Group	718714
23	Stony Creek	Tehama-Colusa Irrigation	Glenn	Road crossing	Needs assessment			7 - Northwestern California Diversity Group	717650
23	Stony Creek	Tehama-Colusa Irrigation	Glenn	Road crossing	Needs assessment			7 - Northwestern California Diversity Group	717648
24	Merced River	Ingalsbe Slough Dam	Merced	Dam	Needs assessment			8 - Southern Sierra Diversity Group	737067
24	Merced River	Merced Falls Dam	Merced	Dam	Needs assessment			8 - Southern Sierra Diversity Group	718982
24	Merced River	Mrcdrv_D1_47.189_09	Merced	Flood control channel	Needs assessment			8 - Southern Sierra Diversity Group	737068
24	Mokelumne River	Woodbridge Diversion Dam	San Joaquin	Dam	Partial			8 - Southern Sierra Diversity Group	718813
24	Mosher Slough	Bear Creek Diversion Dam	San Joaquin	Dam	Partial			8 - Southern Sierra Diversity Group	704500

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	Mosher Slough	Lyon Dam	San Joaquin	Dam	Partial			8 - Southern Sierra Diversity Group	704495
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704525
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704549
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704665
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704546
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704534
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704527
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704526
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704550
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704533
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704606
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704641

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704605
24	San Joaquin River	Culvert	Merced	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704677
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704606
24	San Joaquin River	Culvert	Merced	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704687
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704585
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704665
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704548
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704548
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704666
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704666
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704550
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704549

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704534
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704527
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704525
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704526
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704546
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704585
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704605
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704641
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704533
24	San Joaquin River	Helm Canal	Fresno	Dam	Needs assessment			8 - Southern Sierra Diversity Group	704667
24	San Joaquin River	Patterson	Stanislaus	Dam	Needs assessment			8 - Southern Sierra Diversity Group	716338
24	San Joaquin River	Stevenson Weir	Merced	Dam	Needs assessment			8 - Southern Sierra Diversity Group	715956

Table 9C.2-1. Prioritized Known and Potential Fish Passage Barriers and DWR-Owned Diversions in the Systemwide Planning Area (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	Stanislaus River	Stnsrv_D1_5.719_09	San Joaquin	Flood control channel	Needs assessment			8 - Southern Sierra Diversity Group	737171
24	Tuolumne River	Dennett Dam	Stanislaus	Dam	Partial			8 - Southern Sierra Diversity Group	
24	Unnamed Tributary	Davis No 2	San Joaquin	Dam	Needs assessment			8 - Southern Sierra Diversity Group	719242
25	Cache Creek	Capay Dam	Yolo	Dam	Needs assessment			--	720131
25	Cache Creek	Clear Lake	Lake	Dam	Needs assessment			--	720062
25	Cache Creek	Clear Lake Imp Dam	Lake	Dam	Needs assessment			--	718900
25	Cache Creek	Moore Dam	Yolo	Dam	Needs assessment			--	720237
25	Cache Creek	Rayhouse Road Crossing	Yolo	Road crossing	Needs assessment			--	717208
25	Cache Creek	Yolo Co. Flood Control	Yolo	Dam	Partial			--	717186

Notes:
[1] A new fish ladder was installed at Willow Slough Weir in 2010. As long as the ladder evaluation confirms that it meets NOAA Fisheries and DFG fish passage criteria, this structure will no longer be a barrier.
[2] Fremont Weir is on the short-term and moderate-term lists. Interim passage could be provided within 1 year. Permanent fish passage may take longer than 5 years because of the project's complexity, level of controversy, and participation of willing partners.
[3] The fish passage plan for the Yolo Bypass should address providing passage at Fremont Weir, Lisbon Weir, numerous structures within the Toe Drain, Tule Canal, and South Fork of Putah Creek, and address straying upstream through the Knights Landing Ridge Cut and the interaction of the Knights Landing Ridge Cut Outfall Gates.
[4] A new fish ladder is being installed at Weir No. 2 in 2011 and 2012.
[5] Because the Calaveras River downstream of New Hogan Dam already has the potential (with passage and flow improvements) to support a viable steelhead population, passage upstream of New Hogan Dam is currently not a high priority for NOAA Fisheries (pers.com. B. Ellrott 2011). DWR staff left New Hogan Dam as Priority 2 because that is how it is listed by NOAA (2009a). New Hogan Dam should be moved to a lower priority for implementation.

Key:
CVRP = Central Valley Recovery Plan
DFG = California Department of Fish and Game
ID = Identification Number
HOV = Highway Occupancy Vehicle
PAD = Passage Assessment Database
S.F. = South Fork
SPFC = State Plan of Flood Control

Table 9C.2-2. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 5 Years

Rank	Stream	Site	County	Status	Type	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
1	East Borrow Canal	Willow Slough Weir[1]	Sutter	Temporal	Dam	1	X	2 - Lower Sacramento River	737025
1	East Borrow Canal	Weir No. 2[3]	Sutter	Partial	Dam	1	X	2 - Lower Sacramento River	703964
1	Sacramento River	Fremont Weir[2]	Yolo	Temporal	Dam	1	X	2 - Lower Sacramento River	704343
2	S.F. Putah Creek	DFG (Yolo)	Yolo	Needs assessment	Road crossing	1		1 - Delta	704788
2	S.F. Putah Creek	DFG (Yolo)	Yolo	Needs assessment	Road crossing	1		1 - Delta	704789
2	S.F. Putah Creek	Weir	Yolo	Needs assessment	Dam	1		1 - Delta	704775
2	S.F. Putah Creek Side Chan	DFG (Yolo)	Yolo	Needs assessment	Road crossing	1		1 - Delta	704794
2	S.F. Putah Creek Side Chan	DFG (Yolo)	Yolo	Needs assessment	Road crossing	1		1 - Delta	704795
2	Toe Drain	Culvert	Yolo	Needs assessment	Road crossing	1		1 - Delta	704338
2	Toe Drain	Culvert	Yolo	Needs assessment	Road crossing	1		1 - Delta	704342
2	Toe Drain	Culvert	Yolo	Needs assessment	Road crossing	1		1 - Delta	704448
2	Toe Drain	Culvert	Yolo	Needs assessment	Road crossing	1		1 - Delta	704451
2	Toe Drain	Culvert	Yolo	Needs assessment	Road crossing	1		1 - Delta	704452
2	Toe Drain	Culvert/Flashboard	Yolo	Needs assessment	Road crossing	1		1 - Delta	704449

Table 9C.2-2. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 5 Years (contd.)

Rank	Stream	Site	County	Status	Type	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
2	Toe Drain	Culvert/Flashboard	Yolo	Needs assessment	Road crossing	1		1 - Delta	704450
2	Toe Drain	Lisbon Weir	Yolo	Partial	Dam	1		1 - Delta	
2	Tule Canal	Culvert	Yolo	Temporal		1		1 - Delta	
2	Tule Canal	Wallace Weir	Yolo	Temporal	Dam	1		1 - Delta	
4	Sacramento River	Red Bluff Diversion Dam	Tehama	Partial	Dam	1		4 - Upper Sacramento River	718713
6	Mormon Slough	Caprini Low-Flow Road Crossing	San Joaquin	Temporal	Road crossing	1		8 - Southern Sierra Diversity Group	735110
6	Stockton Diverting Canal	Budiselich Dam	San Joaquin	Temporal	Dam	1		8 - Southern Sierra Diversity Group	735107

Notes:
[1] A new fish ladder was installed at Willow Slough Weir in 2010. As long as the ladder evaluation confirms that it meets NOAA Fisheries and DFG fish passage criteria, this structure will no longer be a barrier.
[2] Fremont Weir is on the short-term and moderate-term lists. Interim passage could be provided within 1 year. Permanent fish passage may take longer than 5 years because of the project's complexity, level of controversy, and participation of willing partners.
[3] A new fish ladder is being installed at Weir No. 2 in 2011 and 2012.

Key:
CVRP = Central Valley Recovery Plan
DFG = California Department of Fish and Game
ID = Identification Number
PAD = Passage Assessment Database
S.F. = South Fork
SPFC = State Plan of Flood Control

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
1	Sacramento River	Fremont Weir[1]	Yolo	Dam	Temporal	1	X	2 - Lower Sacramento River	704343
1	Sacramento River	Sacramento Weir	Yolo	Dam	Needs assessment	1	X	2 - Lower Sacramento River	700222
4	Sacramento River	Keswick Dam	Shasta	Dam	Total	1		4 - Upper Sacramento River	718711
4	Sacramento River	Shasta Dam	Shasta	Dam	Total	1		4 - Upper Sacramento River	718710
5	American River	Folsom Dam	Sacramento	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718795
6	Calaveras River	Calaveras Headworks	San Joaquin	Dam	Total	1		8 - Southern Sierra Diversity Group	735098
6	Calaveras River	Cherryland Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735090
6	Calaveras River	Dam	Calaveras	Dam	Partial	1		8 - Southern Sierra Diversity Group	704310
6	Calaveras River	Deteriorated Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735104
6	Calaveras River	Eight Mile Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735094
6	Calaveras River	Gotelli #1 Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735097
6	Calaveras River	Gotelli Low-Flow Road Crossing (River Mile 35.3)	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735105
6	Calaveras River	Gotelli Low-Flow Road Crossing (River Mile 6.2)	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735088

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	Calaveras River	Gravel Pit Pond	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735100
6	Calaveras River	McAllen Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735089
6	Calaveras River	McGurk Earth Dam	San Joaquin	Dam	Temporal & Partial	1		8 - Southern Sierra Diversity Group	737024
6	Calaveras River	McGurk Low-Flow Road Crossing	San Joaquin	Road crossing	Partial	1		8 - Southern Sierra Diversity Group	735099
6	Calaveras River	Murphy Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735093
6	Calaveras River	New Hogan Dam Road Bridge	Calaveras	Dam	Partial	1		8 - Southern Sierra Diversity Group	704323
6	Calaveras River	Old Dog Ranch Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735102
6	Calaveras River	Old DWR Stream Gauge Weir	San Joaquin	Flow measurement weir	Temporal	1		8 - Southern Sierra Diversity Group	737023
6	Calaveras River	Old Wooden Bridge	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735087
6	Calaveras River	Pezzi Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735092
6	Calaveras River	Rubble Dam Upstream from Bellota Weir	Stanislaus	Dam	Temporal	1		8 - Southern Sierra Diversity Group	704320
6	Calaveras River	Solari Ranch Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735091
6	Calaveras River	Tully Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735095

Table9 C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	Calaveras River	Williams Crossing	San Joaquin	Road crossing	Needs assessment	1		8 - Southern Sierra Diversity Group	735103
6	Calaveras River	Wilson's Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735101
6	Mormon Slough	Avansino Street Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735121
6	Mormon Slough	Bellota Weir	San Joaquin	Dam	Partial	1		8 - Southern Sierra Diversity Group	703864
6	Mormon Slough	Bonomo Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735118
6	Mormon Slough	Fine Road Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735122
6	Mormon Slough	Fujinaka Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735114
6	Mormon Slough	Highway 26 Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735123
6	Mormon Slough	Hosie Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735120
6	Mormon Slough	Hosie Low-Flow Road Crossing	San Joaquin	Road crossing	Temporal	1		8 - Southern Sierra Diversity Group	735119
6	Mormon Slough	Lavaggi Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735111
6	Mormon Slough	Main Street Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735108
6	Mormon Slough	Panella Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735109

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
6	Mormon Slough	Piazza Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735117
6	Mormon Slough	Prato Flashboard Dam	San Joaquin	Dam	Temporal	1		8 - Southern Sierra Diversity Group	735115
6	Mosher Slough	Webster Dam	San Joaquin	Dam	Partial	1		8 - Southern Sierra Diversity Group	704472
6	San Joaquin River	Sack Dam	Fresno	Dam	Partial	1		8 - Southern Sierra Diversity Group	704635
6	Stanislaus River	Goodwin Dam	Calaveras	Dam	Total	1		8 - Southern Sierra Diversity Group	718977
6	Stanislaus River	New Melones Dam	Tuolumne	Dam	Total	1		8 - Southern Sierra Diversity Group	718821
6	Stanislaus River	Tulloch Dam	Tuolumne	Dam	Total	1		8 - Southern Sierra Diversity Group	718976
6	Stockton Diversion Canal	Central Traction Railroad crossing	San Joaquin	Bridge	Partial	1		8 – Southern Sierra Diversity Group	
7	Sacramento River	Tisdale Weir	Sutter	Dam	Temporal	2	X	2 - Lower Sacramento River	720308
10	Dry Creek	Culvert	Sacramento	Road crossing	Needs assessment	2		2 - Lower Sacramento River	717226
11	Big Chico Creek	One Mile Dam With Pool Fish Ladder	Butte	Dam	Temporal	2		5 - Northern Sierra Nevada Diversity Group	704198
11	Yuba River	Daguerre Point Dam	Yuba	Dam	Partial	2		5 - Northern Sierra Nevada Diversity Group	720147
13	Merced River	Crocker Diversion Dam (Snelling)	Merced	Dam	Temporal	2		8 - Southern Sierra Diversity Group	718981

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
13	San Joaquin River	Mendota Pool Dam And Diversion	Madera	Dam	Partial	2		8 - Southern Sierra Diversity Group	718840
14	Sacramento River	Colusa Weir	Colusa	Dam	Needs assessment		X	2 - Lower Sacramento River	720139
15	Big Chico Creek	Big Chico Flood Control	Butte	Dam	Partial		X	5 - Northern Sierra Nevada Diversity Group	704194
15	Feather River, N Fork	Chester Diversion Dam	Plumas	Dam	Partial		X	5 - Northern Sierra Nevada Diversity Group	718744
16	San Joaquin River	Sand Slough Control Structure	Merced	Dam	Partial		X	8 - Southern Sierra Diversity Group	704663
18	Cache Slough	Culvert	Solano	Road crossing	Needs assessment			1 - Delta	702936
18	Grizzly Slough	Culvert	Sacramento	Road crossing	Needs assessment			1 - Delta	703342
18	Lindsey Slough	Harry Petersen	Solano	Road crossing	Needs assessment			1 - Delta	702950
18	Marsh Creek	Private Ford	Contra Costa	Road crossing	Needs assessment			1 - Delta	713452
18	Middle River	Temporary Rock Barrier – Middle River	San Joaquin	Dam	Temporal			1 - Delta	712740
18	Old River	Coney Island	San Joaquin	Road crossing	Needs assessment			1 - Delta	702115
18	Old River	Head Of Old River Barrier	San Joaquin	Dam	Temporal			1 - Delta	712739
18	Old River	Temporary Rock Barrier – Old River At Tracy	San Joaquin	Dam	Temporal			1 - Delta	712741

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
18	Paradise Cut	Paradise Dam	San Joaquin	Dam	Needs assessment			1 - Delta	720251
18	Ulatis Creek	Maine Prairie Water District	Solano	Dam	Temporal			1 - Delta	703002
18	Unnamed Tributary	Clifton Court Forebay	Contra Costa	Dam	Needs assessment			1 - Delta	719749
18	Unnamed Tributary	Maine Prairie[3]	Solano	Dam	Needs assessment			1 - Delta	719341
19	Cross-Canal	Coppin Dam	Sutter	Dam	Temporal			2 - Lower Sacramento River	704926
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703978
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703977
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703976
19	East Borrow Canal	Culvert/Flashboard	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703975
19	Sacramento River	Sac 80 HOV California Department of Transportation Fish Passage Project	Sacramento	Road crossing	Needs assessment			2 - Lower Sacramento River	735370
19	West Barrow	Butte Slough Irrigation Co., Weir 5	Sutter	Dam	Needs assessment			2 - Lower Sacramento River	703954
19	West Barrow	Frank Guisti, Weir	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703957
19	West Barrow	Frank Guisti, Weir	Sutter	Road crossing	Needs assessment			2 - Lower Sacramento River	703956

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
19	West Barrow	Weir 1	Sutter	Dam	Needs assessment			2 - Lower Sacramento River	703959
20	Craig Creek	Hwy 99 Fish Passage Project	Tehama	Road crossing	Needs assessment			3 - Middle Sacramento River	737012
20	Stony Creek	Culvert	Glenn	Road crossing	Needs assessment			3 - Middle Sacramento River	717652
21	Sacramento River	Anderson Cottonwood Dam (ACID)	Shasta	Dam	Partial			4 - Upper Sacramento River	718712
22	American River	Folsom Left Wing	Sacramento	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	719927
22	American River	Folsom Prison	Sacramento	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	716173
22	American River	Nimbus Dam	Sacramento	Dam	Total			5 - Northern Sierra Nevada Diversity Group	718794
22	Butte Creek	Driver Cut Weir	Sutter	Dam	Partial			5 - Northern Sierra Nevada Diversity Group	703757
22	Butte Creek	RD 833	Sutter	Dam	Partial			5 - Northern Sierra Nevada Diversity Group	703756
22	Feather River	Fthrrv_D1_38.485_09	Sutter	Dam	Temporal			5 - Northern Sierra Nevada Diversity Group	717632
22	Mallard Slough	White Mallard Duck Club	Colusa	Road crossing	Needs assessment			5 - Northern Sierra Nevada Diversity Group	703778
22	Mallard Slough	White Mallard Duck Club	Colusa	Road crossing	Needs assessment			5 - Northern Sierra Nevada Diversity Group	703776

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
22	North Fork American River	Diversion	Placer	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	716129
22	North Fork Feather River	Big Bend Dam	Butte	Dam	Temporal			5 - Northern Sierra Nevada Diversity Group	715750
22	North Yuba River	Colgate Head	Yuba	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	716398
22	South Fork American River	Natomas Diversion	El Dorado	Dam	Needs assessment			5 - Northern Sierra Nevada Diversity Group	715794
23	Natomas East Main Drainage Canal	Pumping Plant	Sacramento		Needs assessment			5 – Northern Sierra Nevada Diversity Group	
23	Stony Creek	Dam	Glenn	Dam	Needs assessment			7 - Northwestern California Diversity Group	717644
23	Stony Creek	Dam	Tehama	Dam	Needs assessment			7 - Northwestern California Diversity Group	717641
23	Stony Creek	Stony Creek Gravel Dam	Glenn	Dam	Needs assessment			7 - Northwestern California Diversity Group	718714
23	Stony Creek	Tehama-Colusa Irrigation	Glenn	Road crossing	Needs assessment			7 - Northwestern California Diversity Group	717650
23	Stony Creek	Tehama-Colusa Irrigation	Glenn	Road crossing	Needs assessment			7 - Northwestern California Diversity Group	717648
24	Merced River	Ingalsbe Slough Dam	Merced	Dam	Needs assessment			8 - Southern Sierra Diversity Group	737067

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	Merced River	Merced Falls Dam	Merced	Dam	Needs assessment			8 - Southern Sierra Diversity Group	718982
24	Merced River	Mrcdrv_D1_47.189_09	Merced	Flood control channel	Needs assessment			8 - Southern Sierra Diversity Group	737068
24	Mokelumne River	Woodbridge Diversion Dam	San Joaquin	Dam	Partial			8 - Southern Sierra Diversity Group	718813
24	Mosher Slough	Bear Creek Diversion Dam	San Joaquin	Dam	Partial			8 - Southern Sierra Diversity Group	704500
24	Mosher Slough	Lyon Dam	San Joaquin	Dam	Partial			8 - Southern Sierra Diversity Group	704495
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704666
24	San Joaquin River	Culvert	Merced	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704677
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704549
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704550
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704550
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704665
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704548
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704666

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704548
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704585
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704585
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704605
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704605
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704606
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704606
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704665
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704527
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704641
24	San Joaquin River	Culvert	Merced	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704687
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704525
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704525

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704526
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704549
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704527
24	San Joaquin River	Culvert	Madera	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704641
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704533
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704533
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704534
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704534
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704546
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704546
24	San Joaquin River	Culvert	Fresno	Road crossing	Needs assessment			8 - Southern Sierra Diversity Group	704526
24	San Joaquin River	Helm Canal	Fresno	Dam	Needs assessment			8 - Southern Sierra Diversity Group	704667
24	San Joaquin River	Patterson	Stanislaus	Dam	Needs assessment			8 - Southern Sierra Diversity Group	716338

Table 9C.2-3. Fish Passage Actions Within the Systemwide Planning Area That Should be Implemented Within 10 Years (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
24	San Joaquin River	Stevenson Weir	Merced	Dam	Needs assessment			8 - Southern Sierra Diversity Group	715956
24	Stanislaus River	Stnsrv_D1_5.719_09	San Joaquin	Flood control channel	Needs assessment			8 - Southern Sierra Diversity Group	737171
24	Unnamed Tributary	Davis No 2	San Joaquin	Dam	Needs assessment			8 - Southern Sierra Diversity Group	719242
25	Cache Creek	Capay Dam	Yolo	Dam	Needs assessment			--	720131
25	Cache Creek	Clear Lake	Lake	Dam	Needs assessment			--	720062
25	Cache Creek	Clear Lake Imp Dam	Lake	Dam	Needs assessment			--	718900
25	Cache Creek	Moore Dam	Yolo	Dam	Needs assessment			--	720237
25	Cache Creek	Rayhouse Road Crossing	Yolo	Road crossing	Needs assessment			--	717208
25	Cache Creek	Yolo Co. Flood Control	Yolo	Dam	Partial			--	717186
25	Tuolumne River	Dennett Dam	Stanislaus	Dam	Partial			8 – Southern Sierra Diversity Group	

Notes:
[1] Fremont Weir is on the short-term and moderate-term lists. Interim passage could be provided within 1 year. Permanent fish passage may take longer than 5 years because of the project's complexity, level of controversy, and participation of willing partners.

Key:
CVRP = Central Valley Recovery Plan
DWR = California Department of Water Resources
ID = Identification Number
PAD = Passage Assessment Database
RD = Reclamation District
SPFC = State Plan of Flood Control

Table 9C.2-4. Long-Term Fish Passage Actions Within the Systemwide Planning Area That Require Work Beginning in 2012 Through 2022 or Longer

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
5	Mokelumne River	Camanche Main Dam	San Joaquin	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718812
5	Mokelumne River	Pardee Dam	Calaveras	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718827
5	North Yuba River	New Bullards Bar Dam	Yuba	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718761
5	Yuba River	Harry L. Englebright Dam	Nevada	Dam	Total	1		5 - Northern Sierra Nevada Diversity Group	718765
6	Tuolumne River	Don Pedro Main Dam	Tuolumne	Dam	Total	1		8 - Southern Sierra Diversity Group	718978
6	Tuolumne River	La Grange Dam	Stanislaus	Dam	Total	1		8 - Southern Sierra Diversity Group	718979
8	Feather River	Fish Barrier Dam	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	718748
8	Feather River	Oroville Dam	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	718746
8	Feather River	Thermalito Diversion Dam	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	718747
8	Unnamed Tributary	Thermalito Afterbay	Butte	Dam	Total	2	X	5 - Northern Sierra Nevada Diversity Group	719986
12	Stony Creek	Black Butte Dam	Tehama	Dam	Total	2		7 - Northwestern California Diversity Group	718715

Table 9C.2-4. Long-Term Fish Passage Actions Within the Systemwide Planning Area That Require Work Beginning in 2012 Through 2022 or Longer (contd.)

Rank	Stream	Site	County	Type	Status	CVRP Priority	SPFC Component	CVRP Geographic Priority	PAD ID
13	Calaveras River	New Hogan Dam[1]	Calaveras	Dam	Total	2		8 - Southern Sierra Diversity Group	718828
13	Merced River	Exchequer Main Dam	Mariposa	Dam	Total	2		8 - Southern Sierra Diversity Group	718975
13	Merced River	Mcswain Dam	Mariposa	Dam	Total	2		8 - Southern Sierra Diversity Group	718983
13	San Joaquin River	Friant Dam	Fresno	Dam	Total	2		8 - Southern Sierra Diversity Group	718954
17	Cache Creek	Cache Creek Settling Basin	Yolo	Dam	Total		X	--	719846
22	South Fork Feather River	Ponderosa Dam	Butte	Dam	Total			5 - Northern Sierra Nevada Diversity Group	737345

Notes:
[1] Because the Calaveras River downstream of New Hogan Dam already has the potential (with passage and flow improvements) to support a viable steelhead population, passage upstream of New Hogan Dam is currently not a high priority for NOAA Fisheries (pers.com. B. Ellrott 2011). DWR staff left New Hogan Dam as Priority 2 because that is how it is listed by NOAA Fisheries (2009a). New Hogan Dam should be moved to a lower priority for implementation.

Key:
CVRP = Central Valley Recovery Plan
DFG = California Department of Fish and Game
ID = Identification Number
HOV = Highway Occupancy Vehicle
PAD = Passage Assessment Database
S.F. = South Fork
SPFC = State Plan of Flood Control

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Attachment 9C.3. Prioritized List of Potential Stranding Areas in the Systemwide Planning Area

Prioritization of stranding areas is shown below. The interim prioritization process, as previously discussed, was used to prioritize stranding areas. The process recognizes the importance of stranding areas within the Systemwide Planning Area, as well as the Priority 1 actions and Geographic Priorities from the NOAA Fisheries (2009a) Recovery Plan (see Table 9C.3-1).

Table 9C.3-1. Prioritized List of Potential Stranding Areas in the Systemwide Planning Area

SPFC Component	CVRP Priority	CVRP Geographic Priority	Site	Rank
X	1	2	Yolo Bypass	1
X	1	2	Sacramento Bypass	1
	1	2	American River side channels	2
	1	5	Yuba River side channels	3
	1	8	Stanislaus River (gravel pits)	4
	1	8	Tuolumne River gravel pits	4
X		2	Colusa Basin Drain	5
X		4	Colusa Bypass	6
X		4	Tisdale Bypass	6
X		8	Chowchilla Bypass system	7
		8	Merced River gravel pits	8
	Depends	8,0, or 1	San Joaquin gravel pits[18] (More detail needed on exact locations)	To be determined

Key:
CVRP = Central Valley Recovery Plan
SPFC = State Plan of Flood Control

[18] It is known that the San Joaquin River contains in-channel and captured pits that have the potential to strand salmon (Mussetter Engineering, Inc., 2005). However, DWR did not have enough information to delineate specific pits on Figure 7-3 or in Table 9C.3-1. Therefore, the entire San Joaquin River is marked as a potential stranding site.

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THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CENTRAL VALLEY
FLOOD MANAGEMENT
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2012 Central Valley Flood Protection Plan

A Path for Improving Public Safety, Environmental Stewardship, and Long-Term Economic Stability

Volume V–Part 2
Attachments 9D through 9G

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

PUBLIC SAFETY ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

2012 Central Valley Flood Protection Plan

Public Draft, January 2012

Volume V – Part 2 Attachments 9D Through 9G

Table of Contents

Attachment 9D Improving Vegetation Data

Attachment 9E Existing Conservation Objectives from Other Plans

Attachment 9F Floodplain restoration Opportunity Analysis

Attachment 9G Regional Permitting Options

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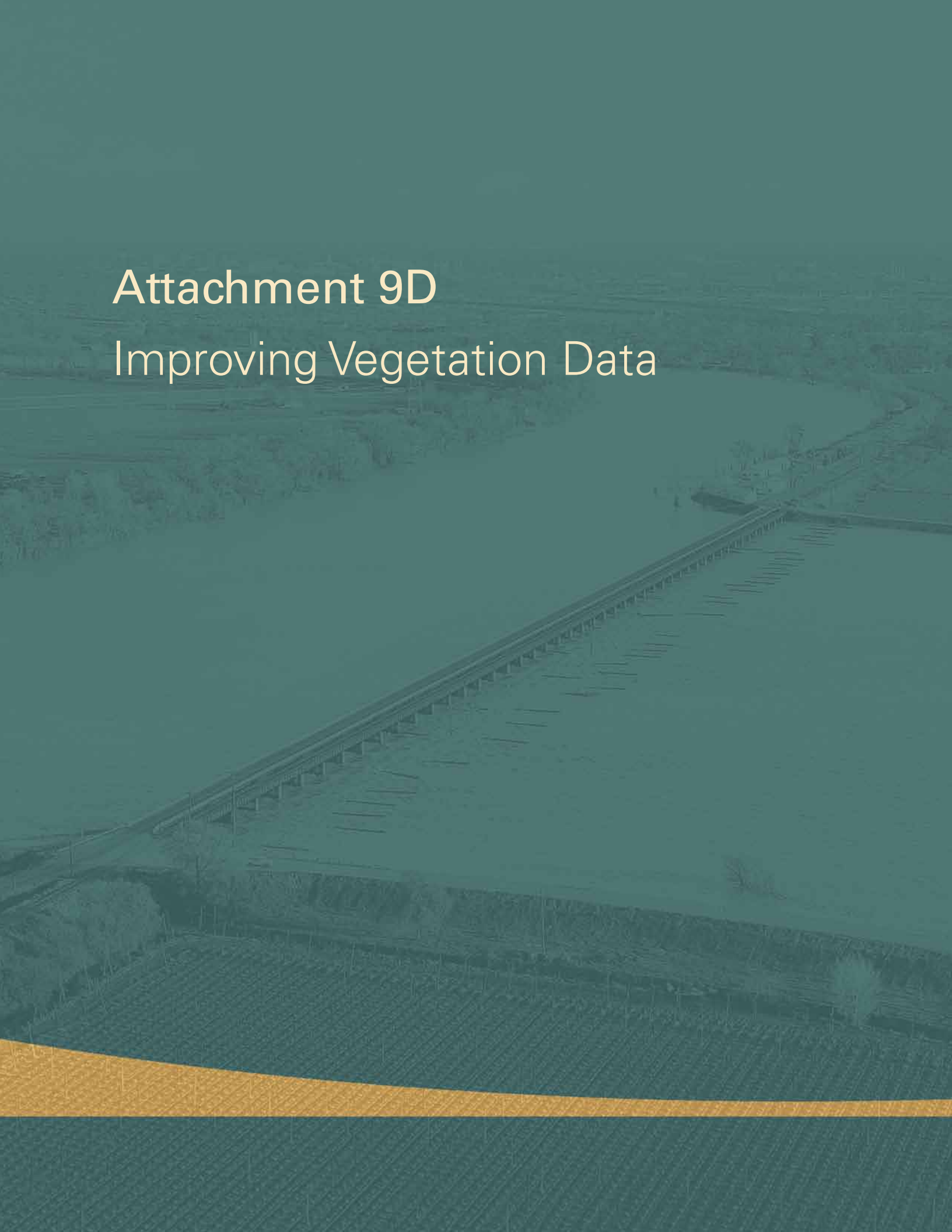
Attachment 9D

Improving Vegetation Data



CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

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Public Draft

2012 Central Valley Flood Protection Plan

Attachment 9D: Improving Vegetation Data

January 2012

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DEPARTMENT OF WATER RESOURCES

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Table of Contents

1.0 Introduction 1-1

2.0 Background and Need for Higher Quality Vegetation Data 2-1

3.0 Past Vegetation Mapping Efforts Within the Central Valley 3-1
- 3.1 Statewide and National Efforts 3-1
- 3.2 Central Valley-Focused Mapping Efforts 3-2

4.0 Statewide Mapping Standards and Consistency 4-1

5.0 DWR's Approach and Progress in Improving Vegetation Data 5-1
- 5.1 Medium-Scale Map and Methodology 5-1
- 5.2 Fine-Scale Mapping 5-5

6.0 References 6-1

7.0 Acronyms and Abbreviations 7-1

List of Figures

Figure 5-1. Medium-Scale Vegetation Mapping Overview for Lower Feather River 5-3

Figure 5-2. Map Application: Close-up of Medium-Scale Vegetation Polygons on Levee 5-4

Figure 5-3. Fine-Scale Vegetation Types in the Delta Illustrating 42 Vegetation Alliances 5-6

Figure 5-4. Medium-Scale Polygons of Riparian Wash/Scrub, with Overlay of Fine-Scale Delineations of (1) Arroyo Willow, and (2) Arroyo Willow-Bulrush-Common Reed Complex Unit 5-7

Figure 5-5. Map Application: California Natural Diversity Database Species Occurrences with Associated Medium-Scale Vegetation Types 5-9

1.0 Introduction

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, the California Department of Water Resources (DWR) has prepared a sustainable, integrated flood management plan called the Central Valley Flood Protection Plan (CVFPP), for adoption by the Central Valley Flood Protection Board (Board). The 2012 CVFPP provides a systemwide approach to protecting lands currently protected from flooding by existing facilities of the State Plan of Flood Control (SPFC), and will be updated every 5 years.

As part of development of the CVFPP, a series of technical analyses were conducted to evaluate hydrologic, hydraulic, geotechnical, economic, ecosystem, and related conditions within the flood management system and to provide baseline data and to support formulation of system improvements. These analyses were conducted in the Sacramento River Basin, San Joaquin River Basin, and Sacramento-San Joaquin Delta (Delta).

DWR needs high-quality vegetation data to support informed planning decisions as part of the CVFPP and the associated Central Valley Flood System Conservation Strategy. To meet this need, DWR is working collaboratively with other agencies to develop a contiguous vegetation data set for the CVFPP Systemwide Planning Area. Despite the importance of this type of data, and the importance of riparian habitat in the State of California (State), no comprehensive Central Valley-wide map of riparian and floodplain vegetation has been available.

DWR is in the process of completing a seamless riparian vegetation map for the Sacramento and San Joaquin Rivers main-stems and tributaries within the CVFPP Systemwide Planning Area. Before the current effort, most riparian vegetation data sets for the study areas were incomplete, or were presented in a varying scales and resolutions. Some vegetation classifications used in earlier studies were not standardized, potentially limiting their usefulness when combined with other data sets. The current mapping efforts will provide baseline data for project impact analysis, and conservation and restoration area planning, and will enable use with other standardized vegetation data.

The purpose of this attachment is to describe the importance of high-quality vegetation data for improving flood management and ecosystem conditions in the Central Valley and to summarize other related mapping efforts. It will also describe DWR's approach, progress, and future steps for improving the quality of vegetation data.

2.0 Background and Need for Higher Quality Vegetation Data

Vegetation mapping continues to be a significant tool for quantifying natural lands and habitat, and for determining baseline habitat values. Medium- and fine-resolution vegetation maps delineate baseline natural vegetation and land uses, provide information on habitat values and connectivity, and may indicate potential for wildlife and sensitive species. Vegetation maps are important tools in natural resource and conservation planning, as well as data analysis. They provide a baseline for a wide range of data-gathering efforts.

Typical uses for vegetation mapping and delineation include identifying individual plant and animal species distributions, predicting the spread of invasive species, prioritizing land acquisitions for mitigation and restoration, identifying important wildlife corridors, setting a baseline for monitoring future impacts such as sea level rise, predicting habitat use by sensitive species, and identifying correlations (e.g., between vegetation and physical features) .

Current vegetation data may be combined with additional data sets in a Geographic Information System (GIS) and provides an important component which contributes to the baseline coverage of a study area. Such vegetation maps may be combined with soils, hydrology, and other physical features; these provide a current status of the system and enable modeling of future conditions. Vegetation data layers can help to inform planning, design work, maintenance, invasive species control, and ecological restoration. Such data document the current distribution of habitats and land uses, help establish baseline conditions for monitoring changes over time, and show the degree of connectivity and fragmentation of habitat

Mapping high-quality vegetation data provides important sets of information for improving planning for and management of flood and ecosystem conditions in the Central Valley. High-quality vegetation data are also useful for identifying both potential habitat for sensitive species and areas of potential infestations of invasive species. These data also are used to strategically identify important locations for conservation actions, such as restoration, habitat enhancement, and acquisitions.

Vegetation data are developed and used at different geographic scales to meet specific needs:

- **Medium-scale (or medium-resolution) data,** with minimum map units of about one acre, classify vegetation by plant associations and dominant species and are useful for regional-level assessments. These data simplify the complex details of localized habitat distribution and show planners and managers the larger context of vegetation patterns. Medium-resolution data can be used, for example, to strategically locate large infrastructure or development projects in ways that avoid or reduce environmental impacts, thus reducing future costs for project redesign, relocation, or mitigation. These data also help to assess landscape-level or watershed conditions and trends, and identify needs for improving regional habitat restoration and connectivity.

- **Fine-scale (or fine-resolution) vegetation data** are a more precise representation of localized vegetation distribution, with minimum mapping units of less than one acre. Fine-resolution data provide significantly more detail on vegetation structure and species relationships than medium-scale data, making these data valuable for project-level planning and management decisions. However, fine-scale data require considerably more detailed field evaluation and time investment, greater computer storage space, and longer analytical processing time than medium-scale data for the same size planning area.

Finally, although these are currently the best data available based on remote imagery, in some cases they may not always be adequate to substitute for highly detailed on-the-ground delineation. For example, identifying and quantifying shaded riverine aquatic habitat (SRA) requires more detailed ground work since there are layers of canopy and vegetation which can't be determined only from aerial photo interpretation. High-quality vegetation maps in this case can support the more detailed field studies necessary for delineating SRA.

3.0 Past Vegetation Mapping Efforts Within the Central Valley

Over the years, State and federal agencies in California have funded a variety of vegetation and land cover mapping efforts. To guide the best use of DWR funding for improving vegetation data, this section evaluates these other efforts for their applicability and usefulness. Useful vegetation data must meet needs for systemwide coverage, adequate resolution of mapping units and classification types, adequate information (attributes) describing each mapping unit, and adequate accuracy.

3.1 Statewide and National Efforts

Statewide and national efforts to generate vegetation mapping data include the following:

- **Gap Analysis Vegetation Layer (Davis et al., 1998)** – This statewide dataset, completed in 1995, maps terrestrial vegetation and natural communities at a coarse scale, with a minimum map unit (MMU) of more than 250 acres. Local areas of vegetation were omitted because of the coarse resolution, and riparian vegetation was underestimated.

- **Central Valley Wetlands and Riparian Areas GIS Database (DFG, 1997)** – This data set is an inventory of wetlands, riparian areas, and associated land cover in the Sacramento and San Joaquin valleys and the Delta. Landsat satellite imagery was used to map land cover classes, such as wetland, agriculture, and uplands. Wetland and riparian features were inventoried at a coarse level but with less specificity than a field-based survey.

- **National Wetland Inventory (USFWS, 2010)** – The U.S. Fish and Wildlife Service mapped wetlands and woody riparian vegetation from aerial photographs. Vegetation was mapped with an MMU greater than one acre, and mapping of some areas of riparian habitat was omitted. This inventory is used for regional and watershed data display and analysis, rather than project-specific data analysis.

Although these efforts cover all of the CVFPP Systemwide Planning Area, they are mapped at coarser resolutions and classifications than DWR needs. The current DWR vegetation mapping effort can be used as a baseline, and

future conditions can be used to provide updated maps and measurements of restored acreage and impacts.

3.2 Central Valley-Focused Mapping Efforts

Higher resolution vegetation data coverage exists for a few portions of the CVFPP Systemwide Planning Area, but these data omit large areas of the entire flood management system. Some of the vegetation mapping efforts previously conducted in the Central Valley are listed below:

- **Sacramento River Region 2007 Sacramento River Riparian Mapping (Carlson and Funes, 2010)** – This large project covers the Sacramento River Conservation Area and was completed by the California State University, Chico, Geographical Information Center.

- **Sacramento-San Joaquin Delta – Vegetation and Land Use Classification and Map (Hickson and Keeler-Wolf 2007)** – These fine-resolution vegetation data were completed using a statewide standardized approach led by the California Department of Fish and Game (DFG). The same methodology was used that DWR will employ in developing its fine-resolution data for the Central Valley. These data cover only the legal Delta, so there is only limited overlap with the current DWR vegetation mapping effort. This map has been extensively for various planning efforts at several agencies, including the Bay-Delta Conservation Plan.

- **San Joaquin River Mapping Study (DWR, 2002)** – This study mapped riparian vegetation on portions of the main-stem San Joaquin River from Millerton Lake to the Merced River confluence. The study was field-based and transects were conducted to measure riparian vegetation. Riparian classifications are based on the Holland classification of California vegetation (Holland, 1986).

- **Central Valley Riparian Mapping Project Interpretation and Mapping Systems (California State University, Chico, 1979)** – The California Riparian Study Program was a series of studies started in 1979 that set out to map riparian areas within Central Valley depositional bottomland using aerial photographs. Work was completed at California State University, Chico, and California State University, Fresno.

4.0 Statewide Mapping Standards and Consistency

In 2000, the California Biodiversity Council (CBC) prepared a Memorandum of Understanding (MOU) among State and federal agencies to establish a cooperative vegetation and habitat mapping standard. Signatories recognized that many mapping efforts were ongoing and that these efforts could be designed to be compatible and complementary for eventually providing signatories statewide coverage of high-quality vegetation data. They also recognized the importance of vegetation mapping as a tool to provide valuable data for conservation and recreation planning and forest and economic analysis.

These statewide vegetation mapping standards (CBC, 2000) are available online at: http://ceres.ca.gov/biodiversity/vegmou.html.

DWR follows these cooperative vegetation mapping standards. The finer scale mapping effort further complies with the *Manual of California Vegetation* (Sawyer et al., 2009) and the National Vegetation Classification Standard (NVCS), as defined in the April 2003 Federal Geographic Data Committee draft standards Source (FGDC, 2008), available at http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation .

Consistency with these standards allows vegetation map data to be available for use across agencies, which, in turn, permits data sharing, provides for longevity of the data (data collected on a unique platform not consistent with others become obsolete more quickly), and for consistency with future mapping efforts and updates.

The State Wetland and Riparian Area Monitoring Program (WRAMP) outlines a standardized approach to wetland and riparian mapping within the State (Collins et al., 2006). The current DWR vegetation mapping effort is consistent with the standard methodology for WRAMP (CWMW, 2010). The statewide WRAMP effort will additionally be able to use the riparian data to contribute to their riparian model building and accuracy within the CVFPP Systemwide Planning Area.

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5.0 DWR's Approach and Progress in Improving Vegetation Data

DWR is developing high-quality vegetation data for Central Valley flood and ecosystem planning in two phases. The first phase, completed in December 2011 was to develop a medium-scale vegetation data set to help with systemwide planning. The second phase, initiated in late 2011 and proposed for completion in late 2013, will develop a fine-scale vegetation data set.

Both the medium- and fine-scale mapping of riparian vegetation for the CVFPP were based on current aerial photography and field studies. The methodology consisted of aerial photo interpretation, ground-based vegetation classifications, and GIS editing and processing. The riparian classification follows State and national standards for vegetation classification described above (CBC, 2000). The riparian classification also can be crosswalked to the widely-used Wildlife Habitat Relationship system (WHR) of habitat classification, (Mayer and Laudenslayer, 1988), allowing users to link both data systems.

5.1 Medium-Scale Map and Methodology

The recently completed effort undertaken by DWR represents the first medium-scale vegetation map to cover the entire CVFPP Systemwide Planning Area. Mapping was conducted for the main-stem Sacramento, Feather, and San Joaquin Rivers and major tributaries within the project area, as defined within the CVFPP Systemwide Planning Area. The project area covers approximately 3,315,582 acres or 5,180 square miles.

Although this map was not completed in time to be used in preparation of the 2012 CVFPP, it will be an important scientific foundation for the Central Valley Flood System Conservation Strategy, the 2017 CVFPP and for planning efforts in the interim. The map will be available for public access[1] after the 2012 CVFPP is released in early 2012. This medium-resolution product provides one- to two-acre MMU resolution for riparian areas and 10-acre resolution for urban and agricultural areas.

[1]Map data will be accessible at http:/bios.dfg.ca.gov

The medium-scale mapping effort was based in part on existing GIS riparian vegetation maps, which were prepared incrementally over the past decade for various parts of the Central Valley; field data were collected throughout the main-stems and tributary areas. Figure 5-1 illustrates an overview of the riparian map in the Feather River watershed.

The mapping method is based on aerial photo interpretation and field verification, and a standard methodology used by DFG. Existing vegetation maps were field-checked and updated to existing classification standards, and gaps in coverage were filled. Field surveys were used to validate the vegetation type and location on the ground. These vegetation plots were surveyed using the California Native Plant Society Rapid Assessment protocol (Hickson and Keeler-Wolf, 2007).

The area covered by each vegetation type or classifications was delineated in a GIS layer into polygons, which delineate the area covered by each vegetation type. These polygons were digitized using interpretation of 2009 color aerial photographs created by the U.S. Department of Agriculture's National Agricultural Imaging Program (USDA, 2009). Digitized polygons were attributed based on vegetation classifications developed in the Manual of Natural Vegetation (Sawyer et al., 2009) to the NVCS Group level (FDGC 2008). A final step included an independent validation and a random sample of plots for accuracy assessment. Figure 5-2 shows a close-up of medium-scale vegetation polygons on a local levee with typical riparian vegetation.

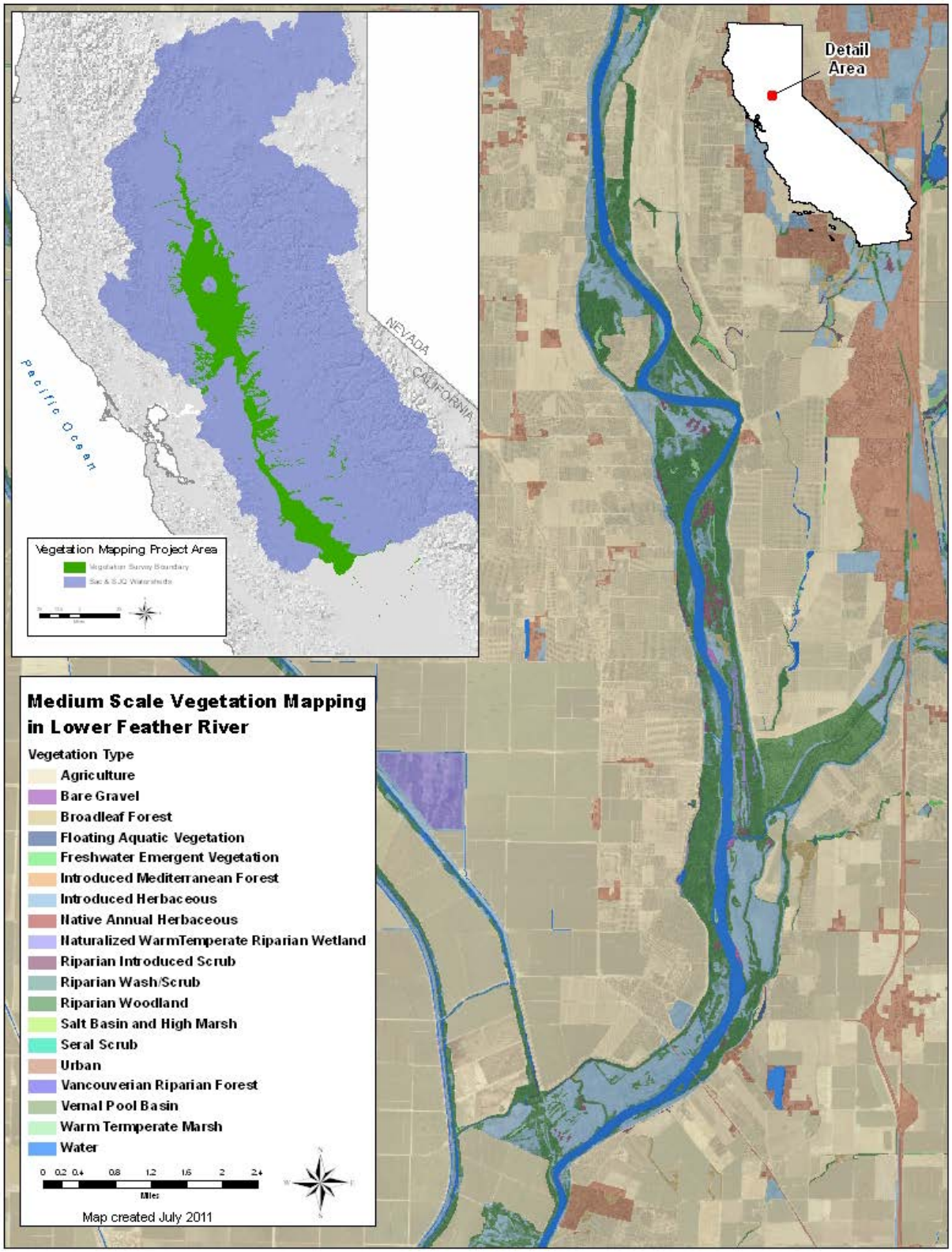

Figure 5-1. Medium-Scale Vegetation Mapping Overview for Lower Feather River

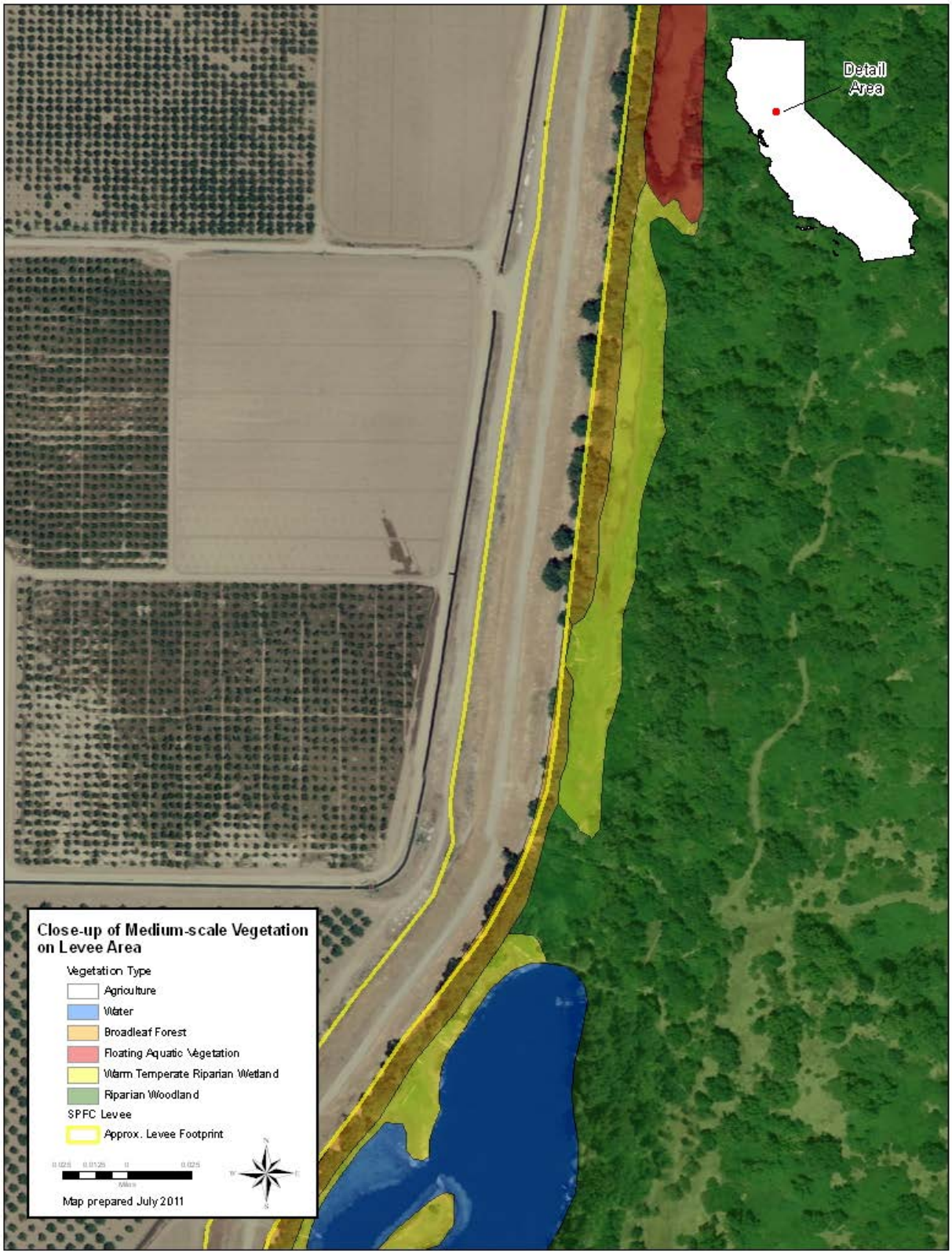

Figure 5-2. Map Application: Close-up of Medium-Scale Vegetation Polygons on Levee

5.2 Fine-Scale Mapping

DWR is currently developing fine-scale vegetation data for the CVFPP Systemwide Planning Area. Data collection began in summer 2011 and final map products and data are expected to be completed in 2013. This fine-scale vegetation mapping effort will use the statewide standardized approach for mapping fine-scale vegetation led by DFG (Hickson and Keeler-Wolf, 2007). Data will be provided at one-acre or less MMU resolution.

The fine-scale vegetation data will refine the area covered by the medium-scale data. Land use will be completed to the Anderson Level II classification (Anderson et al., 1976).

Fine-scale mapping will enable detailed area measurements of specific changes and impacts within project areas, restoration sites, or changes in land use. Components of the fine-scale map may also be used in wetland and riparian modeling efforts, such as the statewide WRAMP. The fine-scale effort will include detailed data sets on invasive species, structural components (tree and shrub cover, height, tree size), processes, and metrics for riparian function in hydrologic modeling.

These additional data will enable planning, data assessment, and impacts analysis at a detailed level. Map data can also be used for conservation planning at the species level: For example, sensitive species location data can be correlated with high, medium, or poorly suitable habitat. In addition, map data can be used to measure the extent of native vegetation on State Plan of Flood Control levees. Map data can be used to determine extent of invasive species, and the extent of selected canopy types can be differentiated and quantified according to size classes. The new riparian map coverage of the full CVFPP Systemwide Planning Area would enable regular updates, as necessary, to determine changes in vegetation status or trends.

Figures 5-3 and 5-4 provide examples of the differences between medium-scale mapping and fine-scale mapping. Figure 5- 3 shows vegetation at the more detailed fine-scale resolution. Figure 5-4 illustrates vegetation polygons mapped at the more general medium scale, with fine-scale delineations overlaid on the medium-scale mapped areas. These illustrate two vegetation alliances found in the Delta, (1) Arroyo Willow, and (2) Arroyo Willow-Bulrush-Common Reed complex unit.

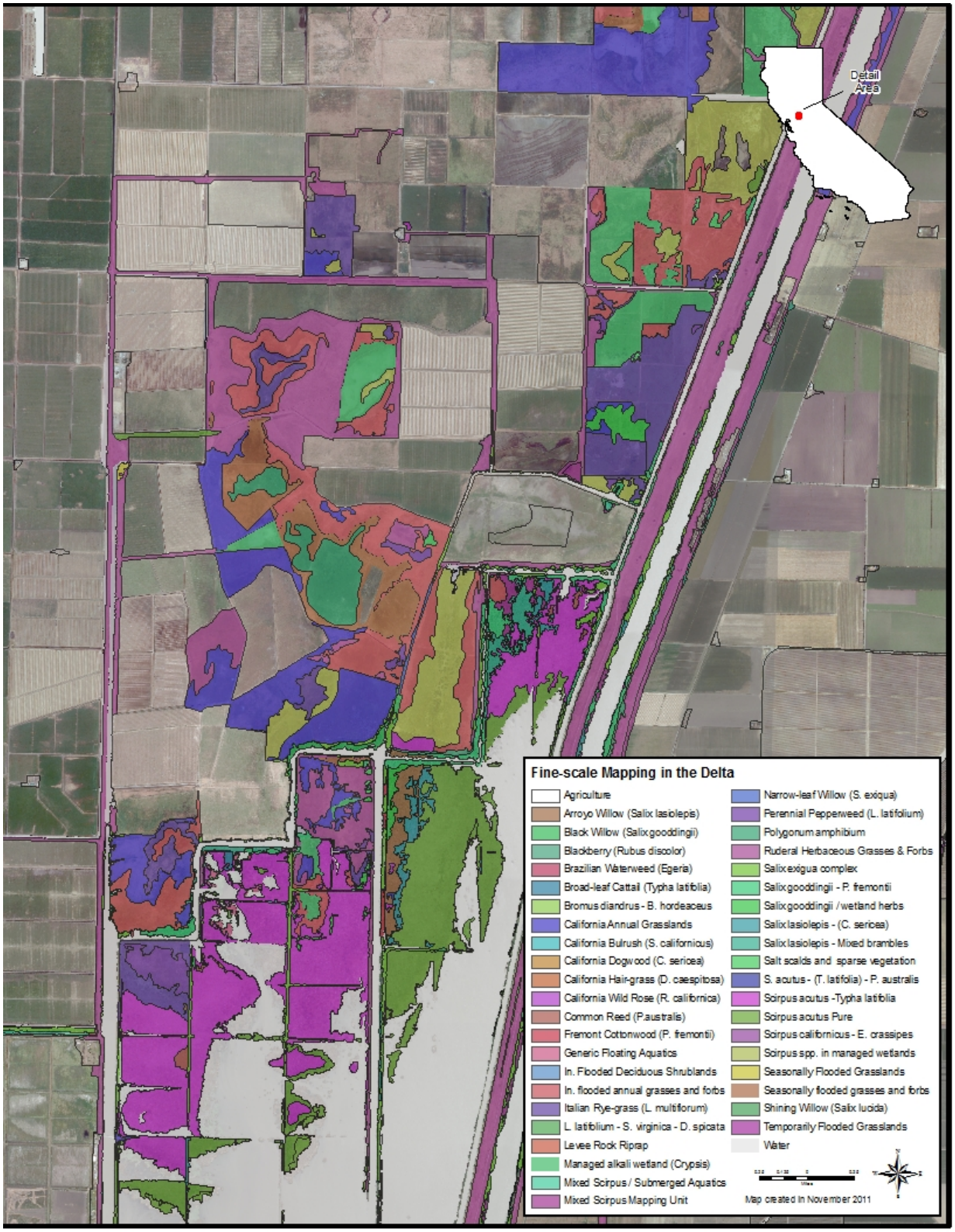

Figure 5-3. Fine-Scale Vegetation Types in the Delta Illustrating 42 Vegetation Alliances

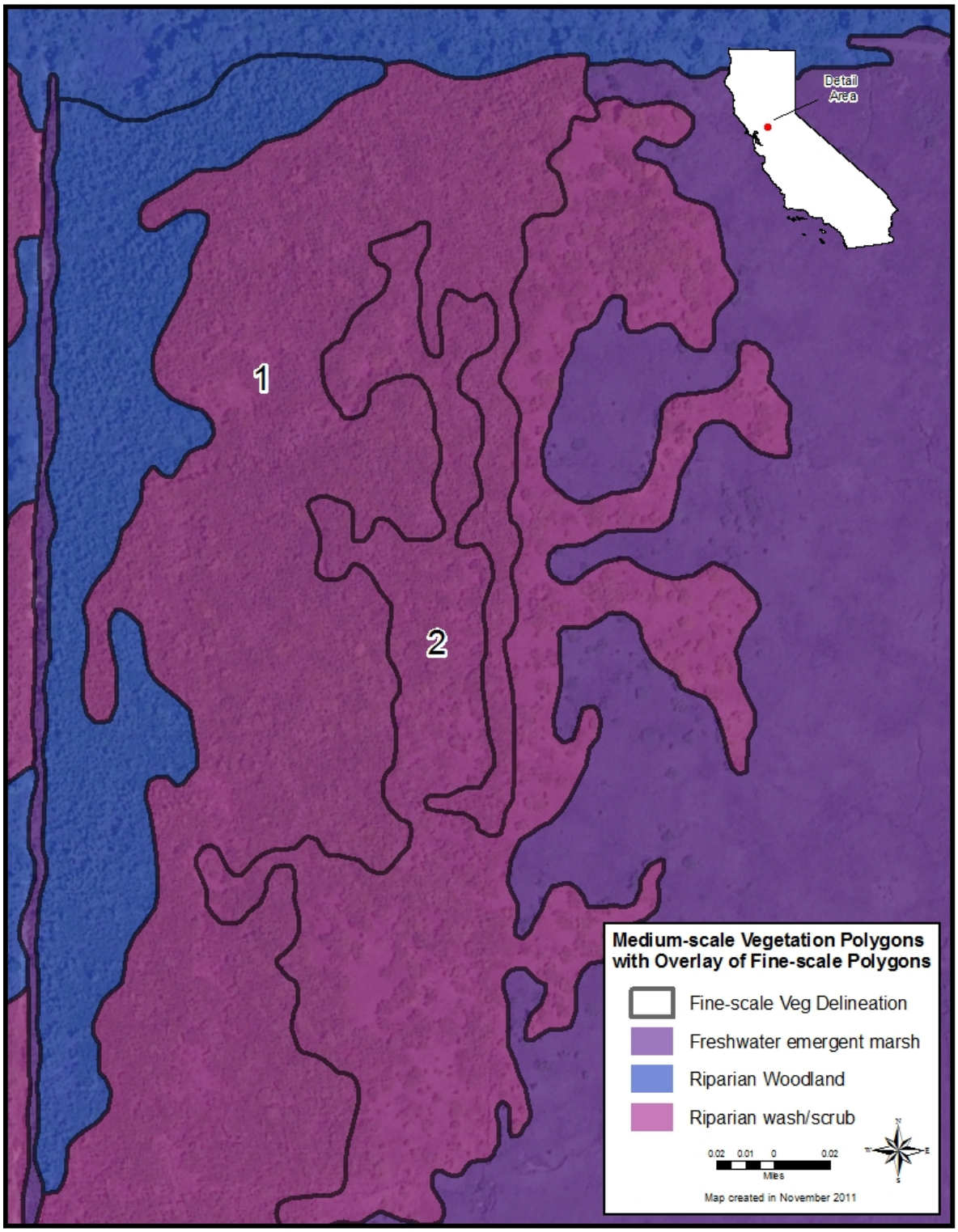

Figure 5-4. Medium-Scale Polygons of Riparian Wash/Scrub, with Overlay of Fine-Scale Delineations of (1) Arroyo Willow, and (2) Arroyo Willow-Bulrush-Common Reed Complex Unit

Vegetation composition and abundance are considered an accurate gauge for identifying important habitats and ecosystems within a given region. Vegetation community data are incorporated into natural lands conservation efforts, and continue to be an important tool for land management planning and impact analysis.

In summary, fine-scale mapping will support a variety of uses for DWR and other organizations, including but not limited to the following:

- Measuring and monitoring vegetative changes over time in the extent, diversity, and connectivity of native vegetation within the Central Valley flood management system (levees, floodways, and other facilities)
- Informing the design and implementation of flood management policies and projects to avoid and minimize adverse effects on vegetation and species
- Identifying priority areas for restoration and conservation actions
- Conducting conservation planning for specific species and modeling their potential distribution based on habitat. For example, sensitive species location data can be correlated with highly, medium, or poorly suitable habitat (Figure 5-5)
- Supporting wetland and riparian modeling efforts such as the statewide WRAMP
- Determining the extent of invasive plant species

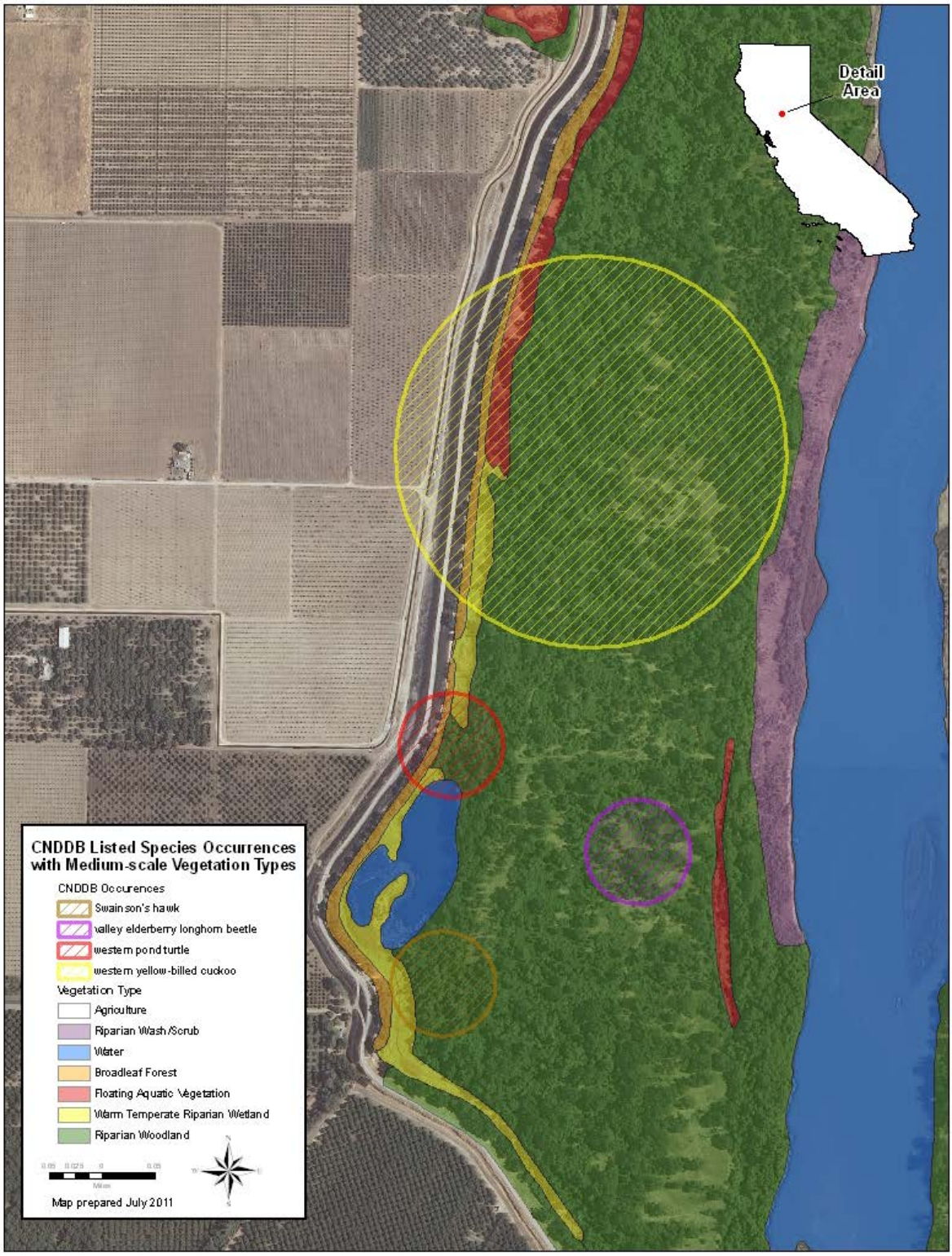

Figure 5-5. Map Application: California Natural Diversity Database Species Occurrences with Associated Medium-Scale Vegetation Types

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6.0 References

Anderson, James R., E. Hardy, J. Roach and R. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964. A revision of the land use classification system as presented in U.S. Geological Survey Circular 671. United States Government Printing Office, Washington: 1976 http://landcover.usgs.gov/pdf/anderson.pdf

California Biodiversity Council (CBC). 2000. Memorandum of Understanding for Cooperative Vegetation and Habitat Mapping and Classification. Available at http://biodiversity.ca.gov/vegmou.html

California Department of Fish and Game (DFG). 1997. Central Valley Wetlands and Riparian Areas GIS layer. Available at http://gis.ca.gov/catalog/BrowseRecord.epl?id=390.

California Department of Water Resources. 2002. Riparian Vegetation of the San Joaquin River. Technical Information Record SJD-02-1.

California State University, Chico (CSU Chico). 1979. Central Valley Riparian Mapping Project – Interpretation and Mapping Systems. In cooperation with California State University, Fresno, Geography Department.

California Wetland Monitoring Work Group (CWMW). 2010. Implementation of State Wetland and Riparian Area Monitoring Program (WRAMP). Available at http://www.swrcb.ca.gov/mywaterquality/monitoring_council/docs/wramp_implementation_letter.pdf.

Carlson, M., and R. Funes. 2010. 2007 Sacramento River Riparian Map Project, Colusa to Red Bluff Ecological Management Zone. California State University Chico, Geographical Information Center.

Collins, J.N., M. Sutula, E. Stein, M. Odayi, E. Zhang, and K. Larned. 2006. Comparison of Methods to Map California Riparian Areas. Final Report. Prepared for the California Riparian Habitat Joint Venture.

Davis, F.W., D.M. Stoms, A.D. Hollander, K.A. Thomas, P.A. Stine, D. Odion, M.I. Borchert, J.H. Thorne, M.V. Gray, R.E. Walker, K. Warner, and J. Graae. 1998. The California Gap Analysis Project. Final Report. University of California, Santa Barbara.

Federal Geographic Data Committee (FGDC). 2008. National Vegetation Classification Standard http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation

Hickson, D., and T. Keeler-Wolf. 2007. Vegetation Classification and Mapping Program. Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta. California Department of Fish and Game.

Holland, R.F. 1986. Preliminary descriptions of the terrestrial vegetation of California. Unpublished report. California Department of Fish and Game. Sacramento.

Mayer, K.E., and W. Laudenslayer. 1988. A Guide to Wildlife Habitats of California. Department of Fish and Game Sacramento, California. Available at http://www.dfg.ca.gov/biogeodata/cwhr/.

Sawyer, J.O., T. Keeler-Wolf, and J.M. Evens. 2009. A Manual of California Vegetation, 2nd edition. California Native Plant Society Press. Sacramento, California.

U.S. Department of Agriculture (USDA). 2009. 2009 National Agricultural Imagery Program Aerial Photography (California). USDA FSA Aerial Photography Field Office, Salt Lake City, Utah.

U. S. Fish and Wildlife Service. 2010 National Wetlands Inventory Web site. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Available at http://www.fws.gov/wetlands/.

7.0 Acronyms and Abbreviations

CVFPP .....Central Valley Flood Protection Plan

Delta.....Sacramento-San Joaquin Delta

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

DWR.....California Department of Water Resources

GIS.....geographic information system

MMU.....minimum map unit

MOU.....Memorandum of Understanding

NVCS .....national Vegetation Classification System

State.....State of California

WHR.....Wildlife Habitat Relationship

WRAMP.....Wetland and Riparian Area Monitoring Program

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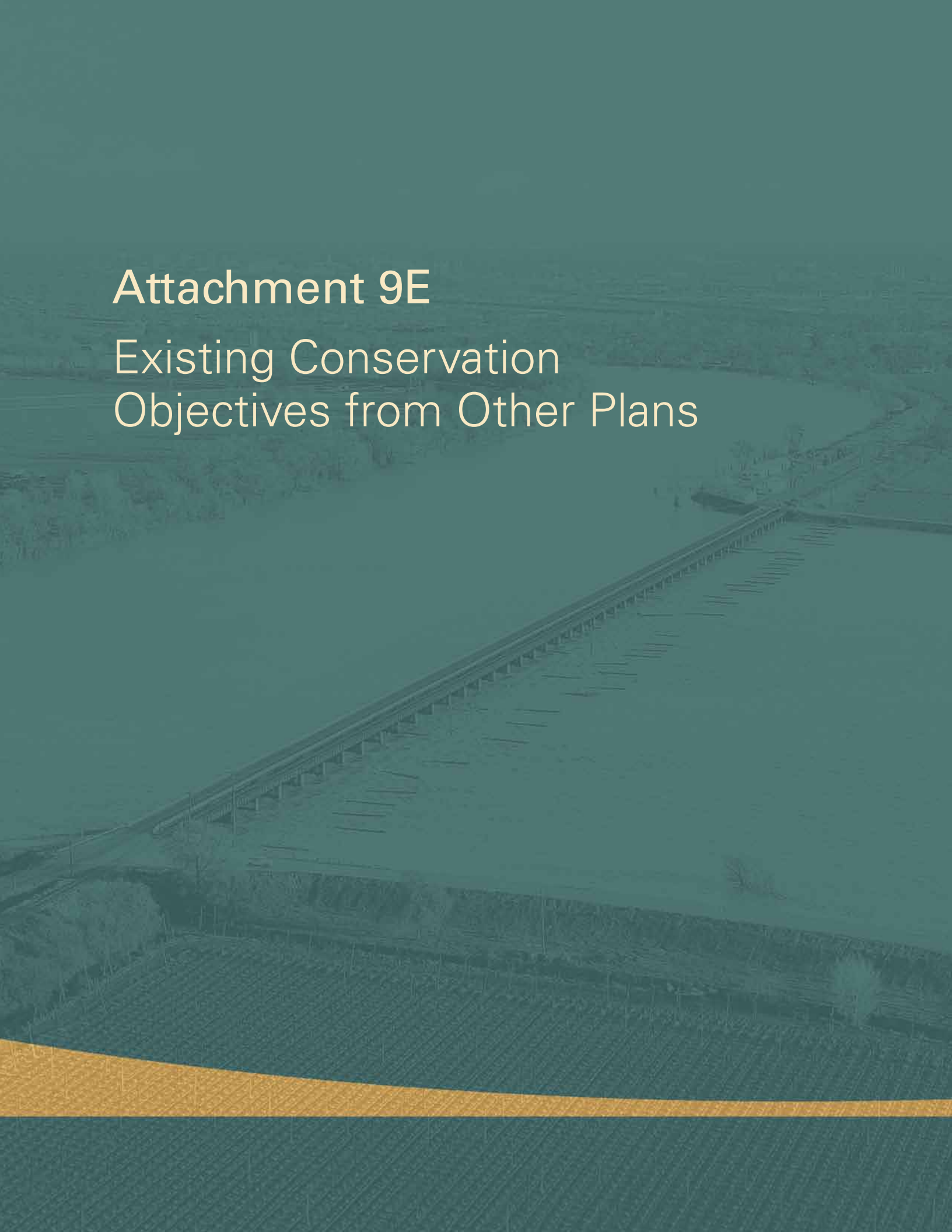
STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

Attachment 9E

Existing Conservation Objectives from Other Plans



CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 9E: Existing Conservation Objectives from Other Plans

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Table of Contents

1.0 Introduction 1-1

2.0 Review of Plans 2-1
2.1 Completed Regional Conservation Planning Efforts 2-1
2.1.1 Natomas Basin Habitat Conservation Plan 2-1
2.1.2 San Joaquin County Multi-Species Habitat Conservation Plan and Open Space Plan 2-3
2.1.3 PG&E San Joaquin Valley Operation & Maintenance Habitat Conservation Plan 2-4
2.1.4 East Contra Costa County Habitat Conservation Plan and Natural Communities Conservation Plan 2-5
2.1.5 San Joaquin River Restoration Program 2-7
2.1.6 Central Valley Project-State Water Project Operations Criteria and Plan and Associated Biological Opinions 2-8
2.1.7 CALFED Multi-Species Conservation Strategy 2-10
2.1.8 Central Valley Project Improvement Act Programs 2-11
2.1.9 Central Valley Joint Venture 2-14
2.1.10 Cosumnes River Preserve Management Plan 2-14
2.1.11 Sacramento River National Wildlife Refuge Comprehensive Conservation Plan 2-16
2.1.12 Sacramento, Delevan, Colusa, and Sutter National Wildlife Refuges Final Comprehensive Conservation Plan and Environmental Assessment 2-18
2.1.13 DWR's Oroville Facility Federal Energy Regulatory Commission License Protection, Mitigation and Enhancement Measures 2-19
2.2 Regional Conservation Planning Efforts in Progress 2-20
2.2.1 Bay-Delta Conservation Plan 2-20
2.2.2 Solano Multi-Species Habitat Conservation Plan 2-22
2.2.3 South Sacramento Habitat Conservation Plan 2-22
2.2.4 Butte Regional Habitat Conservation Plan /Natural Community Conservation Plan 2-23
2.2.5 Yuba/ Sutter County Natural Community Conservation Plan/Habitat Conservation Plan 2-25
2.2.6 Yolo County Natural Heritage Program 2-25
2.2.7 Placer County Conservation Plan 2-27

2.2.8 Butte Sink, Willow Creek-Lurline, and North Central Valley Wildlife Management Areas Comprehensive Conservation Plan 2-29
2.2.9 Public Draft Recovery Plan for Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and Distinct Population Segment of Central Valley Steelhead 2-29
2.3 Plans Identifying Specific Geographic Areas Without Quantifying Conservation Measures 2-30
2.3.1 Draft Recovery Plan for the Giant Garter Snake 2-30
2.3.2 Draft Recovery Plan for the Least Bell's Vireo 2-31
2.3.3 Valley Elderberry Longhorn Beetle Recovery Plan 2-32
2.3.4 Bank Swallow Recovery Plan 2-33
2.3.5 California Red-Legged Frog Recovery Plan 2-33
2.3.6 Recovery Plan for Upland Species of the San Joaquin Valley, California 2-34
2.3.7 The Nature Conservancy Sacramento River Project 2-35
2.3.8 Sacramento River Conservation Area Forum 2-35
2.3.9 Comprehensive Management Plan for the Sacramento River Wildlife Area 2-36
2.3.10 Yolo Bypass Wildlife Area Land Management Plan 2-37
2.3.11 California Water Plan 2-38
2.3.12 State and Regional Water Board Plans 2-40

3.0 References 3-1

4.0 Acronyms and Abbreviations 4-1

List of Tables

Table 1-1. Summary of CVFPP Relationships to Conservation Objectives from Other Conservation Plans[1] 1-3

1.0 Introduction

The Central Valley Flood System Conservation Framework (Conservation Framework), in conjunction with the Central Valley Flood Protection Plan (CVFPP), geographically overlaps with multiple regional and collaborative conservation plans that have either been implemented or planned for the Sacramento and San Joaquin valleys. Regional planning efforts such as the Conservation Framework are most effective when coordinated with similar programs and plans to the maximum extent possible. The Conservation Framework is the first phase of a comprehensive and integrated planning effort, leading to a longer-term Conservation Strategy that will be part of the 2017 CVFPP update. When developing the Conservation Strategy[1] as part of the 2017 CVFPP, coordination among similar, related conservation and collaborative planning efforts is essential to determine if the Conservation Strategy can contribute to the shared conservation objectives of other plans or programs while meeting its own objectives. Similarly, understanding the potential flood-risk-reduction benefits associated with implementing other conservation or collaborative planning efforts can aid in the development of the Conservation Strategy.

Coordinating with other planning efforts may increase economy and efficiency. In addition, from an ecological standpoint, coordinating the Conservation Strategy and other planning efforts can provide greater opportunities for effective, integrated, landscape-level conservation. Wildlife and natural resource agencies have limited staffing and funds, so they support and encourage participation in existing plans as further justification for coordination. Integration of related planning efforts could improve the effectiveness of individual plans' important ecological objectives, such as improving habitat connectivity and increasing the size of habitat preserves.

The purpose of this attachment is to describe completed and ongoing planning efforts that have regional, geographically based, and/or quantifiable conservation measures for species and habitats that may be relevant to the Conservation Strategy. All of the plans and programs described overlap at least partially with the State Plan of Flood Control (SPFC) Planning Area or Systemwide Planning Area. The list is not

[1] The Conservation Strategy will provide a comprehensive approach for DWR to (1) achieve the environmental goals and objectives of the Central Valley Flood Protection Act, FloodSAFE, and CVFPP; and (2) implement DWR's environmental stewardship policy. This Conservation Strategy may include regional permitting plans such as NCCPs or HCPs.

comprehensive, but provides examples of efforts that should be considered in developing the Conservation Strategy. Plans not included here could be identified and considered as the Conservation Strategy is developed. In this attachment, completed planning efforts are summarized first, followed by those that are ongoing and in progress. Regional programs with defined conservation goals and measureable biological objectives are also included. Potential relationships between these plans or programs and the Conservation Strategy are summarized in Table 1-1. Some programs, such as identifying Total Maximum Daily Loads and implementing Integrated Regional Water Management Plans, may support conservation efforts, but their objectives are dissimilar to those of the Conservation Framework (i.e., focused on meeting water quality standards), so these were not included.

This attachment is not intended to present an analysis of each plan in detail. Rather, the intent is to identify areas of potential overlap between relevant plans and the upcoming Conservation Strategy. As the Conservation Strategy develops and/or is implemented, potentially synergistic areas and areas of potential conflict between the Conservation Strategy and individual plans can continue to be identified.

Table 1-1. Summary of CVFPP Relationships to Conservation Objectives from Other Conservation Plans[1]

Plan Name	Selected Habitat Targets from Other Conservation Plans				Selected Species Targets from Other Conservation Plans										Geographic Overlap	
	Riparian/ SRA	Wetland	Seasonal Floodplain	Riverine Aquatic	Delta Button Celery	Salmonids	Giant Garter Snake	VELB	Yellow-Billed Cuckoo	Bank Swallow	Swainson's Hawk	Least Bell's Vireo	Riparian Brush Rabbit	Riparian Woodrat	State Plan of Flood Control	Systemwide Planning Area
Completed Regional Planning Efforts																
Natomas Basin HCP		+					+	+			+				++	
San Joaquin County Multi-Species HCP and Open Space Plan	+	+			+		+	+	+	+	+		+	+	+	+
PG&E O&M HCP	+	+	+	+	+		+	+		+	+		+	+	++	++
East Contra Costa County HCP/NCCP	+	+					+				+					+
San Joaquin River Restoration Program	+		+	++		++									++	++
Central Valley Project-State Water Project OCAP and Associated BOs	+		+	++		++									++	++
CALFED Multi-Species Conservation Strategy	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
Central Valley Improvement Act Programs	++		+	++		++	+	+	+	+	+	+	+	+	++	++
Central Valley Joint Venture	++	++							++	++	++	++			++	++
Cosumnes River Preserve Management Plan	+	+	++	+		++	+	+			+	+			+	+
Sacramento River NWR CCP	++	+		+		+	+	+	+	+	+	+			++	+
Sacramento, Delevan, Colusa, and Sutter NWR CCP/EA	+	+	++	+		+	+		+		+				++	+
DWR's Oroville FERC license	+	+	+	++		++	+	+							++	+
Regional Conservation Planning Efforts in Progress																
Bay-Delta Conservation Plan	++	++	++	++	++	++	++	+	++	+	++	+	+	+	+	++

Table 1-1. Summary of CVFPP Relationships to Conservation Objectives from Other Conservation Plans[1] (contd.)

Plan Name	Selected Habitat Targets from Other Conservation Plans				Selected Species Targets from Other Conservation Plans										Geographic Overlap	
	Riparian/ SRA	Wetland	Seasonal Floodplain	Riverine Aquatic	Delta Button Celery	Salmonids	Giant Garter Snake	VELB	Yellow-Billed Cuckoo	Bank Swallow	Swainson's Hawk	Least Bell's Vireo	Riparian Brush Rabbit	Riparian Woodrat	State Plan of Flood Control	Systemwide Planning Area
Solano Multi-Species HCP	+	+		+		+	+	+			+				+	+
South Sacramento HCP		+					+	+			+				+	+
Butte Regional HCP/NCCP	+	+				+	+	+	+	+	+				+	+
Yuba and Sutter County HCP/NCCP	+	+				+	+	+	+	+	+				++	+
Yolo County Natural Heritage Program	++	++						+	+	+	+				+	
Placer County Conservation Plan	+	+				+	+	+		+	+				+	+
Butte Sink, Willow Creek-Lurline, and North Central Valley WMA CCP	+	+		+											++	+
Draft Recovery Plan for Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-run Chinook Salmon ESUs and Central Valley Steelhead DPS	++		++	++		++									++	++
Plans Identifying Specific Geographic Areas without Quantifying Conservation Measures																
Draft Recovery Plan for the Giant Garter Snake		++					+								+	++
Draft Recovery Plan for the Least Bell's Vireo	++											+			+	+
Valley Elderberry Longhorn Beetle Recovery Plan	++							++							++	++
Bank Swallow Recovery Plan	+	+	+	+						++					+	++
California Red-legged Frog Recovery Plan	+	+	+	+												+

Table 1-1. Summary of CVFPP Relationships to Conservation Objectives from Other Conservation Plans[1] (contd.)

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Recovery Plan for Upland Species of the San Joaquin Valley, California	+												++	++		+
The Nature Conservancy Sacramento River Project	++	+	+	++		++		++	++	++	+	++			++	++
Sacramento River Conservation Area Forum	++	+	+	+		++		++	++	++	+	++			+	++
Cosumnes River Preserve Management Plan	+	+	++	+		++	+	+			+	+			++	++
CMP for the Sacramento River Wildlife Area	++	++	++	++		+	+	+		+					++	++
Yolo Bypass Wildlife Area LMP	++	++	++	+		++	++		+		++				++	+
California Water Plan	+	+	+	+											++	++
State Water Resources Control Board Plans				+											+	+

Notes:
[1] Magnitude of relationship between CVFPP and other conservation plan or program specified as follows:
+ A probable or potential relationship exists. The Conservation Strategy is not likely to significantly contribute to the other conservation plan's conservation objectives, or the conservation target is a secondary focus of the conservation plan. For geographic overlap, there is a minor spatial overlap between the conservation plan area and one of the CVFPP planning boundaries.
++ A significant relationship exists. The Conservation Strategy could significantly contribute to the other conservation plan's conservation objectives. For geographic overlap, there is a large spatial overlap between the conservation plan and one of the CVFPP planning boundaries.

Key:
BO = biological opinion
CALFED = California Bay-Delta Program
CCP = Comprehensive Conservation Plan
CMP = Comprehensive Management Plan
CVFPP = Central Valley Flood Protection Plan
DPS = Distinct Population Segment
EA = Environmental Assessment
ESU = Evolutionarily Significant Unit
FERC = Federal Energy Regulatory Commission
HCP = Habitat Conservation Plan
LMP = land management plan
NCCP = Natural Communities Conservation Plan
NWR= National Wildlife Refuge
OCAP = operations criteria and plan
O&M = operations and maintenance
PG&E = Pacifc Gas & Electric Company
VELB = valley elderberry longhorn beetle
WMA= Wildlife Management Area

This attachment supports and recognizes key conservation criteria and considerations that are important as the Conservation Strategy is developed:

- Uses existing information to the greatest extent possible for efficiency and to inform the Conservation Strategy regarding potential conservation goals.

- Recognizes that multiple conservation plans or collaborative planning efforts have been completed, are in development, or are being implemented:

  - In whole or in part, the plans address many of the key species and habitats that occur within the SPFC Planning Area and/or Systemwide Planning Area.

  - The plans help identify conservation needs and priorities within the flood management system.

- Highlights potential conservation partnerships for the California Department of Water Resources (DWR) in implementing the Conservation Strategy, specifically:

  - Describes opportunities to cost-share on conservation projects.

  - Describes opportunities for DWR to simultaneously meet its own conservation goals and those of other plans or programs through specific projects.

- Identifies completed conservation planning efforts that provide “lessons learned” to be applied to the Conservation Strategy.

2.0 Review of Plans

This section summarizes various regional conservation planning efforts, including the following:

- Completed regional conservation planning efforts
- Regional conservation planning efforts in progress
- Plans that identify specific geographic areas but do not provide quantifiable conservation measures

2.1 Completed Regional Conservation Planning Efforts

Completed regional conservation planning efforts include several habitat conservation plans (HCP) and HCP/natural communities conservation plans (NCCP), large-scale conservation programs, and refuge comprehensive conservation plans described below, including goals and measurable objectives.

2.1.1 Natomas Basin Habitat Conservation Plan

The *Natomas Basin Habitat Conservation Plan* (NBHCP) proposes to acquire 8,750 acres of mitigation lands to benefit giant garter snake (*Thamnophis gigas*) and Swainson's hawk (*Buteo swainsonii*) (City of Sacramento et al., 2003). The NBHCP supports applications for incidental take permits under the federal Endangered Species Act (ESA) and the California ESA. The NBHCP intends to create a system of reserves, with both wetland and upland components, which support viable populations of giant garter snake, Swainson's hawk, and other species covered by the HCP (covered species). The overall goals for the NBHCP include the following:

- Establish and manage, in perpetuity, a biologically sound and interconnected habitat-reserve system that mitigates impacts to covered species resulting from covered activities and provides habitat for existing and new viable populations of covered species.
- Implement an adaptive management program that responds to changing circumstances affecting covered species and their habitats.

- Preserve open space and habitat that may also benefit local, non-listed, and transitory wildlife species not identified within the NBHCP.

- Ensure that direct impacts of authorized development upon covered species are avoided or minimized to the maximum extent practicable.

To achieve the above goals, the NBHCP identified the following objectives:

- Minimize conflicts between wildlife and human activities, including conflicts resulting from airplane traffic, roads and automobile traffic, predation by domestic animals, and harassment by people.

- Maintain and operate flood control, irrigation, and drainage facilities in a manner that minimizes take of covered species and promotes vegetative cover that enhances habitat values for covered species, consistent with relevant water agencies' legal obligations.

- Ensure connectivity between The Natomas Basin Conservancy (TNBC) reserves to minimize habitat fragmentation and species isolation. Connections between reserves will generally take the form of common property boundaries between reserves, waterways (primarily irrigation and drainage channels) passing between reserves, or an interlinking network of water supply channels or canals.

- Within individual TNBC reserves, provide a mosaic of habitats that support both wetland and upland species and are configured to support species that use both types of habitat.

- Implement monitoring programs with qualitative or quantitative monitoring methods to evaluate management objectives and strategies for the reserve system.

- Increase the diversity and abundance of covered species on reserve lands.

- Revise the reserve design and management based on the most current biological data.

For giant garter snake, approximately 50 percent of the acquired lands would be in rice production, 25 percent enhanced as managed marsh, and 25 percent as upland habitat. The proportion of marsh habitat may be increased to as much as 75 percent of mitigation lands if certain conditions are met. Approximately 80 percent of the lands would be preserved in the basin and 20 percent of lands may be preserved outside the basin. The plan

identifies the system of agricultural water supply and drainage channels maintained and operated by U.S. Department of Interior, Bureau of Reclamation (Reclamation) District 1000 and the Natomas Central Mutual Water Company as the primary opportunity for giant garter snake habitat connectivity between reserves.

For Swainson's hawk foraging habitat, 3,372 acres of high- and moderate-quality upland habitat would be provided within mitigation land reserves. The NBHCP requires that one habitat block within the reserve system be a minimum of 2,500 acres, and the balance of reserve lands will be in habitat blocks that are a minimum of 400 acres (City of Sacramento et al., 2003).

The entire NBHCP planning area is within the SPFC Planning Area boundary. Conservation Strategy actions may contribute to NBHCP conservation objectives if they result in preserving, restoring, or enhancing giant garter snake aquatic or upland habitat or Swainson's hawk foraging habitat within the Natomas Basin or in adjacent areas outside the Natomas Basin (e.g., Knagg's Ranch in Yolo County, northern Yolo Bypass, southern Sutter Bypass). These actions may not directly contribute to the habitat acreage objectives of the NBHCP, but may increase the regional availability and quality of habitat for the species covered by the NBHCP.

2.1.2 San Joaquin County Multi-Species Habitat Conservation Plan and Open Space Plan

The *San Joaquin County Multi-Species Habitat Conservation Plan* (SJCMSHCP) and Open Space Plan is a county-wide plan for conserving species and their habitats, consistent with the California and federal ESAs (SJCCG 2000). The SJCMSHCP is also intended to support applications for incidental take permits under the California and federal ESAs. The SJCMSHCP covers 97 plant, fish, and wildlife species, including several riparian- and wetland-dependent species that would likely be considered within the Conservation Strategy.

The primary goal of the SJCMSHCP is to preserve a variety of habitat types throughout the county, including grasslands and vernal pools, agricultural land, riparian areas, perennial wetlands, and other aquatic habitats. It will preserve an estimated 100,841 acres of habitat over the plan's 50-year lifespan. Additionally, the SJCMSHCP calls for establishing a 1,200-foot-wide, undeveloped wildlife corridor along much of the San Joaquin River (from Stewart Tract to the Stanislaus/San Joaquin County border). The measureable biological success criteria of the SJCMSHCP are described below.

- Habitat acquisition and protection through the establishment of preserve lands precisely balances habitat losses permitted under the SJCMSHCP.

- At a minimum, existing habitat quality on SJCMSHCP preserve lands is maintained, and, where possible, demonstrable increases in habitat quality of preserve lands are achieved.

- Populations of covered species on SJCMSHCP preserve lands are stabilized and improved where possible.

The SJCMSHCP planning area includes portions of the SPFC Planning Area and the Systemwide Planning Area, as well as additional areas outside their boundaries. Conservation Strategy actions may include fee simple land acquisitions or easement acquisitions that could preserve riparian and wetland habitat within San Joaquin County; these actions would directly contribute to the conservation goals of the SJCMSHCP. Additionally, purchase of flood easements or conservation easements as part of Conservation Strategy actions along the San Joaquin River (e.g., to create transitory storage) could contribute to the SJCMSHCP goal of creating an undeveloped wildlife corridor along this reach.

2.1.3 PG&E San Joaquin Valley Operation & Maintenance Habitat Conservation Plan

The *PG&E San Joaquin Valley Operation & Maintenance Habitat Conservation Plan* (PG&E HCP) is a multi-species HCP for routine operation and maintenance (O&M) activities in the San Joaquin Valley (Jones & Stokes, 2006). The PG&E HCP supports applications for incidental take permits under the California and federal ESAs. The biological goal of the San Joaquin Valley PG&E HCP is to contribute to the conservation of natural communities and their associated covered species in the planning area. The natural communities include wetlands, woodlands, grasslands, woody riparian, and upland scrub.

Three biological objectives were identified:

1. Acquire, protect, manage, and maintain lands for the benefit of covered species to achieve compensation for project habitat effects.

2. Locate compensation lands within regions where project effects occur.

3. Purchase or dedicate land near other preserved areas to maximize the conservation values of the land and assist in meeting land protection goals of existing recovery plans.

The PG&E HCP identifies 30 avoidance and minimization measures designed to reduce effects on species, and compensation to offset effects that cannot be avoided or minimized. To compensate for habitat loss in the 246,350-acre plan area, temporary effects will be mitigated at a ratio of 0.5:1 and permanent effects will be mitigated at a ratio of 3:1; total habitat mitigation is expected to be approximately 1,350 acres over the 30-year permit term. The PG&E HCP covers 23 wildlife and 42 plant species, including aquatic and riverine species such as the valley elderberry longhorn beetle (VELB, *Desmocerus californicus dimorphus*), giant garter snake, Swainson's hawk, bank swallow (*Riparia riparia*), riparian woodrat (*Neotoma fuscipes riparia*), and riparian brush rabbit (*Sylvilagus bachmani riparius*). The PG&E HCP has a specific conservation target identified for these covered species.

The PG&E HCP planning area includes portions of the SPFC Planning Area and the Systemwide Planning Area, as well as additional areas outside their boundaries. Conservation Strategy actions that could contribute to PG&E HCP conservation objectives would include actions that would result in preserving, restoring, enhancing, or creating habitat for covered species in the San Joaquin Valley.

2.1.4 East Contra Costa County Habitat Conservation Plan and Natural Communities Conservation Plan

The conservation strategy for the *East Contra Costa County Habitat Conservation Plan* (ECCCHCP) *and Natural Communities Conservation Plan* (ECCCHCP/NCCP) includes creating and managing a fully functioning preserve system that will preserve approximately 23,800-30,300 acres of land under the urban development area (ECCPHCPA, 2006). To compensate for habitat loss, the strategy also proposes to restore or create approximately 424 to 586 acres (under the initial or maximum urban development areas, respectively) of specific habitats and land cover types. Covered species include the giant garter snake, Swainson's hawk, foothill yellow-legged frog (*Rana boylii*), California red-legged frog (*Rana aurora draytonii*), western pond turtle (*Clemmys marmorata*), and tricolored blackbird (*Agelaius tricolor*). Goals of the ECCCCHCP/NCCP related to riparian and instream habitats include:

- Preserve streams and riparian woodland/scrub in the inventory area
- Enhance riparian woodland/scrub to promote native biological diversity and habitat heterogeneity
- Maintain and enhance instream aquatic habitat for covered species and native fish

- Restore streams and riparian woodland/scrub

Measureable objectives of the ECCCCHCP/NCCP related to riparian and instream habitats include:

- Protect a minimum of 5 linear miles of stream to compensate for permanent loss of habitat
- Acquire riparian/scrub at a ratio of 2:1 (estimated to be 70 acres for maximum urban development area) and protect as part of the preserve system
- Maintain or increase the cover, width, and connectivity of existing riparian vegetation consistent with current stream and habitat function
- Promote natural fluvial disturbances (e.g., flooding, sediment deposition, and scour)
- Reduce water temperature and temperature variation
- Increase inputs of organic matter where appropriate
- Reduce sediment input and downstream sediment transport and deposition where appropriate
- Maintain and enhance instream structural diversity, where appropriate
- Improve stream flow and connectivity for native aquatic wildlife
- Control or reduce nonnative animals, including bullfrogs and fish
- Restore at least 20 acres of riparian woodland/scrub in addition to that required above as compensation for habitat loss
- Replace riparian woodland/scrub at a ratio of 1:1 in the preserve system to compensate for its loss from covered activities (estimated to be 30 acres with maximum urban development area) and restore species richness and diversity, vegetative cover, wildlife habitat function, and hydrologic function

The ECCCHCP/NCCP contains detailed guidelines for management, enhancement, and restoration techniques for a variety of habitat types, including wetlands, ponds, streams, and riparian woodland. It includes a conservation target of 3,750 acres of habitat for Swainson’s hawks.

A portion of the ECCCHCP/NCCP overlaps the Systemwide Planning Area in the Sacramento/San Joaquin Delta (Delta) region of northeastern Contra Costa County. Conservation Strategy actions that could contribute to ECCCHCP/NCCP conservation objectives would include actions within the western Delta that preserve, restore, enhance, or create habitat for covered species, particularly giant garter snake and Swainson's hawk.

2.1.5 San Joaquin River Restoration Program

The San Joaquin River Restoration Program (SJRRP) resulted from a settlement reached in September 2006 between the U.S. Departments of the Interior and Commerce, the Natural Resources Defense Council, and the Friant Water Users Authority. The settlement ended an 18-year lawsuit that sought sufficient fish habitat in the San Joaquin River below Friant Dam to its confluence with the Merced River. Focus species are fall-run and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and other native fish species. The main habitat objective of the SJRRP is to restore habitat for Chinook salmon and other species of fish native to the San Joaquin River and its tributaries above the confluence with the Merced River (SJRRP, 2009). Specific acreage targets were not included as part of this objective.

The geographic boundary of the SJRRP is entirely contained within the SPFC Planning Area from the confluence with the Merced River to approximately Gravelly Ford, and the remainder of the SJRRP boundary is within the Systemwide Planning Area. Conservation Strategy actions that contribute to enhancing, restoring, or creating additional habitat for Chinook salmon and other salmonid species would also contribute to the SJRRP objectives. Additional habitats would include seasonal floodplain, shaded riverine aquatic (SRA), and spawning gravels, as well as the restoration of flows and geomorphic processes that could potentially result in the eventual formation of these habitats. Although the SJRRP focuses on the upper San Joaquin River, Conservation Strategy actions within the lower San Joaquin River and Delta may contribute to SJRRP objectives. Conservation strategy actions may contribute to increased juvenile salmonid production and escapement from the San Joaquin River. Improved passage of spawning adults through lower river reaches through Conservation Strategy actions would align with SJRRP objectives.

2.1.6 Central Valley Project-State Water Project Operations Criteria and Plan and Associated Biological Opinions

Reclamation's *Long-Term Central Valley Operations Criteria and Plan* (OCAP) defines the Central Valley Project (CVP) and State Water Project (SWP) and their operations, constraints, and legal requirements (Reclamation, 2004). The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) developed and published biological opinions (BO) that addressed the potential for OCAP implementation to adversely affect federally listed fish. Because of the jeopardy opinion reached by each BO (i.e., implementing the OCAP, as proposed, would jeopardize the continued existence of federally listed species), each agency developed reasonable and prudent alternatives (RPA) to the proposed OCAP that would minimize impacts to federally listed fish (NMFS, 2009a, 2011; Reclamation, 2004; USFWS, 2008). The USFWS BO, which addressed the effects of OCAP implementation on delta smelt (*Hypomesus transpacificus*), was subsequently invalidated in 2011 (USFWS, 2011), and a new BO is currently being written. The NMFS BO and associated RPAs address salmonids, green sturgeon (*Acipenser medirostris),* and other fish species within the Sacramento and San Joaquin valleys and Delta.

The NMFS RPAs describe actions that, if implemented, would not jeopardize the continued existence of listed salmonids and green sturgeon. Many of these RPAs focus on maintaining flows within the Sacramento and San Joaquin rivers and their tributaries to provide suitable habitat conditions for fish (e.g., water temperature, water depth). Several other RPAs focus on restoration of habitat or fluvial-geomorphic processes (e.g., floodplain activation flows, sediment transport, erosion, deposition) necessary to maintain and regenerate aquatic habitat elements for salmonids and green sturgeon. Specific NMFS RPAs with strong potential links to the Conservation Strategy include the following:

- **Action I.1.3** – Spawning Gravel Augmentation on Clear Creek. This RPA is intended to enhance and maintain previously degraded spawning habitat for spring-run Chinook salmon and steelhead (*Oncorhynchus mykiss*) on Clear Creek below Whiskeytown Reservoir.

- **Action I.6.1** – Restoration of Floodplain Rearing Habitat within the Lower Sacramento River Basin. This RPA requires restoration of at least 17,000 to 20,000 acres of seasonal floodplain, with appropriate inundation periods and durations to support juvenile salmonid rearing.

- **Action I.6.4** – Improvements to Lisbon Weir. This RPA requires modifications to the Lisbon Weir to improve fish passage.

- **Action I.7** – Reduction of Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass. This RPA requires modifications to the Fremont Weir to reduce fish stranding and improve fish passage.

- **Action III.2.1** – Spawning Habitat Increase and Quality Improvement on the Stanislaus River with Addition of 50,000 Cubic Yards of Gravel by 2014 and with a Minimum Addition of 8,000 Cubic Yards per Year for the Duration of the Project Actions. This RPA requires augmentation of spawning gravel to create suitable redd sites on the Stanislaus River below New Melones Reservoir.

- **Action III.2.3** – Restoration of Freshwater Migratory Habitat for Juvenile Steelhead by Implementing Projects to Increase Floodplain Connectivity and to Reduce Predation Risk During Migration. This RPA requires any one of several potential actions to improve habitat conditions for juvenile steelhead and to reduce predation on juvenile steelhead. Potential actions could include habitat restoration, creation of offstream habitats (e.g., side channels), floodplain restoration, and similar actions.

- **Action V** – Fish Passage Program. This RPA includes a series of interrelated near-term and long-term actions to initiate salmonid passage around Shasta, Nimbus, Folsom, New Melones, Tulloch, and Goodwin dams and salmonid spawning and rearing in stream reaches above the reservoirs formed by these dams.

The geographic coverage of the NMFS BO includes all current and potential aquatic habitat for salmonids and green sturgeon within the Delta, Sacramento Valley, and San Joaquin Valley- an area that includes and extends beyond the SPFC Planning Area and Systemwide Planning Area. Due to the significant geographic overlap, Conservation Strategy actions that relate to the aquatic and riparian habitats and restoration of natural river processes (through construction of setback levees, removal of levees and bank revetment, removal of fish passage barriers, riparian and floodplain habitat restoration, including creation of new flood bypasses) could contribute to the success of several RPA actions. As the Conservation Strategy is developed, close coordination between the OCAP, and NMFS and USFWS BOs is anticipated.

2.1.7 CALFED Multi-Species Conservation Strategy

The California Bay-Delta Program (CALFED) *Multi-Species Conservation Strategy* (MSCS) describes, largely at a conceptual and programmatic level, habitat acquisition, restoration, and enhancement actions that could be implemented throughout the Sacramento and San Joaquin river systems, including the Delta, to maintain and enhance the Delta's ecological health (CBDP, 2000). The MSCS served as the program-level biological assessment for initiating consultation with the USFWS and NMFS and obtaining a programmatic BO under Section 7 of federal ESA. The MSCS was also submitted to the California Department of Fish and Game (DFG) as a programmatic NCCP. CALFED also includes a number of actions intended to improve the reliability and quality of water diversions from the Delta. Ecosystem enhancement activities within CALFED MSCS include those listed below:

- Acquiring water from sources throughout the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) watershed to provide flows for fish recovery
- Improving Delta outflow during key periods
- Reconnecting Bay-Delta tributaries with floodplains with setback levees, flood easements, and flood bypasses
- Restoring the sediment management regime by relocating instream mining and introducing gravels
- Modifying or eliminating fish passage barriers

The CALFED MSCS covers 244 special-status species and 20 habitats, including all species and major habitat types within the Sacramento and San Joaquin valleys, adjacent areas of the foothills, and the Delta. CALFED's measurable objectives include (CBDP, 2000) the following:

- Restoring 9,000 acres of tidal perennial aquatic habitat and approximately 150 to 330 miles (900 to 1,700 acres) of tidal sloughs within the Delta and San Francisco Bay regions
- Avoiding, minimizing, and compensating for all CALFED impacts on tidal perennial aquatic habitat
- Restoring approximately 1,200 acres of riparian habitat in the Delta region, 200 to 300 acres in the San Francisco Bay region, 3,650 acres in the Sacramento River region, and 5,450 to 5,950 acres in the San Joaquin River region

- Protecting and enhancing 500 acres of existing riparian habitat in the Delta region

- Enhancing and restoring riparian habitat associated with restoration of 18,000 to 26,000 acres of stream channel meander corridors in the Sacramento and San Joaquin river regions

The CALFED MSCS program area largely includes both the SPFC Planning Area and Systemwide Planning Area and areas beyond such as the adjacent San Francisco Bay and Suisun Marsh. As the Conservation Strategy is developed, close coordination with the CALFED MSCS is anticipated. The Conservation Strategy could significantly contribute to the conservation goals of the MSCS, given the large overlap in geographic coverage and likely overlap in the conservation goals, habitat, and species conservation targets of the two strategies.

2.1.8 Central Valley Project Improvement Act Programs

The Central Valley Project Improvement Act (CVPIA), signed into law in 1992, mandates changes in CVP management to protect, restore, and enhance fish and wildlife. There are a number of programs developed to implement the CVPIA (Reclamation, 2011), including several interrelated programs whose geographic boundaries overlap the SPFC Planning Area and Systemwide Planning Area. These programs are:

- Anadromous Fish Restoration Program (AFRP) (3406(b)(1))

- Habitat Restoration Program (HRP) (3406(b)(1) “other”)

- Management of CVPIA Waters (3406(b)(2))

- Instream Water Acquisition Program (WAP) (3406(b)(3))

- Red Bluff Fish Passage Improvement Project (3406(b)(10))

- Clear Creek Restoration Program (3406(b)(12))

- Spawning and Rearing Habitat Restoration Program (3406(b)(13))

- Anadromous Fish Screen Program (AFSP) (3406)(b)(21))

These programs are described in more detail below.

The goal of the AFRP is to double the natural production of anadromous fish in Central Valley streams. The AFRP covers all species of anadromous fish in the Sacramento and San Joaquin valleys, including Chinook salmon

and steelhead. The AFRP Restoration Plan (USFWS, 2001) is guiding the long-term development of the AFRP. The plan relies on the authorities and resources provided by the CVPIA to meet its goals in cooperation with other California and federal resource management agencies, public and private organizations, and landowners.

The goal of the HRP is to protect, restore, and mitigate for past fish and wildlife impacts of the CVP not already addressed in the Fish and Wildlife Restoration Activities section of the CVPIA. Initial focus will be on habitats known to experience the greatest percentage of decline in habitat quantity and quality since construction of the CVP, including riparian, aquatic, alkali desert scrub, wetlands, foothill chaparral, valley-foothill hardwood, and grassland. Stabilizing and improving populations of listed and non-listed native species associated with the above habitat types is a related goal of the HRP. The program relies on the authorities and resources provided by the CVPIA to meet its goals in cooperation with other California and federal resource management agencies, public and private organizations, and landowners. The types of actions include acquiring existing habitat for special-status species impacted by the CVP; maintaining, restoring, and enhancing priority habitats for priority species; and conducting studies to determine appropriate actions. Projects completed under the HRP have included riparian restoration at the Sacramento River National Wildlife Refuge (NWR) to benefit VELB, and wetland restoration at the Colusa NWR to benefit the giant garter snake.

The CVPIA Program annually manages 800,000 acre-feet of CVP water to either augment instream flows in Clear Creek, Sacramento, American, and Stanislaus rivers, or to curtail Delta exports for fish, wildlife, and habitat restoration. The program’s primary focus is to improve instream conditions for anadromous fishes, primarily salmon and steelhead.

The Instream WAP acquires water from willing sellers to increase flows for fish in support of the AFRP. The main WAP acquisitions for instream flow augmentation have occurred on the San Joaquin River tributaries (Merced, Tuolumne, and Stanislaus rivers) and Battle Creek.

The goal of the Red Bluff Fish Passage Improvement Project is to improve fish passage for anadromous fishes and green sturgeon at the existing Red Bluff Diversion Dam. Scheduled for completion in 2012, a screened pumping plant is being installed that will allow the Diversion Dam gates to be permanently open allowing for free migration of fish while ensuring continued water deliveries to agricultural lands. Goals of the project include allowing passage of 80 to 100 percent of adult spring-run Chinook and 50 to 100 percent of adult green sturgeon, and supplying 115,000 acre-feet of water to the Sacramento NWR.

The goals of the Clear Creek Restoration Program include providing flows to allow sufficient spawning, incubation, rearing, and outmigration for salmon and steelhead, and restoring the stream channel and instream habitat on Clear Creek. Project activities include improving fish passage, reducing erosion in the watershed, channel restoration, providing gravel augmentation, managing flows, and implementing adaptive management and monitoring strategies for the effects of project activities.

The goals of the Spawning and Rearing Habitat Restoration Program include increasing the availability of spawning gravel and rearing habitat lost from the construction and operation of CVP dams. Through this program, gravel augmentation occurs annually on the American, Sacramento, and Stanislaus rivers.

The goal of the AFSP is to protect juvenile anadromous fish from entrainment at priority water diversions throughout the Central Valley and the Sacramento-San Joaquin Delta. Objectives of the program include providing funding and/or technical assistance for fish screen projects, assessing fish entrainment at unscreened diversions, supporting screen/diversion research to determine critical factors resulting in fish losses at diversions and develop cost-effective improvements of fish screen designs, and monitoring and evaluating fish screen effectiveness. AFSP projects contribute to the AFRP goal of doubling natural production of anadromous fish in Central Valley streams.

The Clear Creek Restoration Program area has little geographic overlap with the SPFC Planning Area and Systemwide Planning Area. However, Clear Creek flows into the Sacramento River, and provides important spawning habitat for steelhead and spring-run Chinook salmon. Clear Creek is also the conduit for water delivered to the Sacramento River from the Trinity River and, thus, is strongly linked to the operation of the CVP. The other CVPIA programs have significant geographic overlap with the SPFC Planning Area and Systemwide Planning Area.

Conservation Strategy actions that could contribute to the goals of the various CVPIA programs, most of which focus on anadromous fish and instream habitats, would include actions such as removing fish passage barriers, restoring habitat (including SRA habitat), enhancing aquatic habitat (e.g., addition of spawning gravels), restoring seasonal floodplains (e.g., floodplain lowering, construction of setback levees, construction of new flood bypasses), and restoring natural river processes (e.g., removing bank revetment and levees where not essential for public safety). Modified floodway O&M practices would also contribute to the AFRP's goal and objectives.

2.1.9 Central Valley Joint Venture

The Central Valley Joint Venture (CVJV) is one of six original joint ventures formed under the *North American Waterfowl Management Plan* to coordinate regional waterfowl conservation efforts. It is a collaborative planning group comprising 21 member agencies (primarily California and federal natural resources management and regulatory agencies), nongovernmental organizations, and one corporation (PG&E). The *CVJV Implementation Plan* broadened conservation activities to include numerical objectives for habitats that support shorebirds, waterbirds, and riparian songbirds in the Central Valley (CVJV, 2006).

CVJV objectives have been developed for bird habitat restoration needs in specific geographic areas, including the American, Butte, Colusa, Delta, San Joaquin, Sutter, and Yolo basins and Suisun Marsh. These objectives include 10,000 acres of restored riparian habitat, 12,500 acres of restored semipermanent wetlands, and 108,527 acres of restored seasonal wetlands, the majority of which would be located within either the SPFC Planning Area or Systemwide Planning Area. The CVJV focuses on all migratory birds within the Central Valley, including yellow-billed cuckoo (*Coccyzus americanus*), bank swallow, and least Bell's vireo (*Vireo bellii pusillus*).

The CVJV planning area covers the entire Central Valley, and overlaps the SPFC Planning Area and Systemwide Planning Area as well as areas outside the boundaries of the CVFPP (e.g., Tulare Basin) (CVJV, 2006). Conservation Strategy actions that result in the expansion of riparian and wetland habitat would make significant contributions to the objectives of the CVJV, including active habitat restoration, construction of new flood bypasses, setback levees, removal of levees and bank revetment, revised O&M practices, and similar actions that would either directly restore bird habitat or restore the fluvial and geomorphic processes that contribute to riparian and wetland habitat formation.

2.1.10 Cosumnes River Preserve Management Plan

The *Cosumnes River Preserve Management Plan* (CRPMP) describes how the Cosumnes River Preserve will be managed through 2017 and was developed by several partners, including The Nature Conservancy (TNC), Bureau of Land Management, DFG, Sacramento County, DWR, Ducks Unlimited, and the California State Lands Commission (Kleinschmidt Associates, 2008). The 45,859-acre preserve includes the Cosumnes River and its floodplains and riparian habitat. The CRPMP identifies two overarching goals and numerous subgoals.

The overarching goals of the CRPMP are (1) native biological communities and the resident and migratory species dependent on them are restored and maintained to sustainable conditions and population levels, and (2) compatible uses improve stewardship of the lands in the Cosumnes River watershed. Numerous subgoals were also established by the CRPMP. Those that may be applicable to the Conservation Strategy include:

- Actively manage the preserve, including implementing the flow augmentation project, collecting physical process data, regularly updating infrastructure databases, and collaborating with regional planning processes.

- Protect the free-flowing Cosumnes River within an ecologically functional landscape.

- Protect, maintain, and restore riparian and floodplain communities, the natural hydrologic processes that sustain the habitat, and the native species that depend on the habitat.

- Maintain and restore a mosaic of freshwater wetland habitats (seasonal and permanent) that support native species.

- Maintain and enhance the population of the giant garter snake in the Badger Creek watershed.

- Restore and maintain a population of fall-run Chinook salmon in the Cosumnes River, with an average annual spawning run of 2,000 adults (10-year average range of 1,000 to 5,000 adults).

Conservation targets were identified and include riparian forest, vernal pool grasslands, freshwater emergent wetlands, giant garter snake, blue oak woodland, and fall-run Chinook salmon. Quantitative objectives were developed for the subgoals and conservation targets, including the following subset:

- Maintain a landscape that supports natural processes and habitat for the Preserve's focal conservation targets consisting of natural lands and suitable agriculture at and surrounding the preserve (100-year floodplain up to Sacramento County's Urban Services Boundary).

- Permanently protect the entire 13,200-acre mapped riparian core area (existing habitat and restorable lands) by securing the remaining 7,450 acres of unprotected land up to Wilton Road.

- Restore an additional 1,000 acres of existing preserve lands to riparian and floodplain habitats by 2018.
- Maintain a minimum of 1,000 acres of seasonal managed ponds and evaluate the need for more managed wetland ponds on a case-by-case basis.
- Create and maintain at least 2,750 acres of flooded agriculture as seasonal wetland habitat for target species (sandhill cranes (*Grus canadensis*) and waterfowl).
- Restore and maintain at least 300 acres of seasonal floodplain habitat for juvenile salmonid rearing.

Conservation Strategy actions related to riparian habitat, as well as restoration of natural fluvial and geomorphic processes that would lead to the recruitment and sustainability of riparian communities, seasonal wetland habitat, and floodplain habitat, may contribute to the goals of the preserve. Conservation Strategy actions may contribute to the preserve's conservation objectives if they result in preserving, restoring, or enhancing giant garter snake aquatic or upland habitat or salmonid habitat within the Cosumnes River watershed.

2.1.11 Sacramento River National Wildlife Refuge Comprehensive Conservation Plan

The *Sacramento River National Wildlife Refuge Comprehensive Conservation Plan* (CCP) describes management of the 11,585-acre Sacramento River NWR (USFWS, 2005). The Sacramento River NWR consists of 26 units located along both sides of the Sacramento River stretching 77 miles between Red Bluff and Princeton, an area contained within both the SPFC Planning Area and Systemwide Planning Area. The refuge contains riparian and agricultural habitats and was established to preserve, restore, and enhance riparian habitat for threatened and endangered species, migratory birds, anadromous fish, and resident species. Riparian forests are being restored by converting flood-prone agricultural lands along the Sacramento River in cooperation with TNC, River Partners, and local farmers. The goal of the CCP related to habitat restoration and species conservation is to contribute to the recovery of endangered and threatened species and provide a natural diversity and abundance of migratory birds and anadromous fish, through the restoration and management of viable riparian habitats along the Sacramento River.

The measureable objectives of the CCP related to habitat restoration and species conservation include the following:

- Prepare and implement site assessment and restoration plans to restore an additional 3,255 acres of riparian vegetation and habitats, as well as maintain existing and newly restored riparian habitat for riparian-dependent species by 2015.

- Promote recruitment of fish and wildlife habitat by investigating riverbank stabilization, Sacramento River NWR levees, and floodplain topography for best management options. During this investigation, the Sacramento River NWR will consider impacts on public safety, agriculture, and water conveyance. This investigation will be conducted on 11 Sacramento River NWR units and a written report will be created by 2015.

- Evaluate the response of federal and California threatened and endangered species to habitat restoration projects. Implement eight surveys by 2005 (least Bell's vireo, VELB, bald eagle (*Haliaeetus leucocephalus*), giant garter snake, bank swallow, western yellow-billed cuckoo, willow flycatcher (*Empidonax traillii*), and Swainson's hawk) and four additional surveys by 2015 (winter-run Chinook salmon, spring-run Chinook salmon, fall-run and late-fall run Chinook salmon, and Central Valley Evolutionarily Significant Unit (ESU) of steelhead).

- Enhance, restore, and monitor breeding migratory and resident landbird populations to source population levels (40 percent recruitment) through habitat restoration on 3,255 acres by 2015. Source populations are those where recruitment (annual increase) is high enough to replace the local breeding population with a surplus, which can repopulate other areas. Source populations recruit at levels above 35 percent for most species.

- Provide high-quality habitat for native anadromous fish by enhancing and restoring 33.5 miles of shaded riverine aquatic (SRA) habitat for temperature control and future sources of large woody debris (LWD) by 2015. Where appropriate, enhance or restore floodplain topography and connectivity with the river at 11 units of the Sacramento River NWR by 2015.

The Sacramento River NWR is located within the SPFC Planning Area and Systemwide Planning Area. Conservation Strategy actions may include fee simple land acquisitions or easement acquisitions that could preserve riparian habitat within Sacramento County; these actions could contribute to the conservation goals of the CCP by providing additional habitat for the riparian species managed for in the Sacramento River NWR.

2.1.12 Sacramento, Delevan, Colusa, and Sutter National Wildlife Refuges Final Comprehensive Conservation Plan and Environmental Assessment

The *Sacramento, Delevan, Colusa, and Sutter National Wildlife Refuges Final Comprehensive Conservation Plan and Environmental Assessment* (CCP EA) describes management of the 10,819-acre Sacramento NWR, 5,877-acre Delevan NWR, 4,686-acre Colusa NWR, and the 2,591-acre Sutter NWR for the next 15 years (USFWS, 2009). The refuges provide habitat and manage for a number of species, including salmonids, giant garter snake, western yellow-billed cuckoo, and Swainson's hawk. The following are goals of the CCP EA that are related to habitat restoration and species conservation:

- Wildlife and Habitat Goal: Conserve, manage, restore, and enhance habitats and associated plant and wildlife species, with an emphasis on supporting an abundance and natural diversity of wintering and migrating waterfowl, shorebirds, birds of prey, and songbirds.

- Threatened and Endangered Species Goal: Conserve, manage, restore, and enhance threatened and endangered species and their habitats, including vernal pool plants and invertebrates, and giant garter snakes.

The following are measureable objectives of the CCP EA related to riparian habitat restoration and species conservation.

- Collectively on the four refuges, 16,914 wetland habitat acres have been actively managed since 2009 to provide 80 to 90 percent seasonally flooded wetlands and 10 to 20 percent summer wetlands. Seasonally flooded wetlands will contain 5 to 50 percent tall emergent cover, more than 50 percent desirable forage plant species cover, and an average water depth of 12 inches (range of 1 to 36 inches). Summer wetlands units will contain 20 to 70 percent cover of desirable submergent or floating-leaved emergent species. At least 50 percent of summer wetland units will have 30 to 80 percent tall emergent cover and average water depths of 24 inches (range of 12-36 inches) during May to October and less than 18 inches during November to April.

- Protect and enhance 581 acres of riparian habitat comprised of more than 80 percent native woody vegetation and herbaceous cover by 2014.

- By 2009, actively manage 1,500 acres within the Sutter Bypass portion of Sutter NWR to help prevent excessive accumulation of woody vegetation that may impact flood water conveyance capabilities.

- By 2014, annually implement BMPs and water management strategies to provide for native fish life cycle needs on the NWRs.

- Provide 11,152 acres (47 percent of the NWRs total acres) of wetland, vernal pool/alkali meadow, grassland, and riparian habitats as sanctuary (i.e., no public access) for general wildlife use, nesting, sensitive breeding sites, and plant populations by 2009.

The Sacramento, Delevan, Colusa, and Sutter NWRs are located within the SPFC Planning Area and Systemwide Planning Area. Conservation Strategy actions may include fee simple land acquisitions or easement acquisitions that could preserve riparian and wetland habitat within Sacramento County. These actions could contribute to the conservation goals of the CCP EA by providing additional habitat for the species managed for in the four refuges.

2.1.13 DWR's Oroville Facility Federal Energy Regulatory Commission License Protection, Mitigation and Enhancement Measures

The *FERC license for DWR's Oroville Facility* (FERC license) contains Protection, Mitigation and Enhancement Measures (PMEs) that address impacts of implementing the Oroville Facility under the new project license's 50 year license term (2006-2056) (DWR 2006). PMEs include the Lower Feather River Habitat Improvement Plan that describes programs for gravel supplementation and improvement, channel improvement, structural habitat supplementation and improvement, fish weir, riparian and floodplain improvement, and other programs in support of Chinook salmon and steelhead in the lower Feather River. Terrestrial species habitat improvements are provided for protection of giant garter snake and red legged frog, and vernal pool conservation. The PMEs and FERC license were subject to ESA consultation with NMFS and USFWS and CESA consultation with CDFG. Implementation of the lower Feather River Habitat Improvement Plan will provide beneficial coordination of the proposed measures in the lower Feather River.

The Lower Feather River Habitat Improvement Plan overlaps with the SPFC Planning Area and Systemwide Planning Area. The Conservation

Strategy is unlikely to make a significant contribution to the PMEs required by the FERC license; however, it may benefit some of the covered species found within riparian and aquatic habitats in the lower Feather River and may be able to provide additional benefits above and beyond the PMEs.

2.2 Regional Conservation Planning Efforts in Progress

Regional conservation planning efforts in progress also include HCPs and HCP/NCCPs, large-scale conservation programs, and recovery plans that are described in more detail below, including any defined goals and measureable objectives.

2.2.1 Bay-Delta Conservation Plan

The *Bay-Delta Conservation Plan* (BDCP) describes an integrated conservation strategy to achieve ecosystem restoration and water supply reliability (BDCP, 2010). It will serve as an NCCP under California's Natural Community Conservation Planning Act (NCCPA), and an HCP under Section 10 of the federal ESA. The BDCP will also provide the basis for biological assessments that support new ESA Section 7 consultations among Reclamation, USFWS, and NMFS. The BDCP is further intended to meet the standards set out in the recently enacted Sacramento-San Joaquin Delta Reform Act, which provides for incorporating the BDCP into a comprehensive management plan for the Delta (known as the "Delta Plan").

The BDCP planning area includes the statutory Delta, as defined in California Water Code Section 12220; Suisun Marsh; and the upper Yolo Bypass. The BDCP's list of proposed covered species and habitat conservation targets includes several species of likely concern for the Conservation Strategy, such as Chinook salmon and steelhead, riparian woodrat, riparian brush rabbit, least Bell's vireo, Delta button celery (*Eryngium racemosum*), Swainson's hawk, yellow-billed cuckoo, giant garter snake, and VELB, as well as the aquatic, riparian, floodplain, and wetland habitats used by these species (BDCP, 2010).

BDCP goals related to habitat restoration and species conservation are as follows:

- Provide for the conservation and management of covered species within the BDCP planning area.
- Preserve, restore, and enhance aquatic, riparian, and associated terrestrial natural communities and ecosystems that support covered species within the BDCP planning area through conservation partnerships. This includes restoration of 400 acres of nontidal wetlands, 5,000 acres of riparian habitats, and 5,000 acres of tidal habitats throughout the BDCP planning area.
- Allow for projects to proceed that restore and protect water supply, water quality, and ecosystem health within a stable regulatory framework.
- Provide a means to implement covered activities in a manner that complies with applicable State and federal fish and wildlife protection laws, including the California and federal ESAs, and other environmental laws, such as the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA).
- Provide a basis for permits necessary to lawfully take covered species.
- Provide a comprehensive means to coordinate and standardize mitigation and compensation requirements for covered activities within the BDCP planning area.
- Provide a less costly, more efficient project review process that results in greater conservation values than project-by-project, species-by-species review.
- Provide clear expectations and regulatory assurances regarding covered activities occurring within the BDCP planning area.

With the exception of Suisun Marsh, the BDCP planning area is completely within the Systemwide Planning Area, and the Yolo Bypass lies within both the BDCP planning area and the SPFC Planning Area. The BDCP and the Conservation Strategy could be complementary pieces to a comprehensive conservation strategy for the entire Delta and Sacramento and San Joaquin valleys. It is likely that most, if not all, Conservation Strategy actions would contribute to the BDCP's conservation objectives, particularly those that occur within the Yolo Bypass or Delta. Conservation Strategy actions that could contribute to the BDCP conservation objectives

include the preservation or restoration of habitat for riparian and aquatic species, such as Chinook salmon and steelhead, riparian woodrat, riparian brush rabbit, least Bell's vireo, Delta button celery, Swainson's hawk, western yellow-billed cuckoo, giant garter snake, and VELB.

2.2.2 Solano Multi-Species Habitat Conservation Plan

Similar to other HCPs, the *Solano Multi-Species Habitat Conservation Plan* (SMSHCP) establishes a framework for complying with State and federal endangered species regulations while accommodating future urban growth, infrastructure development, and ongoing O&M activities. The plan has a 30-year lifespan and covers approximately 585,000 acres, nearly all of which (577,000 acres) are in Solano County. The SMSHCP planning area extends into Yolo County to encompass facilities maintained by Reclamation District 2068, Dixon Resource Conservation District, and Dixon Regional Watershed Joint Powers Agency (JPA), as well as for restoration activities along Putah Creek (SCWA, 2009). The SMSHCP addresses 37 covered species, including salmonids, VELB, giant garter snake, and Swainson's hawk, which are also of interest to the CVFPP. Covered habitats include riparian, stream, and freshwater marsh. Conservation goals include the preservation, restoration, and management of approximately 32 miles of stream and riparian habitat within the plan area, and the preservation and restoration of a minimum of 50 acres of riparian habitat (SCWA, 2009).

The easternmost portions of the SMSHCP planning area along the Sacramento River and upper portions of the Delta overlap with the SPFC Planning Area and Systemwide Planning Area. Given the limited geographic overlap between the two planning efforts, the Conservation Strategy is unlikely to make a significant contribution to the conservation objectives of the SCMSHCP; however, it may benefit some of the covered species that would be found within riparian and aquatic habitats in the SCMSHCP planning area and adjacent parts of the SPFC Planning Area or Systemwide Planning Area (e.g., within the Lindsey Slough-Barker Slough-Cache Slough region).

2.2.3 South Sacramento Habitat Conservation Plan

The *South Sacramento Habitat Conservation Plan* (SSHCP) planning area will encompass approximately 374,000 acres within southern Sacramento County and include the cities of Elk Grove, Galt, and Rancho Cordova (County of Sacramento et al., 2010). Covered habitats include vernal pools, oak woodlands, grasslands, riparian, wetlands, and aquatic habitats, and 30 proposed covered species (10 of which are threatened or endangered under the federal or California ESA) including giant garter snake, VELB, vernal pool plants and invertebrate species, and other bird, raptor, bat, reptile, and

amphibian species. The SSHCP will serve as an NCCP under California's NCCPA, and an HCP under Section 10 of the federal ESA.

The strategy for the SSHCP includes requirements to:

- Create a reserve system over the permit term that will preserve a minimum of 41,923 acres and restore 1,786 acres of land that will benefit covered species, other native biota, and natural and naturalized land cover types.
- Configure the reserve system to protect landscape-level ecological processes necessary for covered species and other native biota.
- Integrate the reserve system into the existing network of open space (previously conserved lands) to a contiguous network of 9,500 acres of natural or naturalized habitats in the Urban Development Area (UDA).
- Establish preserve linkages within the reserve system that maintain connectivity between preserves in the planning area to sustain and enhance opportunities for genetic exchange and movement of native biota in the planning area.
- Guide preservation to primary conservation areas.
- Protect streams and creeks in the UDA through the establishment of stream setbacks.
- Establish a framework for long-term management of the reserve system for the benefit of covered species and other native biota

The SSHCP planning area has some overlap with the SPFC Planning Area and Systemwide Planning Area. The focus of the SSHCP is to protect and enhance wetlands (primarily vernal pools) and upland habitats; thus, the Conservation Strategy may not contribute directly to the goals of the SSHCP. However, Conservation Strategy actions would contribute to the overall SSHCP conservation objectives if they result in preserving or restoring aquatic or riparian habitat for covered species, such as giant garter snake and VELB.

2.2.4 Butte Regional Habitat Conservation Plan /Natural Community Conservation Plan

The *Draft Butte Regional Habitat Conservation Plan* (BRHCP) *and Natural Community Conservation Plan* (NCCP) planning area will cover approximately 560,000 acres of lowland and foothill oak woodlands in Butte County and all portions of the SPFC Planning Area and Systemwide

Planning Area within Butte County (BCAG, 2011). Covered habitats include riparian areas, wetlands, and aquatic habitats. The 41 proposed BRHCP/NCCP covered species include fishes (e.g., salmonids), as well as riparian-associated wildlife (e.g., yellow-billed cuckoo, VELB, bank swallow, Swainson's hawk), and wetland- associated species (e.g., giant garter snake) that would likely be Conservation Strategy targets. The draft plan identifies conservation objectives such as preserving covered species and their natural communities and ecosystems, contributing to the recovery of fish, wildlife, plant, and animal communities and species, and identifying and designating biologically sensitive areas. Measureable objectives for the draft plan include:

- Protect 6,370 acres of existing unprotected cottonwood-willow riparian forest and valley oak riparian forest in minimum patch sizes of 25 acres along rivers and streams distributed within the planning area

- Restore 536 acres of cottonwood/willow riparian forest, 140 acres of valley oak riparian forest, and 23 acres of willow scrub along rivers and streams distributed within the planning area

- To the extent consistent with flood control requirements, protect 20 linear miles of channel banks that support dynamic bank formation and erosion processes that create bank swallow nesting habitat along Big Chico Creek and Butte Creek

However, the BRHCP/NCCP notes the following (BCAG, 2011):

> *…although the Sacramento River and Feather River support habitat for several of the covered species in the Plan Area, BRCP goals, objectives, and conservation actions are not proposed for these rivers because the channels, banks, and flow of these rivers are controlled and managed predominately by state and federal agencies (e.g., California Department of Water Resources, U.S. Army Corps of Engineers, and Bureau of Reclamation).*

Thus, riparian areas that would likely be a major focus of the Conservation Strategy are not of central importance to meeting the conservation objectives of the BRHCP/NCCP. As an example, the plan targets just 11 acres of riparian restoration along the Sacramento River. However, the BRHCP/NCCP also calls for salmonid aquatic habitat improvements, including protecting and improving 10 linear miles of steelhead habitat by removing passage barriers; the quality of spawning and rearing habitat is also a Conservation Strategy focus.

Any Conservation Strategy actions that involve restoration of riparian and wetland habitat, particularly along tributaries to the Sacramento River within Butte County (e.g., Butte Creek, Big Chico Creek, Sycamore Creek, Mud Creek), or that focus on removing fish passage barriers along these streams, may significantly contribute to the BRHCP/NCCP's conservation objectives. Restoration of riparian and wetland habitats and natural river processes along the Sacramento and Feather rivers, although not a major focus of the BRHCP/NCCP, would also contribute to the plan's conservation objectives by increasing the regional availability and quality of habitat for BRHCP/NCCP target species.

2.2.5 Yuba/ Sutter County Natural Community Conservation Plan/Habitat Conservation Plan

The Yuba/Sutter Natural Community Conservation Plan (YSNCCP) */Habitat Conservation Plan* is in progress. To date, only the *Report of the Independent Science Advisors* (Spencer et al., 2006) is readily available. The proposed planning area comprises 200,100 acres and includes the majority of Sutter County and significant portions of western Yuba County as well as small portions of southern Butte County and northwestern Placer County (DFG, 2011). Twenty-one species are proposed (17 animals and 4 plants) for coverage under the plan, including the VELB, giant garter snake, Swainson's hawk, yellow-billed cuckoo, and bank swallow. YSNCCP/HCP covered natural communities and land cover types include riverine, riparian, and wetland habitats.

This YSNCCP/HCP planning area significantly overlaps with both the SPFC Planning Area and Systemwide Planning Area. The YSNCCP/HCP has not yet been formally developed and conservation objectives are unknown. However, covered activities within the YSNCCP/HCP are expected to include flood control projects, road improvements, irrigation improvements, and future development. The Conservation Strategy could contribute to the objectives of the YSNCCP/HCP given the overlap in activities. However, given the geographic overlap between the two programs and the overlap in target species and habitats, Conservation Strategy actions are likely to significantly contribute to YSNCCP/HCP objectives of preserving and restoring riparian and wetland habitat, and the species of plants and animals found in these habitats.

2.2.6 Yolo County Natural Heritage Program

The *Yolo County Natural Heritage Program* (YNHP) is a county-wide plan designed to provide for long-term conservation and management of sensitive and at-risk species and the habitats upon which they depend, while accommodating other important land uses. The plan, which is still under development, will serve as an HCP and NCCP and will cover

653,820 acres (YC HCP/NCCP JPA et al., 2004). The plan's goals and objectives are also still under development.

The YNHP HCP/NCCP will cover of a suite of species associated with riverine-lacustrine, emergent wetland, and riparian forest-scrub habitats; including VELB, yellow-billed cuckoo, bank swallow, and several riparian-associated songbirds. YNHP covered habitats potentially related to the Conservation Strategy include both riparian and wetland habitats. No fish species are covered by the YNHP.

The YNHP includes a Riparian Habitat Conservation Strategy, the goals of which are as follows:

- Ensure that the full range of riparian habitat conditions are conserved throughout the planning area
- Conserve lands and associated waterways that support natural or functional ecosystem processes, including hydrology, or where these processes can be restored or provided through management
- Create a riparian habitat network connected to conserved upland areas
- Incorporate a range of habitat patch sizes to provide for area-sensitive species and a "matrix" of conserved lands providing habitat within the working agricultural landscape
- Restore riparian functions and desirable conditions in areas dominated by invasive nonnative species
- Meet and maintain conservation goals for species covered under the YNHP
- Maintain ecosystem functions of conserved lands through monitoring and adaptive management
- Encourage landowner participation in riparian conservation through an incentive-based, collaborative program

Eastern sections of the county, comprising seven YNHP conservation planning units within the Colusa Basin, Yolo Basin, and West Sacramento, are within the SPFC Planning Area, and three additional conservation planning units along Putah and Cache Creeks are within the Systemwide Planning Area. Based on the extensive geographic overlap, target species, and habitat coverage between the two plans, the Conservation Strategy will likely contribute to the goals of the YNHP. While no specific goals for

riparian habitat acreage have yet been established, the Conservation Strategy could significantly contribute to the YNHP riparian goals, especially in the vicinity of the Yolo Bypass through various actions such as habitat restoration, habitat acquisition, and restoration of natural fluvial geomorphic processes.

2.2.7 Placer County Conservation Plan

The *Placer County Conservation Plan* (PCCP) will provide a framework to protect, enhance and restore natural resources in western Placer County (PCCDRA, 2011). The PCCP will achieve conservation goals while complying with State and federal regulations and accommodating urban and rural growth. The PCCP includes a joint NCCP/HCP and a County Aquatic Resources Program that will protect streams, wetlands, and other water resources and fulfill the requirements of the federal Clean Water Act and analogous State laws and regulations. Proposed covered species include riparian and aquatic species such as Swainson's hawk, bank swallow, giant garter snake, and salmonids.

Overall goals of the PCCP that align closely with Conservation Strategy objectives include the following:

- Sustain all natural communities that are currently present in the western Placer County landscape
- Partially restore or enhance certain natural communities and ecosystem processes and functions (in particular, aquatic and wetland ecosystems and riparian habitats overlap with Conservation Strategy objectives)
- Ensure population stability and sustainability of covered species and contribute to the recovery of those species
- Maintain connectivity between habitats across the landscape

Measureable objectives for conservation and management of riverine and riparian communities of the PCCP include:

- Protect stream reaches within the planning area to promote habitat function (i.e., water temperature and shade conditions suitable for covered fish), and movement of animals and plants (i.e., dispersal of seeds of riparian species) along riverine and riparian corridors that traverse the planning area
- Restore stream reaches that support covered fish, amphibians, and reptile species within the reserve system to improve natural community function, connectivity, and water quality

- Enhance stream reaches within the reserve system to maintain and improve ecosystem functions and connectivity between habitats

- Protect valley foothill riparian habitat within the reserve system to promote habitat function within riparian and riverine habitats, and facilitate wildlife movement across the planning area landscape

- Restore valley foothill riparian habitat within the reserve system to: connect fragmented riparian corridors; slow the movement of flood waters; allow the deposition of sediment to improve channel and bank formation processes; reduce sediment loading in river and stream systems; and improve habitat for covered species, including the creation of complex rearing habitat for covered fish species

- Enhance functional valley foothill riparian communities that benefit covered species and promote native biodiversity

PCCP covered activities include instream projects, infrastructure projects, O&M, and conservation strategy implementation. The initial permit term is proposed to be 50 years; 31 species are proposed to be covered (26 animals and 5 plants), including VELB, salmonids, giant garter snake, Swainson's hawk, and bank swallow. PCCP actions include the creation of a 30,000- to 50,000-acre reserve for the benefit of natural communities, covered species, biological diversity, and ecosystem function that, among other goals, will provide for timely restoration, protection, and management of riparian woodland and other wetlands.

The PCCP planning area includes approximately 212,000 acres in western Placer County, the vast majority of which lies outside the SPFC Planning Area and Systemwide Planning Area. Small areas of overlap occur along the Bear River in extreme western Placer County and around Folsom Reservoir. Although geographic overlap is limited between the two planning efforts, Conservation Strategy actions may contribute to PCCP conservation objectives. Potentially relevant actions would be those that contribute to the reserve system or that preserve, restore, or enhance areas adjacent to PCCP reserves and those that benefit covered riparian aquatic species such as VELB, salmonids, giant garter snake, Swainson's hawk, and bank swallow.

2.2.8 Butte Sink, Willow Creek-Lurline, and North Central Valley Wildlife Management Areas Comprehensive Conservation Plan

The USFWS is preparing a CCP for Butte Sink, Willow-Creek-Lurline, and North Central Valley Wildlife Management Areas (WMA) located within the Central Valley (USFWS, 2010). The 10,260-acre Butte Sink WMA, 5,795-acre Willow-Creek Lurline WMA, and the 14,740-acre North Central Valley WMA include both USFWS-owned lands and private lands protected with conservation easements. These WMAs were established primarily to preserve existing and restored wetlands for waterfowl and other wetland-dependent wildlife. The CCP planning area is located within the SPFC Planning Area and Systemwide Planning Area. The CCP's goals and objectives are still under development; thus, it is unknown whether the Conservation Strategy would contribute to the goals and objectives of the CCP.

2.2.9 Public Draft Recovery Plan for Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and Distinct Population Segment of Central Valley Steelhead

The *NMFS Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run and Central Valley Spring-Run Chinook Salmon, and the Distinct Population Segment of Central Valley Steelhead*, has been in draft form since 2009. Its primary goal is to improve the viability of these species and remove them from federal protection under the ESA. The draft recovery plan identifies recovery objectives and criteria based on attaining viable populations of each of the ESUs and district population segments (DPS) in specific geographic areas. Priority recovery actions include phased reintroduction of fish into primary candidate watersheds, restoration of ecological flows throughout the Sacramento and San Joaquin river basins and the Delta, large-scale Delta ecosystem restoration, restoration of ecological habitat function and decrease in nonnative fish predation, implementation of all phases of the Battle Creek Restoration Program and the SJRRP, and incentives for statewide water conservation, among other priorities. In addition, it specifies a recovery criterion of restoring and maintaining a continuous 100-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" (NMFS, 2009b).

The draft recovery plan area overlaps the SPFC Planning Area and Systemwide Planning Area, but the recovery plan area is larger and

includes many more miles of rivers and tributary creeks that provide rearing, migration, or spawning habitat for these species. Conservation Strategy actions may contribute significantly to the draft recovery plan; such actions are those that (1) restore floodplain habitat to support juvenile Chinook salmon and steelhead rearing (e.g., constructing new flood bypasses, expanding existing bypasses, setting back existing levees), (2) increase instream habitat suitability and complexity (removing bank revetment, modifying O&M practices), and (3) increase availability of SRA habitat.

2.3 Plans Identifying Specific Geographic Areas Without Quantifying Conservation Measures

Plans that are spatially defined but lack quantitative objectives are described below, and include recovery plans and other geographically based planning efforts.

2.3.1 Draft Recovery Plan for the Giant Garter Snake

The *Draft Recovery Plan for the Giant Garter Snake* describes conservation actions that, if implemented, could contribute to delisting the federally threatened giant garter snake (USFWS, 1999). The draft recovery plan contains several conservation actions, including protection of existing giant garter snake populations and habitat and restoration of populations to former habitat. The draft recovery plan estimates that giant garter snake could be delisted by 2028 if recovery criteria are met.

The draft recovery plan defines four recovery units in the Sacramento and San Joaquin valleys: (1) the Sacramento Valley Unit, extending from the vicinity of Red Bluff south to the confluence of the Sacramento and Feather rivers; (2) the Mid-Valley Unit, extending from the American and Yolo basins south to Duck Slough near the City of Stockton; (3) the San Joaquin Valley Unit, extending south from Duck Slough to the Kings River; and (4) the South Valley Unit, extending south from the Kings River to the Kern River Basin. Recovery Units 1 and 2 overlap with the SPFC Planning Area and Systemwide Planning Area as does the majority of Recovery Unit 3; Recovery Unit 4 lies outside the boundaries of both CVFPP planning areas.

The giant garter snake and its habitat (i.e., marshes, sloughs, and other perennial waters dominated by emergent, herbaceous vegetation as well as suitable brumation habitat above floodwaters) are the focus of the draft recovery plan; however, species that use wetland and marsh habitats within the Sacramento and San Joaquin valleys, such as tricolored blackbird,

white-faced ibis (*Plegadis chihi*), western pond turtle, and various species of waterfowl, would also likely benefit from implementation of the draft recovery plan.

Conservation Strategy actions that may contribute to the conservation objectives of the draft recovery plan include those that restore or enhance giant garter snake habitat outside floodways associated with major rivers of the Sacramento and San Joaquin valleys, and those that create suitable giant garter snake aquatic habitat by creating new flood bypasses or changing the operation of existing bypasses.

2.3.2 Draft Recovery Plan for the Least Bell's Vireo

The *Draft Recovery Plan for the Least Bell's Vireo* describes conservation actions that, if implemented, could contribute to reclassification of the least Bell's vireo from endangered to threatened, and ultimately, delisting (USFWS, 1998a). Instrumental to this strategy is securing and managing riparian habitat within the historical breeding range of the least Bell's vireo, annual monitoring and range-wide surveys, and research activities necessary to monitor and guide the recovery effort. A delisting target date was not projected in the draft recovery plan.

Historically, least Bell's vireo was widespread throughout riparian woodlands in the Central Valley and low-elevation riverine valleys of California. The breeding distribution of the least Bell's vireo is currently restricted to areas outside the SPFC Planning Area and Systemwide Planning Area in Southern California and Baja California, although singing birds have recently been recorded within the historical breeding range, for example in Yolo County. Within CVFPP planning area, potential least Bell's vireo habitat includes Caswell Memorial State Park (Stanislaus River), Cosumnes River Preserve, Bobelaine Sanctuary (Feather River), Butte Sink, Big Chico Creek to the mouth of Pine Creek, and the Sacramento River (Hanson Island to Parrot Landing, River Miles (RM) 170 to 181; Merrill's Landing at RM 212 to 215; and Woodson Bridge-Kopta Slough at RM 218 to 220).

The least Bell's vireo typically inhabits structurally diverse riparian areas, including cottonwood-willow forests, oak woodlands, and mule fat (*Baccharis salicifolia*) scrub. While the draft recovery plan focuses on the least Bell's vireo, implementing actions contained in the draft recovery plan could benefit other sensitive species found in San Joaquin and Sacramento valley riparian ecosystems, including VELB, ye1low-billed cuckoo, bank swallow, and riparian brush rabbit.

Conservation Strategy actions that restore or enhance riparian and wetland habitat along major rivers of the Sacramento and San Joaquin valley could

contribute to the conservation objectives of the draft recovery plan. Conservation Strategy actions may contribute to the availability of suitable least Bell's vireo habitat in the Sacramento and San Joaquin valleys, if those actions result in (1) restoration of natural fluvial and geomorphic processes, such as meander migration, bank erosion, sediment deposition, and riparian habitat disturbance and succession (e.g., construction of setback levees, removal of levees, removal of bank revetment), and (2) active restoration of riparian habitat (i.e., planting trees and shrubs). Successful reintroduction of least Bell's vireo to the Conservation Strategy's SPFC Planning Area or Systemwide Planning Area may be enhanced by an expansion of potentially suitable riparian habitat.

2.3.3 Valley Elderberry Longhorn Beetle Recovery Plan

The *Recovery Plan for the Valley Elderberry Longhorn Beetle* (USFWS, 1994) summarizes the current literature on VELB, prescribes actions necessary to acquire additional biological data, and recommends actions necessary for species preservation, maintenance, and recovery. Primary objectives of the recovery plan are to protect the three known localities that support the species (at the time of plan development), survey riparian vegetation along certain Central Valley rivers for remaining VELB colonies and habitat, provide protection to remaining habitat within its suspected historic range, and determine the number of sites and populations necessary to eventually delist the species. According to the recovery plan, information on VELB life history, distribution, and habitat requirements is insufficient and, therefore, precise recommendations for its recovery are not provided. Additionally, the conditions under which the species can be considered "recovered" are to be determined.

Although the entire historical distribution of the VELB is unknown, extensive destruction of riparian forests of the Central Valley during the past 150 years strongly suggests that the species' range has decreased and become fragmented. At the time that the recovery plan was prepared, the VELB was known from only four locations within SPFC Planning Area or Systemwide Planning Area. After the recovery plan was prepared, VELB were located in suitable riparian habitat throughout the Systemwide Planning Area and SPFC Planning Area, and occasionally in oak woodlands and other nonriparian areas supporting the species' host plant, blue elderberry (*Sambuccus mexicana*). The USFWS is currently determining whether delisting is warranted based on additional information collected since the species was originally listed.

The recovery plan calls for protection of VELB habitat throughout riparian areas within the Sacramento and San Joaquin valleys, an area that overlaps the entirety of the SPFC Planning Area and Systemwide Planning Area as

well as areas outside their boundaries (e.g., the lower Kern River). Conservation Strategy actions that result in the preservation, protection, and restoration, or enhancement of VELB habitat (i.e., elderberry scrub and riparian woodland) associated with the major rivers of the Sacramento and San Joaquin valleys would significantly contribute to the conservation objectives of the recovery plan.

2.3.4 Bank Swallow Recovery Plan

The *Recovery Plan for the Bank Swallow* (DFG, 1992) describes specific management strategies for recovery of the bank swallow. The primary recovery goal is the maintenance of a self-sustaining wild population. Objectives are to ensure that (1) the remaining population of this species does not suffer further declines in either range or abundance, and (2) sufficient habitat is available to ensure that the species will be able to survive as a member of California's native avifauna. Enhancing existing populations and reestablishing populations in target areas are additional objectives. Specific habitat protection objectives include maintaining riparian vegetation on the Sacramento River between Chico Landing and Red Bluff and habitat acquisitions in the Sacramento River NWR and the upper Sacramento River where there are abundant bank swallow colonies. Setback levees allowing channel meander have also been identified as alternative recovery actions.

Conservation Strategy actions that result in the restoration or enhancement of riparian and wetland habitat associated with major rivers of the Sacramento and San Joaquin river valleys would potentially contribute to the conservation objectives of the recovery plan. Conservation Strategy actions may contribute to the availability of potentially suitable bank swallow nesting habitat in the Sacramento and San Joaquin river valleys, if those actions result in the restoration of natural fluvial and geomorphic processes, such as meander migration and bank erosion.

2.3.5 California Red-Legged Frog Recovery Plan

The *Recovery Plan for the California Red-Legged Frog* (USFWS, 2002) describes eight recovery units, so that recovery strategies can be tailored to each recovery unit to best meet the goal of delisting the species. The strategy for recovery includes: (1) protecting existing populations by reducing threats, (2) restoring and creating habitat that will be protected and managed in perpetuity, (3) surveying and monitoring populations and conduction research on the biology of and threats to the species, and (4) reestablishing populations of the subspecies within its historic range.

Two recovery units overlap with the SPFC Planning Area and Systemwide Planning Area: the Sierra Nevada foothills and Central Valley and the North Coast range foothills and western Central Valley recovery units. Core areas were identified within each recovery unit where recovery actions are focused. The core areas, when protected and managed for California red-legged frogs, will allow for long-term viability of existing populations and reestablishment of populations within the historic range. They were selected based on the following criteria: (1) occupied by California red-legged frogs, (2) where populations of California red-legged frogs are source populations, (3) areas that provide connectivity between source populations, and (4) that represent areas of ecological significance. Channelization and flood control maintenance degrade California red-legged frog habitat.

Conservation Strategy goals of increasing and improving the quantity, diversity, quality, and connectivity of riverine habitats through corridor management planning and easements in areas where recovery unit core areas have been identified (e.g., Yuba River, Feather River) could potentially contribute to the conservation objectives of the recovery plan. Conservation Strategy actions may contribute to the availability of potentially suitable California red-legged frog habitat in tributaries of the Sacramento River, if those actions protect suitable habitats and buffer areas long term though conservation easements, preserves, or mitigation banks.

2.3.6 Recovery Plan for Upland Species of the San Joaquin Valley, California

The riparian brush rabbit and riparian woodrat are addressed in the *Recovery Plan for Upland Species of the San Joaquin Valley, California* (USFWS, 1998b). Most of the 34 species addressed in the recovery plan occur in arid grasslands and shrublands; however, the riparian woodrat and riparian brush rabbit inhabit forested river corridors of portions of the San Joaquin River and its tributaries on the San Joaquin Valley floor. Potential conservation actions for the riparian brush rabbit include expansion of Caswell Memorial State Park and establishment of viable populations within the historical range through reintroduction, habitat restoration, and management of habitat. Potential conservation actions for the riparian woodrat include establishing habitat linkages between remnants of riparian habitat, reintroduction, habitat restoration, and habitat management. Conservation Strategy actions that include restoration or enhancement of riparian habitat in the San Joaquin Valley may contribute to the conservation of the riparian brush rabbit and riparian woodrat by increasing their population sizes and distribution in the San Joaquin Valley.

2.3.7 The Nature Conservancy Sacramento River Project

Through the *Sacramento River Project* (SRP), TNC and its partners, which include local landowners, nonprofit organizations, the California Department of Parks and Recreation, DWR, USFWS, and U.S. Army Corps of Engineers (USACE), are implementing projects to protect and restore riparian habitat on the Sacramento River between Red Bluff and Colusa (TNC 2011). TNC intends to preserve an additional 6,000 acres of land by 2015 within this reach of the Sacramento River and to restore riparian habitat, where appropriate, on these lands. Focus species include those that use riparian areas and SRA habitat along the Sacramento River, including VELB, salmonids, bank swallow, least Bell's vireo, yellow-billed cuckoo, and Swainson's hawk. The SRP area is wholly contained within the SPFC Planning Area and Systemwide Planning Area.

Conservation Strategy actions that may be implemented within this reach of the Sacramento River, such as construction of setback levees, removal of levees and bank revetment, habitat restoration, floodplain creation (including creation of off-channel habitats), and similar conservation actions, would make a significant contribution to TNC's goals for the SRP.

2.3.8 Sacramento River Conservation Area Forum

The *Sacramento River Conservation Area Forum* (SRCAF) is a nonprofit organization that evolved from California Senate Bill 1086, which called for creating a management plan to protect, restore, and enhance fisheries and riparian habitat along the Sacramento River. Since passage of Senate Bill 1086 in 1986, SRCAF has published numerous planning documents, including the following:

- *Upper Sacramento River Fisheries and Riparian Habitat Management Plan*, 1989 (USRFRHAC, 1989)
- *SRCAF Handbook*, 2003 (SRAC, 2003)
- *Draft Programmatic Safe Harbor Agreement* (ongoing, N.D.; SRCAF, 2009)
- *Strategic Plan* covering 2008 to 2011 (SRCAF, date unknown)

The Sacramento River Conservation Area defined in the 2003 SRCAF Handbook includes the Sacramento River from Verona (the confluence of the Feather and Sacramento rivers), upstream to Keswick Dam north of Redding. This area overlaps completely with the Systemwide Planning Area with a small portion near Verona extending into the SPFC Planning Area.

The goal of SRCAF is to preserve remaining riparian habitat and reestablish a continuous riparian ecosystem along the Sacramento River between Redding and Chico, and to reestablish riparian vegetation below Chico to Verona wherever possible. In achieving those goals, six principles are to be followed as actions are planned and implemented. Main ideas of the principles are as follows:

- Use an ecosystem approach that contributes to recovery of threatened and endangered species and that is sustainable by natural processes.
- Use effective and least environmentally damaging bank protection measures, and, where appropriate, operate within the parameters of local, State, and federal flood control programs.
- Operate within the parameters of local, State and federal flood control and bank protection programs.
- Recognize that landowners' participation is voluntary, never mandatory.
- Give full consideration to landowner, public, and local government concerns.
- Provide accurate and accessible information and education.

Conservation Strategy actions that could contribute to the conservation objectives of the SRCAF are any related to riparian habitat acquisition and restoration along the Sacramento River above Verona, as well as restoration of natural fluvial and geomorphic processes that lead to the recruitment and sustainability of riparian communities.

2.3.9 Comprehensive Management Plan for the Sacramento River Wildlife Area

The Sacramento River Wildlife Area (SRWA) encompasses approximately 3,770 acres of important riparian habitat located along a 70-mile reach of the Sacramento River. The SRWA includes 13 physically separate units that extend from RM 145 just north of the City of Colusa, upstream to RM 215, which is three miles south of Woodson Bridge near Corning.

Biological goals were developed in the *Comprehensive Management Plan for the Sacramento River Wildlife Area* to guide management based on maintaining natural riverine processes, and enhancing or restoring species populations or habitats (DFG, 2004). Biological element goals include:

- Preserving remaining riparian habitat and reestablishing a continuous riparian ecosystem along the Sacramento River between Red Bluff and Chico and reestablishing riparian vegetation along the river from Chico to Verona.
- Maintaining and enhancing habitat for special status species.
- Supporting natural processes that result in the creation and enhancement of habitat.
- Maximizing habitat value of the SRWA.
- Supporting scientific research and monitoring.
- Supporting the conservation of wildlife habitat on privately owned land along the Sacramento River.

Specific tasks were also identified to achieve the biological element goals. Management coordination element goals were also identified and include supporting the Hamilton City flood damage reduction and ecosystem restoration project.

Conservation Strategy actions related to riparian habitat, as well as restoration of natural fluvial and geomorphic processes that would lead to the recruitment and sustainability of riparian communities and habitat for special status species, would contribute to the goals of the SRWA. Conservation Strategy actions may contribute to the overall goal of preserving remaining riparian habitat, reestablishing a continuous riparian ecosystem along the Sacramento River between Red Bluff and Chico and reestablishing riparian vegetation along the river from Chico to Verona, and supporting natural processes that result in the creation and enhancement of habitat.

2.3.10 Yolo Bypass Wildlife Area Land Management Plan

The Yolo Bypass Wildlife Area (YBWA) is composed of approximately 16,770 acres of managed wildlife habitat and agricultural land within the Yolo Bypass. The Yolo Bypass conveys seasonal high flows from the Sacramento River to help control river stage and protect the cities of Sacramento, West Sacramento, and Davis and other local communities, farms, and lands from flooding.

Biological goals were developed in the *Yolo Bypass Wildlife Area Land Management Plan* (LMP) to address specific biological elements, such as (1) including management and maintenance of habitat supporting the following species guilds: waterfowl, shorebird/wading birds, upland game

birds, raptors, cavity-nesting birds, neotropical birds, waterbird species associated with emergent marsh vegetation, and (2) maintaining and enhancing foraging opportunities for breeding colonies of bats (DFG and Yolo Basin Foundation, 2008). The goal for nonnative invasive species is to prevent introduction and spread of species that have no benefit to wildlife or impacts to special-status plants.

The goals include maintaining and enhancing communities for native species diversity and abundance, and restoring and enhancing communities to conditions that provide desired ecological functions. These goals apply to seasonal and permanent wetlands, riparian, grassland and upland vegetative communities, and aquatic ecosystems.

Management goals include coordinating federal, state, and local agencies regarding plans and projects that may affect habitats and/or management at the YBWA, and coordinating with flood control agencies regarding flood control and management in the Yolo Bypass.

The Conservation Strategy may contribute to the LMP goals, based on the extensive geographic overlap and target species and habitat coverage between the two plans. While no specific goals for riparian habitat acreage have yet been established, the Conservation Strategy actions may significantly contribute to the wildlife area's riparian goals in the Yolo Bypass through various actions such as habitat restoration, habitat acquisition, and restoration of natural fluvial geomorphic processes. Conservation Strategy actions may also contribute to increasing seasonal and permanent wetland habitats important for supporting the LMP's biological goals (species guilds).

2.3.11 California Water Plan

The *California Water Plan* (CWP), last updated in 2009, provides a planning framework for elected officials, agencies, tribes, water and resource managers, businesses, academia, stakeholders, and the public for making informed decisions about California's water future (DWR, 2009). The CWP is updated every five years and presents the status and trends of California's water-dependent natural resources; water supplies; and agricultural, urban, and environmental water demands for a range of plausible future scenarios. The CWP also evaluates different combinations of regional and statewide resource management strategies to reduce water demand, increase water supply, reduce flood risk, improve water quality, and enhance environmental and resource stewardship. Objectives of the CWP that may be relevant to the Conservation Strategy include:

- Promote, improve, and expand Integrated Regional Water Management to create and build on partnerships that are essential for California water resources planning, sustainable watershed and floodplain management, and increasing regional self-sufficiency.

- Use water more efficiently with significantly greater water conservation, recycling, and reuse to help meet future water demands and adapt to climate change.

- Advance and expand conjunctive management of multiple water supply sources with existing and new surface and groundwater storage to prepare for future droughts, floods, and climate change.

- Protect and restore surface water and groundwater quality to safeguard public and environmental health and secure California's water supplies for beneficial uses.

- Practice, promote, improve, and expand environmental stewardship to protect and enhance the environment by improving watershed, floodplain, and instream functions and to sustain water and flood management systems.

- Promote and practice integrated flood management to provide multiple benefits including better emergency preparedness and response, higher flood protection, more sustainable flood and water management systems, and enhanced floodplain ecosystems.

- Set as co-equal goals a healthy Delta ecosystem and a reliable water supply for California and recognize the Delta as a unique and valued community and ecosystem to promote and practice management for a sustainable California Delta.

The CWP includes the entire state of California which, therefore, includes the entire SPFC Planning Area and Systemwide Planning Area. The Conservation Strategy would contribute to the objectives of the CWP because the objectives of both plans include flood management while promoting floodplain and instream protection and enhancement. The CWP can be used as a guide for developing recommended actions within the Conservation Strategy. As the Conservation Strategy is being developed, synergies between it and the CWP will be explored.

2.3.12 State and Regional Water Board Plans

The California State and Regional Water Boards are involved in several efforts within the Systemwide Planning Area, including the *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Hart et al., 2011), *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (Kapahi et al., 2006), and the *Wetland and Riparian Protection Policy* (DFG and SWRCB, 2011).

The *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Hart et al., 2006) provides numerical and narrative water quality objectives for fish and wildlife beneficial uses, and for agriculture, silviculture, recreational, fishing, municipal and industrial beneficial uses. The plan overlaps spatially with the SPFC and SPA, but its objectives are based on water quality, rather than habitat.

The *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (Kapahi et al., 2006) provides numerical and narrative water quality objectives for fish and wildlife beneficial uses, and for agriculture, municipal and industrial beneficial uses. Implementation measures include flow-based objectives: Delta outflows, river flows on the Sacramento River at Rio Vista, river flows on the San Joaquin River at Airport Way Bridge, Vernalis, export limits, Delta Cross Channel gates operation; and salinity objectives. The plan overlaps spatially with the SPFC and SPA, but its objectives are based on flows and water quality, rather than habitat.

The *Wetland and Riparian Protection Policy* 5-year coordinated work plan for wetlands conservation (DFG and SWRCB, 2011) describes a state-wide approach to wetlands conservation to be conducted by each agency. The WRCB identifies adoption of the Wetland and Riparian Protection Policy, which is under development, to occur in late 2012, providing the foundation for additional phases:

- Phase 1 includes developing a wetland definition, a regulatory mechanism for discharge of dredge and fill material to State waters, including wetlands, and an assessment method for collecting water quality and wetland data to monitor progress toward water quality and wetland protection and evaluate program development.

- Phase 2 expands the scope of the policy to protect wetlands from all other activities potentially impacting water quality, and includes identification of water quality objectives to support beneficial uses.

- Phase 3 will identify, protect, and promote restoration of riparian areas and their functioning to support water quality and beneficial uses,

including a definition for riparian areas and identification of water quality objectives to support beneficial uses.

As the Conservation Strategy is being developed, synergies between it and the Wetland and Riparian Protection Policy will be explored.

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3.0 References

Bay-Delta Conservation Plan (BDCP). 2010. Bay Delta Conservation Plan working draft. (Internet). (cited 15 July 2011). Available from: http://baydeltaconservationplan.com/BDCPPlanningProcess/ReadDraftPlan/ReadDraftPlan_copy1.aspx

BCAG. *See* Butte County Association of Governments

BDCP. *See* Bay-Delta Conservation Plan

Butte County Association of Governments (BCAG). 2011. Butte regional conservation plan HCP/NCCP 1st administrative draft. (Internet). (cited 15 July 2011). Available from: http://www.buttehcp.com/Document/1st_Admin_Draft_BRCP.html

CALFED Bay-Delta Program (CBDP). 2000. Multi-Species Conservation Strategy - Final programmatic EIS/EIR technical appendix. July 2000. (Internet). (cited 18 July 2011). Available from: http://www.dfg.ca.gov/ERP/envcomp_mscs.asp

California Department of Fish and Game (DFG). 1992. Recovery plan: Bank swallow (*Riparia riparia*). California Department of Fish and Game, Nongame Bird and Mammal Section, Wildlife Management Division. Nongame Bird and Mammal Section Report 93.02.

_____. 2004. Comprehensive Management Plan for the Sacramento River Wildlife Area.

_____ and Yolo Basin Foundation. 2008. Yolo Bypass Wildlife Area Land Management Plan.

_____. 2011. NCCP Plan Summary – Yuba/Sutter. (Internet). (cited 18 July 2011). Available from: http://www.dfg.ca.gov/habcon/nccp/status/YubaSutter/

California Department of Fish and Game and State Water Resources Control Board (DFG and SWRCB). 2011. Five year coordinated work plan for wetlands conservation program development.

California Department of Water Resources (DWR). 2006. United States of America before the Federal Energy Regulatory Commission. Explanatory Statement. Project No. 2100-052. (Internet). (cited 26

January 2012). Available from: http://www.water.ca.gov/orovillerelicensing/docs/settlement_agreement/Explanatory%20Statement%20on%20SA.pdf

California Department of Water Resources (DWR). 2009. California Water Plan: update 2009. Volume 1: the strategic plan. Bulletin 160-09. (Internet). (cited 1 December 2011). Available from: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

CBDP. *See* CALFED Bay-Delta Program

Central Valley Joint Venture (CVJV). 2006. Central Valley Joint Venture implementation plan – Conserving bird habitat. Sacramento, California: U.S. Fish and Wildlife Service.

City of Sacramento, Sutter County, Natomas Basin Conservance (NBC), Reclamation District #1000, and Natomas Central Mutual Water Company (NCMWC). 2003. Final Natomas Basin habitat conservation plan. (Internet). (cited 15 July 2011). Available from: http://www.natomasbasin.org/index.php?option=com_content&view=article&id=144&Itemid=118

County of Sacramento, City of Elk Grove, City of Galt, City of Rancho Cordova, Sacramento Regional County Sanitation District, Sacramento Area Sewer District, Sacramento County Water Agency, Southeastern Connector. 2010. South Sacramento Habitat Conservation Plan. Working Draft. (Internet). (cited 13 December 2011). Available from: http://www.southsachcp.com/Documents.aspx

CVJV. *See* Central Valley Joint Venture

DFG. *See* California Department of Fish and Game

DFG and SWRCB. *See* California Department of Fish and Game and State Water Resources Control Board

DWR. *See* California Department of Water Resources

East Contra Costa County Habitat Conservation Plan Association (ECCCHCPA). 2006. The final East Contra Costa County habitat conservation plan/natural community conservation plan. (Internet). (cited 15 July 2011). Available from: http://www.co.contra-costa.ca.us/depart/cd/water/HCP/documents.html

ECCCHCPA. *See* East Contra Costa County Habitat Conservation Plan Association

Hart, K., L. Hoag, K. Longley, S. Meraz, and D. Odenweller. 2011. Water Quality Control Plan for the Sacramento River Basin and San Joaquin River Basin. Sacramento (CA): California Regional Water Quality Control Board, Central Valley Region. (Internet). (cited 23 January 2011). Available from: http://www.swrcb.ca.gov/rwqcb5/water_issues/basin_plans/sacsjr.pdf

Jones & Stokes. 2006. Final PG&E San Joaquin Valley Operation & Maintenance Habitat Conservation Plan. Prepared for Pacific Gas and Electric Company. (Internet). (cited 25 October 2011). Available from: http://www.fws.gov/ecos/ajax/docs/plan_documents/thcp/thcp_838.pdf

Kapahi, G., I. Baer, J. Farwell, D. Riddle, and G. Wilson. 2006. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Sacramento (CA): California Environmental Protection Agency, State Water Resources Control Board.

Kleinschmidt Associates. 2008. Cosumnes River Preserve Managament Plan. Prepared for Cosumnes River Preserve, Galt, CA.

National Marine Fisheries Service (NMFS). 2009a. Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project. (Internet). (cited 15 July 2011). Available from: http://www.swr.noaa.gov/ocap.htm

_____. 2009b. Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Sacramento, California: National Marine Fisheries Service, Sacramento Protected Resources Division.

_____. 2011. April 7, 2011 - Mr. Donald Glaser. (Internet). (cited 9 September 2011). Available from: http://swr.nmfs.noaa.gov/ocap/040711_OCAP_opinion_2011_amendments.pdf

NMFS. *See* National Marine Fisheries Service

Placer County Community Development Resources Agency (PCCDRA). 2011. Placer County Conservation Plan; Western Placer County. Agency Review Draft document; February 1, 2011.

Reclamation. *See* U.S. Department of the Interior, Bureau of Reclamation

Sacramento River Advisory Council (SRAC). 2003. Sacramento River Conservation Area forum handbook. Sacramento (CA): The Resources Agency, State of California.

Sacramento River Conservation Area Forum (SRCAF). (date unknown). Sacramento River Conservation Area Forum 2008-2011 Strategic Plan. (Internet). Red Bluff (CA): Sacramento River Conservation Area Forum; (cited 31 October 2011). Available from: http://www.sacramentoriver.org/srcaf/publications/stragegic_plan_2011.pdf

_____. 2009. Sacramento River Conservation Area Forum programmatic Safe Harbor Agreement. (Internet). Red Bluff (CA): Sacramento River Conservation Area Forum; (cited 31 October 2011). Available from: http://www.sacramentoriver.org/srcaf/publications/SHA/SHA_SRCAF_Draft_11-23-09.pdf

San Joaquin County Council of Governments (SJCCG). 2000. San Joaquin County Multi-Species Habitat Conservation Plan and Open Space Plan.

San Joaquin River Restoration Program (SJRRP). 2009. San Joaquin River Restoration Program. (Internet). (cited 15 July 2011). Available from: http://www.restoresjr.net/

SCWA. *See* Solano County Water Agency

SJCCG. *See* San Joaquin County Council of Governments

SJRRP. *See* San Joaquin River Restoration Program

Solano County Water Agency (SCWA). 2009. Solano Multispecies Habitat Conservation Plan Administrative Draft. (Internet). (cited 15 July 2011). Available from: http://www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx

Spencer, W., R. Noss, J. Marty, M. Schwartz, S. Gregory, R. Hansen, and G. Wylie. 2006. Report of Independent Science Advisors for Yuba and Sutter County Natural Community Conservation Plan/Habitat Conservation Plan. Prepared for County of Sutter.

SRAC. *See* Sacramento River Advisory Committee

SRCAF. *See* Sacramento River Conservation Area Forum

The Nature Conservancy (TNC). 2011. California – Sacramento River. (Internet). (cited 15 July 2011). Available from: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/placesweprotect/sacramento-river-1.xml

TNC. *See* The Nature Conservancy

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (USRFRHAC). 1989. Upper Sacramento River fisheries and riparian habitat management plan. The Resources Agency.

U.S. Department of the Interior, Bureau of Reclamation (Reclamation). 2004. Long-term Central Valley Project operations criteria and plan CVP-OCAP. (Internet). (cited 15 July 2011). Available from: http://www.usbr.gov/mp/cvo/OCAP/OCAP_6_30_04.pdf

_____. 2011. 2011 Draft CVPIA Annual Workplans. (Internet). (cited 25 October 2011). Available from: http://www.usbr.gov/mp/cvpia/docs_reports/awp/2011/index.html

U.S. Fish and Wildlife Service (USFWS). 1994. Draft recovery plan for the valley elderberry longhorn beetle. (Internet). (cited 15 July 2011). Available from: http://ecos.fws.gov/docs/recovery_plan/840628.pdf

_____.1998a. Draft recovery plan for the Least Bell's Vireo. (Internet). (cited 15 July 2011). Available from: http://ecos.fws.gov/docs/recovery_plan/980506.pdf

_____. 1998b. Recovery plan for the upland species of the San Joaquin Valley, California. Portland (OR): U. S. Fish and Wildlife Service, Region 1.

_____.1999. Draft recovery plan for the Giant Garter Snake. (Internet). (cited 15 July 2011). Available from: ftp://ftp.water.ca.gov/DES/BDCP/USFWS%201999%20GGS.pdf

_____.2001. AFRP final restoration plan. (Internet). (cited 9 September 2011). Available from: http://www.fws.gov/stockton/afrp/restplan_final.cfm

_____. 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). Portland (OR): U.S. Fish and Wildlife Service.

_____.2005. Sacramento River National Wildlife Refuge; Final Comprehensive Conservation Plan. (Internet). (cited 24 October

2011). Available from: http://www.fws.gov/sacramentovalley refuges/CCP/Final%20CCP%20for%20web.pdf

_____. 2008. Formal Endangered Species Act consultation on the proposed coordinated operations of the Central Valley Project (CVP) and State Water Project (SWP). (Internet). (cited 15 July 2011). Available from: http://www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf

_____. 2009. Sacramento, Delevan, Colusa, and Sutter National Wildlife Refuges; Final Comprehensive Conservation Plan and Environmental Assessment. (Internet). (cited 24 October 2011). Available from: http://www.fws.gov/sacramentovalleyrefuges/CCP/Final%20CCP.pdf

_____. 2010. Butte Sink, Willow Creek-Lurline, and North Central Valley Wildlife Management Areas – April, 2010 Planning Update #2. U.S. Fish and Wildlife Service.

_____. 2011. Joint Stipulation and Order Amending Schedule for Transmittal of Draft Smelt Biological Opinion. (Internet). (cited 8 November 2011). Available from: http://www.fws.gov/sfbaydelta/documents/SMELT_Doc_1061%20_Order_on_BiOp_Sched_Sept_30_2011.pdf

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

USRFRHAC. *See* Upper Sacramento River Fisheries and Riparian Habitat Advisory Council

YC HCP/NCCP JPA. *See* Yolo County HCP/NCCP Joint Powers Agency

Yolo County HCP/NCCP Joint Powers Agency (YC HCP/NCCP JPA), California Department of Fish and Game (DFG), and U.S. Fish and Wildlife Service (USFWS). 2004. Planning agreement No. 2810-2003-003-02 for the Yolo County NCCP/HCP. (Internet). (cited 15 July 2011). Available from: http://www.yoloconservationplan.org/yolo_pdfs/agreements/Yolo-planningagreement_2004-11-09.pdf

4.0 Acronyms and Abbreviations

AFRP ..... Anadromous Fish Restoration Program

AFSP…… Anadromous Fish Screen Program

Bay-Delta ..... San Francisco Bay/Sacramento-San Joaquin Delta

BDCP ..... Bay-Delta Conservation Plan

BO..... biological opinion

BRHCP ..... Butte Regional Habitat Conservation Plan

BRHCP/NCCP..... Butte Regional Habitat Conservation Plan/ Natural Communities Conservation Plan

CALFED ..... California Bay-Delta Program

CCP ..... Comprehensive Conservation Plan

CCP EA..... Comprehensive Conservation Plan Environmental Assessment

CEQA..... California Environmental Quality Act

Conservation Framework ..... Central Valley Flood System Conservation Framework

Conservation Strategy ..... Central Valley Flood System Conservation Strategy

Covered species..... Species covered by an Habitat Conservation Plan

CRPMP ..... Cosumnes River Preserve Management Plan

CVFPP ..... Central Valley Flood Protection Plan

CVJV..... Central Valley Joint Venture

CVP..... Central Valley Project

CVPIA ..... Central Valley Project Improvement Act

CWP..... California Water Plan

Delta..... Sacramento-San Joaquin Delta

DFG……California Department of Fish and Game

DPS..... distinct population segment

DWR ..... California Department of Water Resources

ECCCHCP ..... East Contra Costa County Habitat Conservation Plan

ESA..... Endangered Species Act

ESU..... ecologically significant unit

HCP ..... Habitat Conservation Plan

HRP……Habitat Restoration Program

JPA ..... Joint Powers Agency

LMP..... Land Management Plan

LWD……large woody debris

MSCS..... Multi-Species Conservation Strategy

NBHCP ..... Natomas Basin Habitat Conservation Plan

NCCP..... Natural Communities Conservation Plan

NCCPA ..... Natural Community Conservation Planning Act

NEPA ..... National Environmental Policy Act

NMFS..... National Marine Fisheries Service

NWR ..... National Wildlife Refuge

O&M..... operations and maintenance

OCAP..... Operations Criteria and Plan

PCCP ..... Placer County Conservation Plan

PG&E……Pacific Gas & Electric Company

PG&E HCP……Pacific Gas & Electric Company, Habitat Conservation Plan

Reclamation ..... U.S. Department of the Interior, Bureau of Reclamation

RM ..... river mile

RPA..... reasonable and prudent alternative

SJMSCP..... San Joaquin County Multi-Species HCP

SJRRP ..... San Joaquin River Restoration Program

SMSHCP..... Solano Multi-Species Habitat Conservation Plan

SPFC ..... State Plan of Flood Control

SRA..... shaded riverine aquatic

SRCAF..... Sacramento River Conservation Area Forum

SRP..... Sacramento River Project

SRWA ..... Sacramento River Wildlife Area

SSHCP..... South Sacramento Habitat Conservation Plan

SWP..... State Water Project

TNBC…….The Natomas Basin Conservancy

TNC..... The Nature Conservancy

UDA ..... Urban Development Area

USACE..... US Army Corps of Engineers

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

VELB..... valley elderberry longhorn beetle

WAP…….. Water Acquisition Program

WMA ..... Wildlife Management Area

YBWA ..... Yolo Bypass Wildlife Area

YNHP ..... Yolo County Natural Heritage Program

YSNCCP ..... Yuba/Sutter Natural Community Conservation Plan

YSNCCP/HCP..... Yuba/Sutter Natural Community Conservation Plan and Habitat Conservation Plan

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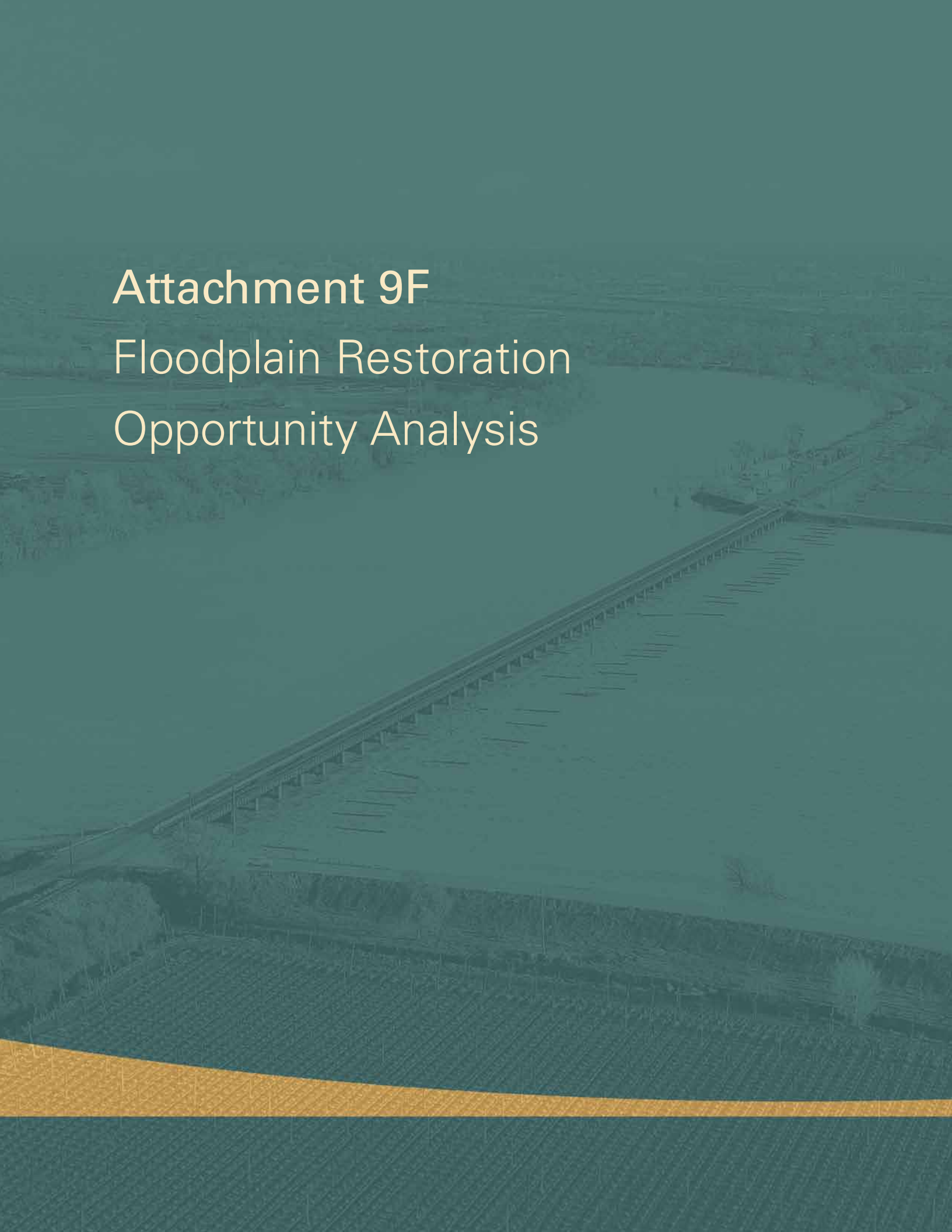
STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

Attachment 9F

Floodplain Restoration Opportunity Analysis



CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 9F: Floodplain Restoration Opportunity Analysis

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Table of Contents

1.0 Introduction 1-1
1.1 Overview 1-1
1.2 Report Organization 1-4
1.3 Acknowledgments 1-5

2.0 Methods 2-1
2.1 Overview 2-1
2.2 Floodplain Restoration Opportunity Analysis Approach 2-3
2.2.1 Step 1: Identify Areas of Physical Suitability 2-4
2.2.2 Step 2: Identify Opportunities and Constraints 2-10
2.2.3 Step 3: Evaluate Potential for Restoration 2-13

3.0 Results of Floodplain Restoration Opportunities Analysis 3-1
3.1 Sacramento River Reach Descriptions 3-3
3.1.1 Woodson Bridge State Recreation Area to Chico Landing 3-3
3.1.2 Chico Landing to Colusa 3-4
3.1.3 Colusa to Verona 3-5
3.1.4 Verona to American River 3-6
3.1.5 American River to Freeport 3-7
3.1.6 Freeport to Delta Cross Channel 3-8
3.1.7 Delta Cross Channel to Deep Water Ship Channel 3-9
3.1.8 Deep Water Ship Channel to Collinsville 3-10
3.2 Sacramento River Tributary Reach Descriptions 3-11
3.2.1 Feather River – Thermalito Afterbay to Yuba River 3-11
3.2.2 Feather River – Yuba River to Bear River 3-12
3.2.3 Feather River – Bear River to Sutter Bypass 3-13
3.2.4 Feather River – Sutter Bypass to Sacramento River 3-14
3.2.5 Yuba River 3-15
3.2.6 Bear River 3-15
3.2.7 American River 3-16
3.3 Sutter and Yolo Bypass Descriptions 3-17
3.3.1 Sutter Bypass 3-17
3.3.2 Yolo Bypass 3-18
3.4 San Joaquin River Reach Descriptions 3-19
3.4.1 Friant Dam to SR 99 3-19

3.4.2 SR 99 to Gravelly Ford 3-20
3.4.3 Gravelly Ford to Chowchilla Bypass 3-20
3.4.4 Chowchilla Bypass to Mendota Dam 3-21
3.4.5 Mendota Dam to Sack Dam 3-22
3.4.6 Sack Dam to Sand Slough Control Structure 3-23
3.4.7 Sand Slough Control Structure to Mariposa Bypass 3-23
3.4.8 Mariposa Bypass to Bear Creek 3-24
3.4.9 Bear Creek to Merced River 3-25
3.4.10 Merced River to Tuolumne River 3-26
3.4.11 Tuolumne River to Stanislaus River 3-26
3.4.12 Stanislaus River to Stockton 3-27
3.5 San Joaquin River Tributary Reach Descriptions 3-28
3.5.1 Merced River 3-28
3.5.2 Tuolumne River 3-29
3.5.3 Stanislaus River 3-30
3.6 Maps and Tables of Results 3-31

4.0 Floodplain Restoration Opportunities: Conclusions and Recommendations 4-1
4.1 Conclusions 4-1
4.2 Recommendations 4-6

5.0 References 5-1

6.0 Abbreviations and Acronyms 6-1

List of Tables

Table 3-1. Floodplain Inundation Potential of Sacramento River 3-57

Table 3-2. Nonurban Floodplain Connectivity Percentages for the Sacramento River 3-58

Table 3-3. Sacramento River Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1] 3-59

Table 3-4. Floodplain Inundation Potential of Sacramento River Tributaries .. 3-60

Table 3-5. Nonurban Floodplain Connectivity Percentages for Sacramento River Tributaries 3-61

Table 3-6. Sacramento River Tributaries Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1] 3-62

Table 3-7. Floodplain Inundation Potential of Upper San Joaquin River 3-63

Table 3-8. Nonurban Floodplain Connectivity Percentages for Upper San Joaquin River 3-64

Table 3-9. Upper San Joaquin Valley Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1] 3-65

Table 3-10. Floodplain Inundation Potential of Lower San Joaquin River and Tributaries 3-66

Table 3-11. Nonurban Floodplain Connectivity Percentages for Lower San Joaquin River and Tributaries 3-67

Table 3-12. Lower San Joaquin Valley Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1] 3-68

Table 4-1. Restoration Opportunities Along Sacramento River System 4-3

Table 4-2. Restoration Opportunities Along San Joaquin River System 4-4

List of Figures

Figure 1-1. Central Valley Flood Protection Plan Planning Area 1-2

Figure 2-1. FROA Approach 2-4

Figure 3-1. Hypothetical Cross Section with Boundary Water Surfaces of FIP Categories 3-2

Figure 3-2. Floodplain Inundation Potential of Major River Corridors in the Upper Sacramento Basin 3-32

Figure 3-3. Land Use/Land Cover of River Corridors in the Upper Sacramento Basin 3-33

Figure 3-4. Conserved Areas of River Corridors in the Upper Sacramento Basin 3-34

Figure 3-5. Major Infrastructure in River Corridors in the Upper Sacramento Basin 3-35

Figure 3-6. Connectivity of FlP-Land Cover Types in the Upper Sacramento Basin 3-36

Figure 3-7. Depth of 50 Percent Chance Floodplain Inundation Potential in the Sutter and Yolo Bypasses 3-37

Figure 3-8. Land Use/Land Cover of River Corridors in the Sutter and Yolo Bypasses 3-38

Figure 3-9. Conserved Areas of River Corridors in the Sutter and Yolo Bypasses 3-39

Figure 3-10. Major Infrastructure in River Corridors in the Sutter and Yolo Bypasses 3-40

Figure 3-11. Connectivity of FlP-Land Cover Types in the Sutter and Yolo Bypasses 3-41

Figure 3-12. Floodplain Inundation Potential of Major River Corridors in the Lower Sacramento Basin 3-42

Figure 3-13. Land Use/Land Cover of River Corridors in the Lower Sacramento Basin 3-43

Figure 3-14. Conserved Areas of River Corridors in the Lower Sacramento Basin 3-44

Figure 3-15. Major Infrastructure in River Corridors in the Lower Sacramento Basin 3-45

Figure 3-16. Connectivity of FlP-Land Cover Types in Lower Sacramento Basin 3-46

Figure 3-17. Floodplain Inundation Potential of River Corridors in the Upper San Joaquin Basin 3-47

Figure 3-18. Land Use/Land Cover of River Corridors in the Upper San Joaquin Basin 3-48

Figure 3-19. Conserved Areas of River Corridors in the Upper San Joaquin River Basin 3-49

Figure 3-20. Major Infrastructure in River Corridors in the Upper San Joaquin Basin 3-50

Figure 3-21. Connectivity of FlP-Land Cover Types in the Upper San Joaquin Basin 3-51

Figure 3-22. Floodplain Inundation Potential of River Corridors in the Lower San Joaquin Basin 3-52

Figure 3-23. Land Use/Land Cover of River Corridors in the Lower San Joaquin Basin 3-53

Figure 3-24. Conserved Areas of River Corridors in the Lower San Joaquin Basin 3-54

Figure 3-25. Major Infrastructure in River Corridors in the Lower San Joaquin Basin 3-55

Figure 3-26. Connectivity of FlP-Land Cover Types in Lower San Joaquin Basin 3-56

List of Appendices

Appendix A Floodplain Inundation and Ecosystem Functions Model Pilot Studies

Appendix B Investigation of USGS 10-Meter DEM Accuracy

Appendix C CVFED LiDAR Terrain Data Comparisons

Appendix D Levee Realignment Methodology

Appendix E Synthetic vs. Observed Hydrographs

Appendix F HEC-EFM Ecosystem Functional Relationships

Appendix G RAS/EFM Analysis HAR-Based Mapping

1.0 Introduction

This section provides an overview of the attachment and document organization.

1.1 Overview

Ecosystem restoration is a key component of the Central Valley Flood Protection Plan (CVFPP), and actions related to ecosystem restoration have been proposed as part of the CVFPP. This report documents an analysis of the potential for ecosystem restoration of floodplains within the Systemwide Planning Area of the State Plan of Flood Control (SPFC) (Figure 1-1).

To support the identification, development, and implementation of specific restoration actions, a Floodplain Restoration Opportunity Analysis (FROA) was conducted, which is summarized in this report. This FROA identifies areas with greater and/or more extensive potential opportunities for ecological restoration of floodplains. It does so by considering physical suitability; and opportunities and constraints related to existing land cover and land uses, locations and physical condition of levees, locations of other major infrastructure, conservation status of land, and locations that stakeholders are interested in restoring.

To evaluate physical suitability, the concept of floodplain inundation potential (FIP) was applied in a geographic information system (GIS) analysis of corridors along the Sacramento and San Joaquin rivers and their major tributaries. This analysis was selected because of the importance of floodplain inundation for ecosystem functions. To assess physical suitability for restoration actions, the FIP analysis adapted concepts from the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (USACE-HEC) (USACE-HEC, 2009), the Frequently Activated Floodplain concept of Williams et al. (2009), and the Height Above River (HAR) GIS tool of Dilts et al. (2010). FIP analysis identifies areas of floodplain, both directly connected to the river and disconnected from the river (e.g., behind natural or built levees or other flow obstructions) that could be inundated by particular floodplain flows. The flows evaluated by the FROA included a spring flow sustained for at least 7 days and occurring in 2 out of 3 years (a 77 percent chance event), and 50 and 10 percent chance peak flows.

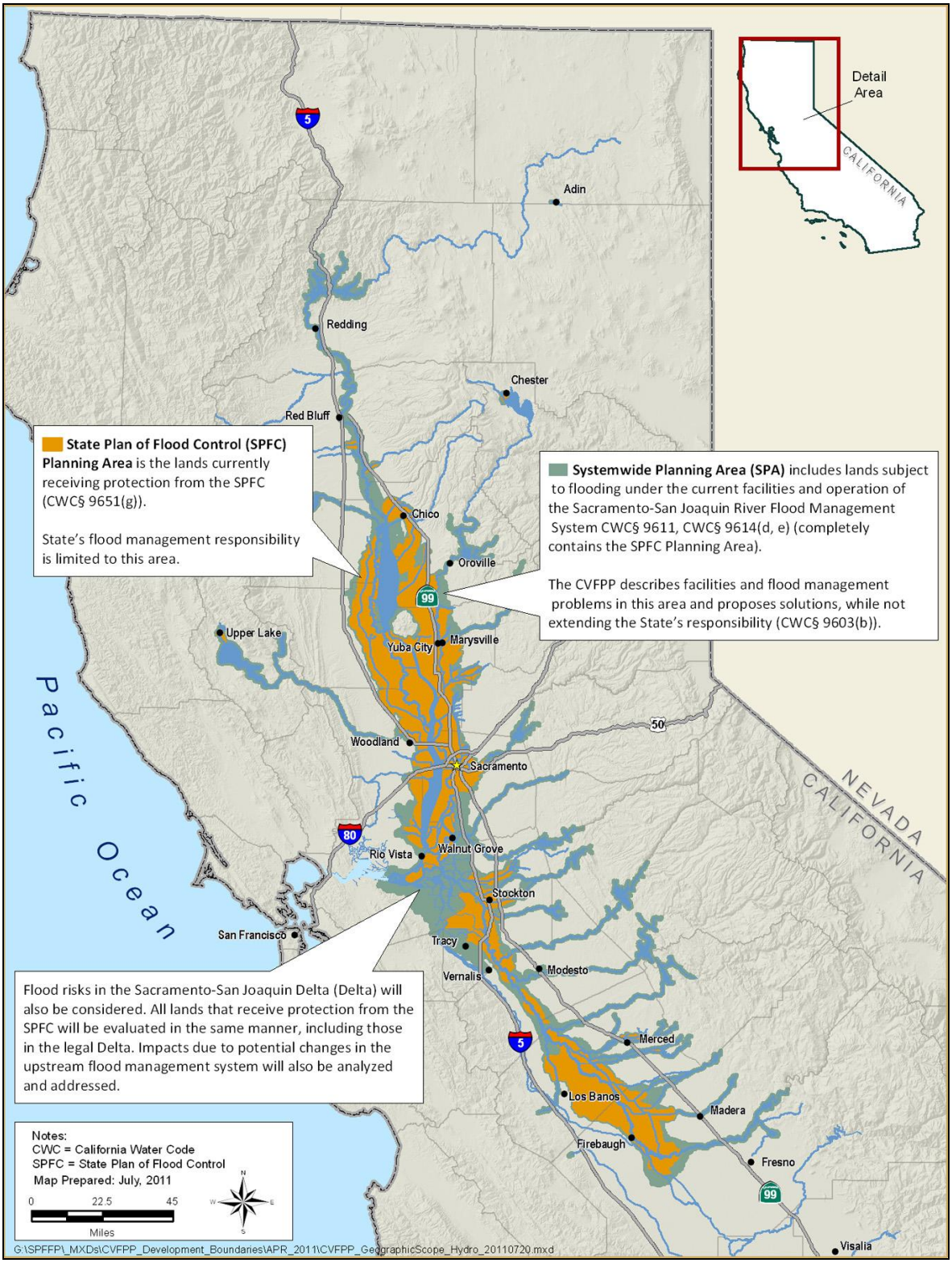

Figure 1-1. Central Valley Flood Protection Plan Planning Area

This analysis adapted existing models and hydrologic data, and thus, the FROA is limited to those reaches of the Sacramento and San Joaquin rivers and their tributaries for which such resources were available. Consequently, the FROA includes the Sacramento River from Woodson Bridge State Recreation Area to Collinsville, the San Joaquin River from Friant Dam to Stockton, the lower Feather River, and the lowermost reaches of other major tributaries of the Sacramento and San Joaquin rivers (i.e., the Bear, Yuba, American, Stanislaus, Tuolumne, and Merced rivers). It does not include smaller tributaries. The Sutter and Yolo bypasses are also included.

For the included river reaches and bypasses, oopportunities and constraints based on existing land use and land cover, major infrastructure locations, and conservation status were determined from existing and available geospatial data for existing wetland and riparian vegetation, Important Farmland (as defined by DOC, 2011), and urban areas; locations of major roads, highways, and railways; and land ownership and management. Four primary categories of existing land use and land cover were considered: developed, irrigated agricultural, open water, and natural; with natural land cover subdivided into wetland, riparian, and upland.

Stakeholder interest in restoration actions was compiled through focused outreach and review of existing reports. Stakeholders were interviewed to document potential ecosystem restoration projects previously identified by various CVFPP stakeholder groups throughout the Systemwide Planning Area. Specific information regarding potential restoration projects identified by stakeholders has been considered confidential. In addition to these interviews, existing reports that identified potential ecosystem restoration opportunities were also reviewed. Projects in reviewed reports that were located within the Systemwide Planning Area and that would provide ecosystem benefits were included with the group of stakeholder-identified projects and areas of interest.

The relationships among areas of physical suitability and opportunities and constraints were used to characterize river reaches and identify reaches with greater and/or more extensive potential opportunities for restoration. Reach boundaries were at junctions with tributaries and other frequently recognized boundaries (e.g., reach boundaries used by the San Joaquin River Restoration Program (SJRRP)).

The results of the FROA are intended to support the subsequent identification, prioritization, and further development of specific restoration opportunities. Through this subsequent planning, specific opportunities would be identified and prioritized on the basis of their potential ecological, flood management, and other benefits (e.g., reduced maintenance and regulatory compliance costs); cost; and regulatory,

institutional, technological, and operational feasibility. This process for identifying and prioritizing opportunities would be both part of the continuing development of the overall CVFPP and of the development of species-focused conservation planning and corridor management strategies.

The following report summarizes the methods, results, and recommendations of the FROA.

1.2 Report Organization

The remainder of this attachment is organized into the following sections:

- Section 2.0, Methods
- Section 3.0, Results of the Floodplain Restoration Opportunities Analysis
- Section 4.0, Floodplain Restoration Opportunities: Conclusions and Recommendations
- Section 5.0, References
- Section 6.0, Abbreviations and Acronyms
- Appendix A, Floodplain Inundation and Ecosystem Functions Model Pilot Studies
- Appendix B, Investigation of USGS 10-Meter DEM Accuracy
- Appendix C, CVFED LiDAR Terrain Data Comparisons
- Appendix D, Levee Realignment Methodology
- Appendix E, Synthetic vs. Observed Hydrographs
- Appendix F, HEC-EFM Ecosystem Functional Relationships
- Appendix G, RAS/EFM Analysis FIP-based Mapping

1.3 Acknowledgments

This work was performed for the Floodway Ecosystem Sustainability Branch of the FloodSAFE Environmental Stewardship and Statewide Resources Office, California Department of Water Resources (DWR), and was accomplished by AECOM through Task Order 10-07 to Master Consulting Services Subcontract No. DWR-MSA08-EDAW-AECOM, effective July 26, 2010, with MWH Americas, Inc. (MWH). An independent review of the work was provided by cbec eco engineering, and USACE-HEC responded to technical questions regarding the application of HEC's Ecosystem Functions Model (HEC-EFM). Guidance on the application of the HAR/FIP method was also provided by the author of the software, Thomas Dilts of the University of Nevada, Reno.

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2.0 Methods

2.1 Overview

This chapter describes the general approach and methods of the FROA, which was based in part on the results and conclusions of two pilot studies conducted on the lower Feather River. The specific method used to determine FIP is described in detail in Appendix A, which provides the methods, results, and conclusions of the two pilot studies conducted on the lower Feather River to evaluate the suitability of FIP (an expanded version of the HAR method) (Dilts et al., 2010) and USACE-HEC-FEM (USACE-HEC, 2009) analyses for use in the FROA.

Traditional approaches for analyzing the inundation characteristics of river channel-floodplain land areas typically involve hydraulic models that rely on one-dimensional cross sections to describe the land surface. In addition to the limitations of cross sections to describe land surfaces, these traditional approaches also generally involve a significant amount of time to develop and use. However, because of the large geographic area covered by the CVFPP and the number of potential ecosystem restoration activities within this region, a computational tool capable of rapidly identifying and quantifying habitat restoration opportunities was desired.

Therefore, for this **planning-level study**, a simplified approach was preferred to understand the spatial extent of floodplain land areas that are connected and disconnected from the river channel for certain flow conditions. The FIP method is a GIS-based approach that does this, requires limited field data, is based on simple concepts, and is computationally efficient (Dilts et al., 2010). The FIP approach uses readily available topographic and hydrologic data sets and GIS analyses to identify floodplains potentially inundated under more frequent, ecologically valuable flow events (e.g., 50 and 10 percent chance events). Thus, GIS layers based on the results of the FIP analysis show floodplains that are connected, or could be more readily reconnected, to the river during specific flow events. **The FIP method is not intended to be a replacement for detailed hydraulic models**; instead, it is considered a viable tool for relatively quickly assessing areas that are physically suitable for restoration.

For the purpose of this work, the “FIP method” is the term used to describe the application of GIS tools provided within the ArcGIS Riparian Topography Toolbox, as described by Dilts et al. (2010). The ArcGIS

Riparian Topography Toolbox is distributed by Environmental Systems Research Institute, Inc. (ESRI) (ESRI, 2011). This GIS software uses digital terrain models and water surface elevations from hydraulic modeling to calculate the relative height of terrain above a water surface and the depth of terrain below a water surface (and thus FIP). It also determines the inundated areas that are connected or disconnected from a river channel by levees or other obstructions for a given flow event.

The Floodplain Inundation Pilot Study on the lower Feather River (Appendix A) evaluated the adaptation of the HAR tool for use in this FIP analysis. It found that the FIP method is a relatively effective way to quickly and easily find features on the land surface that are either above or below a specified water-surface profile. Color ramping of GIS layers of FIP output showing height increments both above the river (i.e., water surface) and below can provide a rapid visualization of the low-lying land areas physically connected to a river channel, or capable of being connected, and the relative depth of these topographic depressions. The results can also be used to guide qualitative assessments of potential levee setback locations. Although the FIP method is not a substitute for detailed hydraulic modeling, it does provide an ability to relatively quickly understand flood characteristics across the floodplain landscape.

The FROA is focused on identifying potential restoration areas based on the ecological functions that could be provided by inundated or potentially inundated floodplains. Initially, the Ecosystem Functions Model (HEC-EFM), developed by the USACE-HEC, was considered as a potential tool for identifying the ecological functions provided by inundated and potentially inundated floodplains. HEC-EFM allows criteria (e.g., timing and duration of inundation) to be defined for eco-hydrologic relationships. By applying these criteria to stage and flow hydrographs produced by the HEC's River Analysis System (HEC-RAS), HEC-EFM identifies specific stages and flows providing specific ecological functions to be identified and visualized.

Consequently, a second pilot study, the HEC-EFM Pilot Study, was conducted along the lower Feather River to evaluate use of the HEC-EFM in the FROA. For this pilot study, criteria were developed for the relationship of cottonwood regeneration and salmonid rearing to flow conditions. These criteria were adapted from a previous application of HEC-EFM to support the Sacramento-San Joaquin Comprehensive Study (Comprehensive Study) (USACE and The Reclamation Board, 2002) and from criteria included as part of the Sacramento River Ecological Flows Tool (SacEFT) (ESSA Technologies, 2009). These functions were selected because of their relationship to lower stage floodplains and the limited

extent of these habitat functions throughout the Sacramento and San Joaquin river systems.

The methods, results, and conclusions of this pilot study are provided in Appendix A. The study identified several limitations of HEC-EFM for use in the FROA:

- Constraints on the realism of habitat evaluations: (1) use of a single set of criteria as opposed to a range that distinguishes optimal from suboptimal conditions, (2) lack of coupling of relationships (e.g., cottonwood seedling recruitment depends on suitable conditions for germination in spring followed by minimal inundation during the winter), and (3) the potential for varied relationships between ecological functions and hydrologic conditions among the Sacramento and San Joaquin rivers and their tributaries.

- Lack of functional distinctions among evaluated areas: potential habitat for the ecological functions selected was largely absent, resulting in similar habitat attributes; similar results could occur throughout the Sacramento and San Joaquin river systems,

- Cost of application: the time required to apply the HEC-EFM model would limit analysis to selected reaches of the Sacramento and San Joaquin river system.

Consequently, a more generalized approach was developed for identifying floodplain areas where inundation could provide desired ecological functions: four types of flows were used in conjunction with the FIP method to distinguish floodplain areas that could be physically suitable for providing different types or amounts of multiple ecological functions. This approach is described in the following section.

2.2 Floodplain Restoration Opportunity Analysis Approach

As diagrammed in Figure 2-1, the FROA approach consists of three steps:

- Identify Areas of Physical Suitability.
- Identify Opportunities and Constraints.
- Identify Potential Restoration Opportunities.

The methodology of each of these steps is described in the following sections.

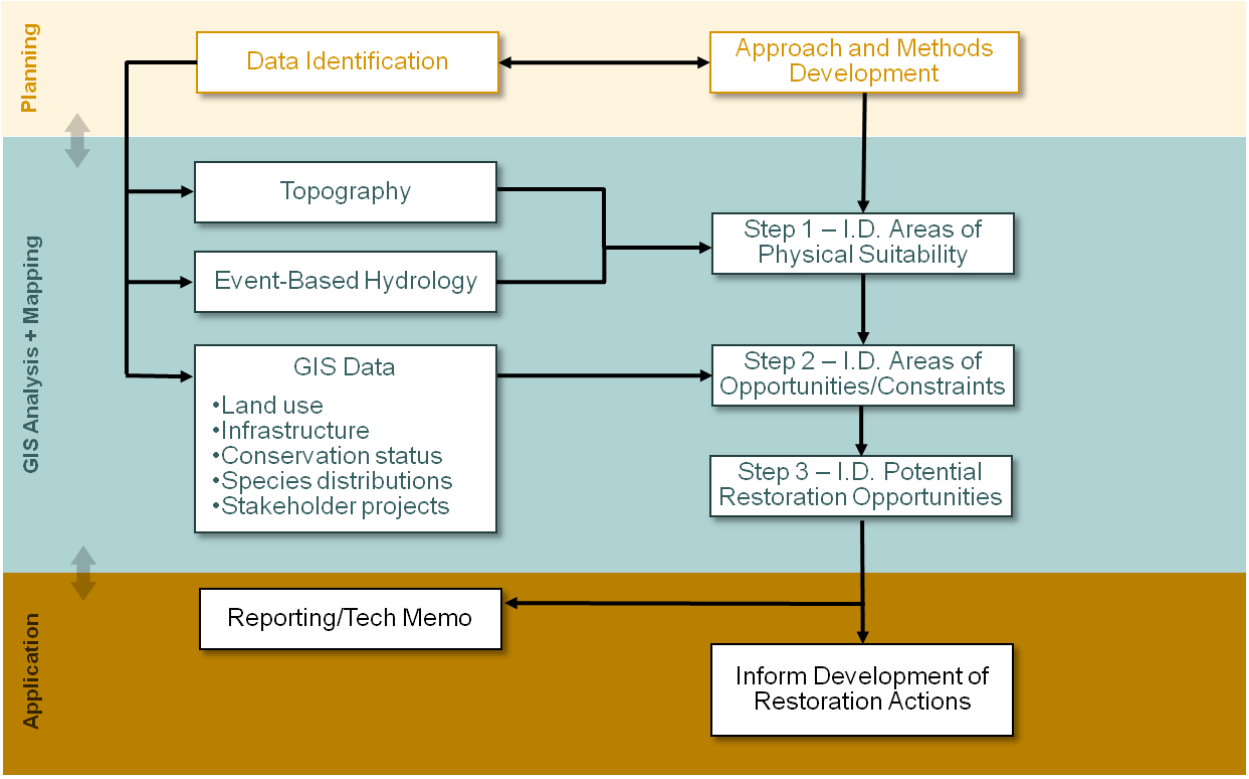

Figure 2-1. FROA Approach

2.2.1 Step 1: Identify Areas of Physical Suitability

To evaluate physical suitability for restoration actions, the FIP method was applied in a GIS analysis of corridors along the Sacramento and San Joaquin rivers and their major tributaries. This analysis was selected because of the importance of floodplain inundation for ecosystem functions, and because, at this planning level of investigation, the FIP method provided a relatively rapid approach for assessing floodplain inundation, as compared to the alternative use of more detailed hydraulic modeling. Furthermore, the pilot project application of the FIP method on the Feather River indicated its feasibility for application to the larger Sacramento and San Joaquin river systems.

The FIP analysis provides a spatial representation of floodplain inundation areas, and depths, relative to a varying water-surface profile. The FIP analysis "projects" a designated water-surface profile laterally from a stream centerline through levees or other obstructions out to a predetermined distance from a river centerline to provide an estimate of floodplain extent and depths if these obstructions were not present. It is acknowledged, however, that the actual water surface resulting from the removal of a levee or other obstruction would differ from that presented in the FIP analysis, but at this planning level the representation of potential

floodplain inundation provided by the FIP analysis was deemed acceptable. The analysis was based on the results and conclusions of the pilot projects (Appendix A). It adapted concepts from the USACE HEC-EFM (USACE-HEC, 2009), the Frequently Activated Floodplain concept of Williams et al. (2009), and the HAR GIS tool of Dilts et al. (2010).

Several flows and associated water-surface profiles were evaluated using the FIP analysis, including:

- Water-surface profiles at the time of the CVFED (Central Valley Floodplain Evaluation and Delineation) Light Detection and Ranging (LiDAR) flights in March 2008 representing a low-water baseflow condition; termed the "Baseflow" FIP. Areas with Baseflow FIP would provide aquatic (riverine or lacustrine) habitats if hydrologically connected to a river.

- Seasonal flows and water-surface profiles derived using HEC-EFM representing a spring flow sustained for at least 7 days and occurring in 2 out of 3 years; termed the "67 percent chance Sustained Spring" FIP. Floodplains experiencing such sustained spring inundation would provide a variety of ecological functions, and greater aquatic foodweb productivity and fish utilization benefits than other floodplains (Williams et al. 2009).

- Peak flows and water-surface profiles associated with the 50 percent chance recurrence intervals; termed "50 percent chance" FIP. Floodplains inundated by these relatively frequent events would regularly sustain fluvial geomorphic processes (such as sediment scour and deposition) and provide inputs to the aquatic ecosystem (e.g., organic matter, including large woody material), among other functions, even where not experiencing sustained spring inundation.

- Peak flows and water-surface profiles associated with the 10 percent chance recurrence interval; termed the "10 percent chance" FIP. Floodplains inundated by these less-frequent events but not by 50 percent chance events would provide ecological functions similar to those inundated by more frequent events, but less frequently.

The analysis of FIP within the Systemwide Planning Area along the Sacramento and San Joaquin rivers and their major tributaries required topographic and hydraulic data. These data and the specific methods of the FIP analysis are described in the following sections.

Topographic Data

Accurate topographic data were required to evaluate FIP for these areas. AECOM completed an evaluation of readily available U.S. Geological Survey (USGS) 10-meter digital elevation models (DEM), and found that the data were not sufficiently detailed for this purpose.

The CVFED program recently mapped topography throughout the Central Valley, using LiDAR. AECOM received the raw LiDAR data files from the CVFED program in the fall of 2010. However, the raw data files were not usable for the Step 3 analysis, and creation of suitable files from the raw data (i.e., a digital terrain model) would duplicate work being completed by CVFED, which is not feasible from a cost or time standpoint.

As a solution to the lack of suitable topographic data, third-party software, Global Mapper, was used with the raw CVFED LiDAR data to create unprocessed digital terrain models. AECOM completed a test conversion of these digital terrain models to ArcGIS format, and found that the resultant topographic surface was usable for the FIP analysis, with minor modification and post-processing.

Hydraulic Data

For the various FIP analyses described above, hydraulic data were required to obtain water-surface profiles, with the exception of the Baseflow FIP analysis, which simply relied upon the water surfaces at the time of the CVFED LiDAR flight.

Hydraulic data for the 67 percent chance Sustained Spring FIP analysis were obtained from an analysis similar to the Feather River HEC-EFM/HEC-RAS pilot study; with a few differences that are noted and in Appendix A. Similar to the pilot study, HEC-EFM was used to query synthetic flow records for the Sacramento and San Joaquin river basins based on an ecosystem function relationship (EFR). The EFR included user-defined criteria such as a season, duration, and frequency. However, while the pilot study involved a HEC-EFM analysis of flow and stage time series produced by unsteady HEC-RAS modeling, findings from the study indicated this was not necessary and the remainder of the FROA effort simply used CalSim-derived synthetic flows that were queried directly by HEC-EFM. Comprehensive Study and Common Features HEC-RAS models were then used in a steady-flow analysis to model the flows identified by HEC-EFM, and the FIP tool was used to map the HEC-RAS water surface elevations (i.e., stages) at model cross-section locations. Major differences between the large-scale HEC-EFM/HEC-RAS analyses and the pilot-study analysis included:

1. Flow Estimation – CalSim-derived synthetic flows were queried directly by HEC-EFM after converting the Excel-based time series flow data to USACE-HEC's Data Storage System (HEC-DSS) format. For the pilot study, the flows were used as boundary conditions to an unsteady-flow HEC-RAS model developed by AECOM from the Comprehensive Study and Common Features models, and the flows and stage time series produced by unsteady HEC-RAS were queried using HEC-EFM. It was initially believed that using HEC-RAS would improve the estimate of flows and would also provide useful stage data. Following the pilot study however, it was agreed that this step was unnecessary and potentially misleading, as it could be perceived that using HEC-RAS unsteady flow provided an improvement in the estimate of flow rates. Because of the nature of the CalSim-derived flows, it was agreed that HEC-RAS would not provide any improvement in the estimate of flows (primarily because the flows were originally based on a monthly time step). In addition, the hydrographs produced by unsteady HEC-RAS for areas with strong backwater influence produced significant hysteresis (see HEC-EFM), resulting in large run-times for HEC-EFM and major errors in the resulting HEC-EFM rating curves. Lastly, because the EFR used in the final analysis did not require stage data, the CalSim-derived flows alone were sufficient for completing the HEC-EFM analysis. The consensus decision by the project team was that this approach provided reasonable results consistent with the level of detail provided by the CalSim-derived flows.

2. HEC-RAS Modeling – The Sacramento and San Joaquin river basins were modeled in HEC-RAS as a single basin-wide model (as opposed to subdividing the models into individual rivers). The flow rates selected by HEC-EFM were applied at the nearest river station and a steady-flow analysis was performed. The main purpose of modeling the entire basin as a single model was to provide consistent water surfaces at tributary confluences. A secondary benefit was that the Comprehensive Study and Common Features models were originally developed as basin-wide models and this reduced the level of effort required to subdivide the models. In addition, since the HEC-EFM analysis was performed using the CalSim-derived flows directly, individual Habitat Analysis Areas (HAA) were not needed (see Section 2.3.1 for an explanation of HAAs). Additional details regarding the HEC-RAS modeling include the following:

    a. Flow regimes were developed in HEC-EFM for each CalSim-derived node and for those hydrographs developed for tributaries not included in the CalSim-derived flow hydrographs. For the San Joaquin River, flow regimes were based on the restoration flows

required by the San Joaquin River Restoration Settlement (as described in Reclamation, 2011). These flow regimes were developed by editing the HEC-EFM data file directly with a text-editor, as opposed to entering them individually in HEC-EFM. Also note that the stage data "required" by HEC-EFM is not necessary if stage results are not desired; thus, the flow hydrograph was used for both the flow and stage data source.

b. Where CalSim-derived flows were unavailable (e.g., Bear River, Yuba River, and Fresno Slough) flow hydrographs were developed by taking the difference between the upstream and downstream CalSim-derived hydrographs. This approach was used in the Lower Feather River Pilot Study and considered to be a reasonable estimate of the tributary flows. At confluences farther upstream on these tributaries (e.g., Union Pacific Interceptor Canal (UPIC), Dry Creek and Bear Creek (upstream from UPIC/Dry Creek)), the same approach could not be used and flows were not available; therefore, these areas were not mapped. For other areas where flows were unavailable, such as flood control bypasses and diversions and sloughs within the northern Sacramento-San Joaquin Delta (Delta), these areas were removed from the HEC-RAS models and not mapped.

c. The vertical datum of each model was not revised and was left in National Geodetic Vertical Datum of 1929 (NGVD 29). The stages output from the GIS extension to the HEC's River Analysis System (HEC-GeoRAS) and used during the FIP were adjusted to North American Vertical Datum 1988 (NAVD 88) using the same approach as was used for the conversion of the 50 percent and 10 percent chance stages.

d. The Sacramento and San Joaquin models were converted to HEC-RAS 4.1.0 to simplify the export of results to HEC-GeoRAS and ArcGIS.

e. The Sacramento River upstream from River Mile (RM) 143.24 was taken from the Sacramento Comprehensive Study model and added to the Sacramento River basin-wide Common Features model. The Common Features model did not include the Sacramento River upstream from RM 143.24. The Comprehensive Study river stations were revised to match the Common Features model by subtracting 0.8812 mile.

f. The Mean Tidal Level (MTL) at the Port Chicago tide gage was used for a constant downstream stage boundary condition for the Sacramento and San Joaquin rivers. This approach was discussed by the project team and considered reasonable. Tidal data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (NOAA, 2011). The gage's MTL datum and NAVD datum values and the NGVD-to-NAVD conversion factor were applied, as follows:

   MTL(NGVD) = (MTL – NAVD) – (NAVD NGVD Conversion Factor)

   MTL(NGVD) = (6.56 – 2.89) – (2.613205)

   MTL(NGVD) = 1.0558 feet

g. The existing HEC-RAS model cross sections were not updated because the official DWR review of the new CVFED Task Order 20 LiDAR-derived DEMs was not complete at the time of this work.

h. Additional consideration was given to whether alternative analyses of sustained spring flows should be performed using either a higher/lower frequency, extended duration, or different season. It was agreed that the 67 percent chance relationship used for this study was the best suited to identifying potential habitat areas and was consistent with past work by others.

Hydraulic data (flows and stages) for the 50 percent chance and 10 percent chance recurrence interval FIP analyses were derived directly from the Comprehensive Study UNET models. Each pair of flow and stage values represents a discrete reach within the Sacramento and San Joaquin river systems.

An important point to clarify is the difference between the 50 percent chance and 10 percent chance recurrence interval FIP analyses versus the 67 percent chance Sustained Spring FIP analysis. The 50 percent chance and 10 percent chance water-surface profile elevations (stages) used for the FIP analysis correspond to peak flow conditions derived from a statistical flood frequency analysis of a series of maximum annual flows. The stages developed for the 67 percent chance Sustained Spring FIP analysis, while corresponding to a 67 percent chance frequency, are limited to those events that occur between March 15 and May 15 and for no less than 7 days. As a result, the 67 percent chance Sustained Spring events are significantly smaller flow events than the 50 percent chance and 10 percent chance

events and may correspond to non-storm conditions. For example, 67 percent chance Sustained Spring FIP on the lower American River and Sacramento River downstream from the American River correspond to flows of approximately 2,900 to 3,100 cubic feet per second (cfs) and 21,000 cfs, respectively, which are less than mean monthly winter flows. The 67 percent chance Sustained Spring FIP analysis primarily identifies potential habitat during spring (e.g., salmonid rearing habitat), while the 50 percent chance and 10 percent chance provides information about more general inundated floodplain habitat attributes.

FIP Analysis

The FIP analysis methodology established during the Feather River pilot study was applied to the remainder of the Sacramento and San Joaquin river systems. All aspects of this approach remained the same except that the CVFED pre-processed LiDAR and breakline data, which were used in the pilot study, were not available for the remainder of the Systemwide Planning Area study area. Therefore, the analysis used the unprocessed digital terrain models developed with the Global Mapper software.

Based on the results of this analysis, in combination with the data regarding opportunities and constraints described in Section 2.4.2 below, reaches were identified with greater and/or more extensive potential opportunities for restoration, as described below in Section 2.4.3.

2.2.2 Step 2: Identify Opportunities and Constraints

The identification of other opportunities and constraints besides physical suitability relied on readily available geospatial data layers, except for information on the location of existing interest in restoration, which was compiled from stakeholders for this analysis.

As part of the CVFPP planning process, existing datasets potentially of use in development of the CVFPP and related documents and appendices were reviewed (AECOM, 2010a). The intent of this review was to document those readily available and public-domain geospatial datasets that would be used for the CVFPP, subject to a defined set of selection rules. Included among these rules were the following:

- Data had to be freely available on the Internet or available from a CVFPP participant (i.e., DWR, MWH, or AECOM).
- Data had to cover the entirety of the study area, or as much of the area as possible.

- Where a choice between data currency and data detail (i.e., spatial resolution) was available, more current data were preferred over more detailed data unless it was felt that enhanced data resolution (either spatial or attribute) was essential.

Data collected to help identify areas with opportunities and/or constraints, subject to these rules, are described below.

- **Agricultural and Natural Land Use/Land Cover** – Land use/land cover data were compiled for Important Farmland (as defined by DOC, 2011) from the California Department of Conservation's Farmland Mapping and Monitoring Program (DOC, 2008) and wetlands and riparian vegetation (DWR, 2012).

- **Urban Areas** – These data were developed by DWR (2010a) using data provided by the California Department of Conservation's Farmland Mapping and Monitoring Program.

- **Major Infrastructure** – Major infrastructure consisted of data showing the locations of major roads and highways (U.S. Census Bureau, 2007), railways (Caltrans, 2009), and levees and levee condition (developed by DWR during the CVFPP planning process, and under development by DWR's Urban and Non-Urban Levee Evaluation projects).

- **Terrestrial Sensitive Species Occurrences** – Occurrences of terrestrial sensitive species, meaning species considered to be threatened, endangered, rare, fully protected, or species with similar status that are tracked by the California Department of Fish and Game (DFG) in the California Natural Diversity Database (CNDDB). The January 2011 version of the database (DFG, 2011) was used for this analysis.

- **Salmonid Spawning Reaches** – Reaches of rivers known to support spawning of fall-late-fall-run, winter-run, and spring-run Chinook salmon (*Oncorhynchus tshawytscha*), as well as Central Valley steelhead (*Oncorhynchus mykiss)*, were mapped from the CalFish abundance database (DFG, 2005).

- **Conservation Status** – Locations of preserved and protected habitat were based on the California protected areas database (GreenInfo Network, 2010).

Because of the nature of these data and known data gaps, limitations, or inaccuracies, these data were not considered to conclusively indicate areas that would be more suitable for ecological restoration relative to other areas. For example, the CNDDB only records positive sightings of species

based on field surveys. It does not document the actual distribution of species, because additional populations of species tracked by CNDDB may be found in areas that have not been surveyed. This does not indicate that these data have no value in identifying potential ecosystem restoration opportunities, but it does underscore the inherent limitations of these data for use in evaluations of potential ecosystem restoration sites, particularly without considering the physical suitability of potential sites and other applicable data.

In addition to these selected geospatial datasets, information on existing interest in restoring particular areas was compiled from stakeholders. Focused outreach was conducted throughout the study area to document potential ecosystem restoration projects previously identified by various CVFPP stakeholders. Meetings were held with the stakeholder groups listed below.

- The Nature Conservancy (Northern Central Valley, California Water Program, San Joaquin Valley Project)
- American Rivers
- DWR Northern Regional Office
- DWR South Central Regional Office
- River Partners
- San Joaquin River Conservancy
- DFG (Central Region)
- U.S. Department of the Interior, Bureau of Reclamation (SJRRP)
- San Joaquin River Parkway and Conservation Trust
- Natural Resources Defense Council
- NewFields River Basin Services, LLC
- ESA PWA, Inc.

Owing to time constraints, not all potential ecosystem restoration stakeholders in the study area were interviewed.

Each interview consisted of a facilitated discussion, lead by DWR staff, to solicit stakeholder input on previously identified ecosystem restoration projects. Specific information provided by stakeholders regarding their planned projects has been treated as confidential. For each identified project, stakeholders were asked to provide the following information:

- Location of the potential project site, along with geospatial data depicting the project footprint, if available
- Project purpose, including ecosystem functions targeted for restoration
- Specific restoration activities proposed for the project, including a formal restoration plan, if available
- Current biological and physical conditions on the site, including an existing conditions report, if available
- Name and contact information for the project proponent
- Funding sources for the project
- Sources of the information described above

In addition to stakeholder interviews, existing reports that identified potential ecosystem restoration opportunities were also reviewed. These included the Sutter Basin Feasibility Study (USACE, 2010) and the Final Database of Potential Multi-Objective Flood Damage Reduction Actions (CBDA, 2004). Projects located within the study area and that would provide ecosystem benefits were included with the group of stakeholder-identified projects.

As previously described, these areas will be considered as potential restoration opportunities in the identification of reaches to be analyzed in more detail.

2.2.3 Step 3: Evaluate Potential for Restoration

The potential for restoration was determined by evaluating relationships among physically suitable areas and the locations of opportunities and constraints. This evaluation was based on the review and combination of geospatial data layers with ESRI's ArcGIS software. Through it, reaches with greater and/or more extensive potential opportunities for restoration were identified.

The Sacramento and San Joaquin river systems were subdivided into 29 reaches. Boundaries between reaches were located at discontinuities in river or floodplain morphology, and/or to major junctions with tributaries, bypasses, or canals. In the upper Sacramento and San Joaquin river basins, reaches correspond to those established by the Sacramento River Conservation Area Forum and the SJRRP, respectively.

For each reach, four combinations of physically suitable conditions and suitable land use/land cover representing different restoration opportunities were mapped and their acreages tabulated:

- Nonurban floodplain with 67 percent chance Sustained Spring Flow or 50 percent chance FIP hydrologically connected to the river with riparian vegetation
- Nonurban floodplain with 67 percent chance Sustained Spring Flow or 50 percent chance FIP hydrologically connected to the river without riparian vegetation
- Nonurban floodplain with 67 percent chance Sustained Spring Flow FIP hydrologically disconnected from the river
- Nonurban floodplain with 50 percent chance FIP hydrologically disconnected from the river

Additional information regarding the location and extent of opportunities and constraints was also compiled for each reach.

3.0 Results of Floodplain Restoration Opportunities Analysis

For river reaches and bypasses included in the FROA, results are summarized in narrative descriptions, tables, and maps. FROA includes the Sacramento River from Woodson Bridge State Recreation Area to Collinsville, the San Joaquin River from Friant Dam to Stockton, the lower Feather River, and the lowermost reaches of other major tributaries of the Sacramento and San Joaquin rivers (i.e., the Bear, Yuba, American, Stanislaus, Tuolumne, and Merced rivers). It does not include smaller tributaries. The Sutter and Yolo bypasses are also included.

Narrative descriptions of reaches are provided in Sections 3.1 through 3.5. Maps and tables are provided in Section 3.6. Maps and tables are provided in a separate section to facilitate ease of use, particularly for comparisons of multiple maps.

In the reach descriptions, information is provided for the approximately 2-mile-wide corridors modeled along each river (with the exception of the Yolo Bypass where a 14,000-foot-wide corridor was modeled to account for levees that are set more than 2 miles apart). This information includes physical conditions (FIP and hydrologic connectivity), land use/land cover, infrastructure, conservation status, and occurrences of sensitive species.

Information in the narrative descriptions was primarily derived from the data sources displayed on the maps in this chapter, and previously described in Section 2.4. In addition, some supporting information from the following sources was also incorporated:

- Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area (DWR, 2011);
- State Plan of Flood Control Descriptive Document (DWR, 2010b);
- California Natural Diversity Database (DFG, 2011);

- Sacramento River Conservation Area Forum Handbook (Sacramento River Conservation Area Forum, 2003); and
- Draft Program Environmental Impact Statement/Environmental Impact Report San Joaquin River Restoration Program (Reclamation, 2011).

Several terms are used repeatedly in describing the reaches. “Corridor” refers to the extent of the modeled area, which generally extends approximately 1 mile from the river’s centerline. “Connected” and “disconnected” refer to hydrologic connection to the river during a 50 percent chance event (i.e., connected areas would be inundated during a 50 percent chance event). Also, throughout this text, 67 percent chance Sustained Spring FIP refers to a floodplain area 1 foot or more above the water surface of a 67 percent chance spring flow sustained for at least 7 days, but at a lower elevation than the 50 percent chance water surface. Similarly, 50 percent chance FIP refers to floodplain areas 1 foot or more above the 50 percent chance water surface and below the water surface of the 10 percent chance flow. As described in Section 2.2.9, the process used to estimate water surface elevations resulted in elevations that varied within 1 foot of true elevations. Figure 3-1 illustrates the relationship between these different water surfaces and the elevation zones corresponding to areas with a different FIP.

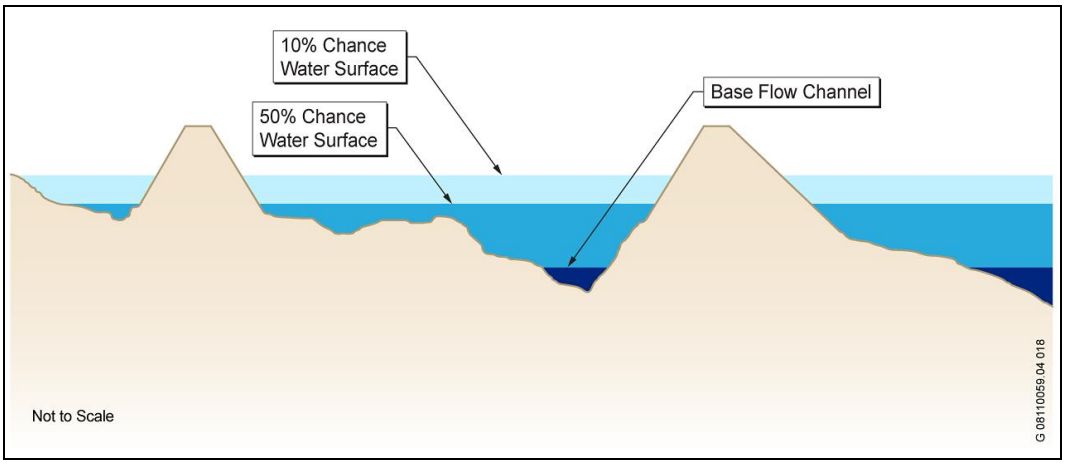

Figure 3-1. Hypothetical Cross Section with Boundary Water Surfaces of FIP Categories

3.1 Sacramento River Reach Descriptions

3.1.1 Woodson Bridge State Recreation Area to Chico Landing

From Woodson Bridge State Recreation Area (SRA) to Chico Landing, the Sacramento River actively meanders through the valley floor along much of this reach. (The majority of the banks along this reach are natural (i.e., without revetment) (DWR, 2011).) The active channel is fairly wide in some stretches and the river splits into multiple forks at many different locations, creating gravel islands, often with riparian vegetation. Historic bends in the river are visible throughout this reach and are remainders of historical channel locations with the riparian corridor and oxbow lakes still present in many locations.

In this reach, the corridor along the river is relatively evenly distributed among areas with 50 percent chance, 10 percent chance, and greater than 10 percent chance FIP. Most areas with 50 percent chance FIP are connected to the river. Only a small percentage of the floodplain has Below Baseflow FIP, and there are almost no areas with 67 percent chance Sustained Spring FIP.

Nearly 25 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas include portions of the Sacramento River National Wildlife Refuge, Sacramento River Wildlife Area, Butte Sink Wildlife Management Area, and Bidwell-Sacramento River State Park; the Woodson Bridge SRA; Merrill's Landing Wildlife Area; Westermann, Brattan, Kaplan, and Verschagin preserves; and Bureau of Land Management-managed land.

Natural vegetation covers one-third of the corridor along this reach, and riparian/wetland vegetation approximately an eighth of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sacramento anthicid beetle (*Anthicus sacramento*), Valley elderberry longhorn beetle (VELB) (*Desmocerus californicus dimorphus*), Swainson's hawk (*Buteo swainsoni*), colonies of bank swallow (*Riparia riparia*), yellow-billed cuckoo (*Coccyzus americanus*), western red bat (*Lasiurus blossevilli*), and western mastiff bat (*Eumops perotis*). This reach also provides habitat for several sensitive fish: foraging adult green sturgeon (*Acipenser medirostris*); migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Developed land uses occupy only a very small portion of the corridor along this reach (less than 2 percent), primarily in the vicinity of Hamilton City.

Other than levees, there is very little major infrastructure along this reach of the Sacramento River except between RM 196 and 197, where State Route (SR) 32, a natural gas pipeline, and an electrical transmission line cross the river.

Along this reach, several nonproject levees (i.e., levees that are not part of the SPFC) protect portions of both banks. This reach does not have project levees.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.2 Chico Landing to Colusa

From Chico Landing to Colusa, the Sacramento River actively meanders through the valley floor, actively eroding banks, producing oxbows and meander scrolls on the floodplain along much of this reach. (The majority of the banks along this reach are natural (i.e., without revetment) (DWR, 2011).) In this reach, it also historically overflowed into floodbasins. Currently, during flood flows, water from the Sacramento River enters the Butte Basin at the 3Bs natural overflow, the M&T and Goose Lake flood relief structures, and at Moulton and Colusa weirs.

In this reach, more than two-thirds of the corridor along the river has 50 percent chance FIP, and more than half of this area is connected to the river. Only a very small area has 67 percent chance Sustained Spring FIP.

Natural vegetation covers more than one-third of the corridor along this reach, and riparian/wetland vegetation approximately an eighth of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow (*Hibiscus lasiocarpus* var. *occidentalis*), several beetles (Antioch Dunes anthicid beetle (*Anthicus antiochensis*), Sacramento anthicid beetle, Sacramento Valley tiger beetle (*Cicindela hirticollis abrupta*), VELB), giant garter snake (*Thamniopsis gigas*), colonies of bank swallow, Swainson's hawk, colonies of tricolored blackbirds (*Agelaius tricolor*), yellow-billed cuckoo, western mastiff bat, and western red bat. This reach also provides habitat for several sensitive fish including foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas along this reach include portions of the Sacramento River National Wildlife Refuge, Bidwell-Sacramento River State Park, Sacramento River Wildlife Area, and Butte Sink Wildlife

Management Area; the Colusa Bypass Wildlife Area; and the Hartley Island, Jensen, and Cannell preserves.

Developed land uses occupy only a small portion of the corridor along this reach (only about 1 percent), primarily at Colusa. Other than levees, there is little major infrastructure along this reach of the Sacramento River. Natural gas pipelines cross near RMs 184, 174, and 162. SR 162 crosses the river near RM 166, and natural gas pipelines and electrical transmission lines are along the river corridor at several hundred to several thousand feet from the river.

At Ord Ferry on the west bank and 7.5 miles downstream from Ord Ferry on the east bank, SPFC levees border the river downstream along this reach, but are often as far as 1 mile apart. The physical condition of these levees is of medium concern, except for a 10- to 12-mile-long stretch upstream from Colusa where levee physical condition is of higher concern. Upstream from these SPFC levees are several nonproject levees on portions of the reach.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.3 Colusa to Verona

The general character of the Sacramento River changes downstream from Colusa from a dynamic and active meandering channel to a confined, narrow channel generally restricted from migration along the majority of its length. (DWR, 2011). While levees exist along portions of the river upstream from Colusa, levees are located much closer to the river edge as the river continues south to the Delta. The channel width is fairly uniform and river bends are static as a result of confinement by levees.

From Colusa to Verona, more than half of the corridor along the river has 50 percent chance FIP, but only a small portion of this area remains connected to the river. There also are large areas with Below Base Flow FIP. Most of these areas represent historical floodbasins that are disconnected from the river. Along this reach, about 10 percent of evaluated floodplain has a 67 percent chance Sustained Spring FIP, almost all of which is disconnected from the river.

Natural vegetation covers approximately one-eighth of the corridor along this reach, and riparian/wetland vegetation covers about 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, Sacramento tiger beetle, VELB, giant garter snake, colonies of bank swallows, Swainson’s hawk, colonies of tricolored blackbirds, yellow-billed cuckoo, and western red

bat. This reach also provides habitat for several sensitive fish, including Sacramento splittail (*pogonichthys macrolepidotus*), foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Along this reach of the Sacramento River, very little of the land has been conserved (about 1 percent of the corridor). Conserved areas along this reach of the Sacramento River include the Rohleder Preserve, Collins Eddy Wildlife Area, and the Fremont Weir Wildlife Area.

Developed land uses occupy only a small portion of the corridor along this reach (only about 2 percent), primarily in the vicinity of Colusa. However, there is more major infrastructure along this reach of the Sacramento River than along upstream reaches. The Colusa Highway crosses the river between RMs 134 and 133, and SR 113 crosses near RM 90. Natural gas pipelines cross the river near RMs 140, 127, 126; and electrical transmission lines cross the river near RMs 134, 121, 92, 86, and 80. Also, major roads, natural gas pipelines, and electrical transmission lines are located within 1 mile of the river at a number of locations.

There are SPFC levees along both river banks in this reach. The physical condition of these levees is of higher concern, except for several miles of levee east of the river downstream from Colusa.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.4 Verona to American River

From Verona to the American River, about two-thirds of the corridor along the river has 50 percent chance FIP and about a quarter has 67 percent chance Sustained Spring FIP. Almost all of this floodplain is disconnected from the river.

Natural vegetation covers more than 20 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, VELB, giant garter snake, western pond turtle, rookeries of wading birds, colonies of tricolored blackbird, and Swainson’s hawk. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Less than 10 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas along this reach include Elkhorn Regional County Park, Sacramento Bypass Wildlife Area, several Natomas Basin Conservancy reserves, and Discovery Park at the downstream end of the American River Parkway.

Developed land uses only occupy about 15 percent of the corridor along this reach. However, at the southern end of this reach, where the river enters Sacramento and West Sacramento, developed land uses occupy most of the 2-mile-wide corridor. Along this reach of the Sacramento River, Interstate (I)-5 crosses the river near RM 71 and crosses the American River at its junction with the Sacramento, and I-80 crosses the river near RM 63. Natural gas pipelines cross near RMs 67 and 64, and an electrical transmission line crosses near RM 63. In addition to major infrastructure facilities crossing the river, the Sacramento International Airport is within 2 miles of this reach of the river, and consequently is an important constraint on the restoration of habitat.

There are SPFC levees along both banks. The physical condition of these levees varies from lower concern where sections of the Natomas levees have recently been improved and medium concern for approximately 3.5 miles of the west levee south of the I-5 crossing, to higher concern elsewhere.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.5 American River to Freeport

From the American River to Freeport, about 20 percent of the corridor along the river has Below Baseflow FIP, nearly 30 percent has 67 percent chance Sustained Spring FIP, and more than 40 percent has 50 percent chance FIP. This FIP distribution reflects the varied landforms along this reach that include historical floodbasins and natural levees along the river channel. Almost all of this floodplain is disconnected from the river. In this tidally influenced reach, the Sacramento River enters the legal Delta.

Natural vegetation covers nearly 20 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 1 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford's arrowhead (*Sagittaria sanfordii*), VELB, and Swainson's hawk. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon;

and this reach contains delta smelt (*Hypomesus transpacificus*)-designated critical habitat.

Along this reach of the Sacramento River, only a small amount of land has been conserved (less than 5 percent of the corridor). Conserved areas along this reach are limited to smaller city and county parks and several other public-owned parcels.

Developed land uses occupy nearly two-thirds of the floodplain along this reach. Because this reach of the Sacramento River passes through the city of Sacramento, the corridor along the river has a high density of infrastructure, particularly from RMs 60 to 57. In addition to multiple major road, pipeline, and transmission line crossings, there are a number of Cortese sites (which have hazardous materials issues) and refineries. In addition, Sacramento Executive Airport is within 2 miles of this reach of the river.

There are SPFC levees along both banks of the river. The physical condition of these levees is generally of higher concern, but the physical condition of several sections of the west levee is of lower concern.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.6 Freeport to Delta Cross Channel

From Freeport to the Delta Cross Channel, approximately 60 percent of the corridor along the river has a Below Baseflow FIP, and of the remainder, most has a 67 percent chance Sustained Spring FIP. This FIP distribution reflects both historical landforms, and historical and ongoing changes to landforms (e.g., subsidence of areas with drained, organic soils). Almost all of this floodplain is isolated from the river. This Delta reach of the Sacramento River is tidally influenced.

Natural vegetation covers nearly 20 percent of the corridor along this reach, and riparian/wetland vegetation covers about 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, Sanford's arrowhead, several plants characteristic of sloughs and tidal marshes (e.g., Suisun Marsh aster (*Symphyotrichum lentum*), Delta tule pea (*Lathyrus jepsonii*), and Mason's lilaeopsis (*Lilaeopsis masonii*)) VELB, giant garter snake, western pond turtle (*Emys marmorata*), wading bird rookeries, white-tailed kite (*Elanus leucurus*), and Swainson's hawk, among others. This reach also provides habitat for several sensitive fish, including Sacramento splittail, delta smelt; foraging adult green sturgeon; migrating, holding, and rearing steelhead

and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Less than 10 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved lands include sanitation district and county open space land, Delta Meadows State Park, and a portion of Stone Lakes National Wildlife Refuge.

Along this reach, there are small areas of developed land uses at Cortland and near Walnut Grove, but developed land uses only occupy several percent of the corridor along this reach. Besides levees, there is little major infrastructure along this reach. SR 160 runs along the east bank of the river, and an electrical transmission line crosses the river between RMs 31 and 32.

SPFC levees are along both river banks. In the upstream half of this reach, the physical condition of the levees is generally of higher concern, but in the downstream half of this reach, their physical condition is generally of medium concern.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.7 Delta Cross Channel to Deep Water Ship Channel

From the Delta Cross Channel to the Deep Water Ship Channel, almost all of the corridor along the river has a Below Baseflow FIP, and is disconnected from the river. This floodplain consists of Delta islands bordered by sloughs, and that have been leveed and drained, and are in agricultural use. Consequently, the organic soils of these islands have been oxidizing and the land surface subsiding. There are only a few hundred acres along this reach with either 67 percent chance Sustained Spring FIP or 50 percent chance FIP, most of which is connected to the river. This Delta reach of the Sacramento River is tidally influenced.

Natural vegetation covers more than 10 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, several plants characteristic of sloughs and tidal marshes, Sacramento anthicid beetle, VELB, western pond turtle, Swainson’s hawk, and western red bat. This reach also provides habitat for several sensitive fish: delta smelt; foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Very little of the corridor along this reach of the Sacramento River has been conserved (less than 2 percent of the corridor). Conserved land along this reach is limited to a small area of state land near RM 15.

Along this reach there are small areas of developed land uses at Walnut Grove and Isleton, but developed land uses only account for several percent of the corridor along this reach. SR 160 runs along the river bank, and other major infrastructure includes an electrical transmission line that crosses the river near RM 17, and natural gas pipelines that cross the river near RMs 21, 20, and 15.

SPFC levees are along both river banks. The physical condition of the west levee is of medium concern; the physical condition of the west levee is of medium concern from the Delta Cross Channel to approximately RM 20, and of higher concern from near RM 20 to the junction with the Deep Water Ship Channel.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.8 Deep Water Ship Channel to Collinsville

From the Deep Water Ship Channel to Collinsville, the corridor along the river consists of Delta islands with a Below Base Flow FIP but disconnected from the river, and an area of uplands downstream from Rio Vista. There are only a few hundred acres along this reach with either 67 percent chance Sustained Spring FIP or 50 percent chance FIP, most of which is disconnected from the river. This Delta reach of the Sacramento River is strongly tidally influenced.

Natural vegetation covers more than two-thirds of the corridor along this reach, but riparian/wetland vegetation only covers about 1 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, several plants characteristic of sloughs and tidal marshes, Antioch Dunes and Sacramento anthicid beetles, VELB, giant garter snake, Swainson’s hawk, and western red bat. This reach also provides habitat for several sensitive fish, including delta smelt; foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Approximately 5 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas along this reach include Brannan Island SRA, Decker Island Wildlife Area, and Lower Sherman Island Wildlife Area.

A small portion of this reach has developed land uses at Rio Vista. In addition to levees, this reach has a high density of other major infrastructure. At Rio Vista, SR 12 crosses the river, as do two natural gas pipelines, and the Rio Vista Municipal Airport is within 1 mile of the river. Also, near the downstream end of this reach, from approximately RMs 7 to 4, nine natural gas pipelines and electrical transmission lines cross the river.

SPFC levees are on the east river bank for the entire length of the reach and on the west bank at RMs 13 to 14 (near Rio Vista). The physical condition of these levees is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the Sacramento River.

3.2 Sacramento River Tributary Reach Descriptions

The lowermost reaches of the Feather, Yuba, Bear, and American rivers were evaluated. These reaches begin approximately 1 mile upstream from the tributary's junction with the Sacramento River because the corridor along the Sacramento River extends 1 mile from the centerline of the Sacramento River.

3.2.1 Feather River – Thermalito Afterbay to Yuba River

Along the Feather River from Thermolito Afterbay to the Yuba River, the floodplain has almost no areas with 67 percent chance Sustained Spring FIP. Areas with 50 percent chance FIP, however, account for more than 40 percent of the corridor along the river, with the remainder evenly divided between 10 percent chance and greater than 10 percent chance FIP. More than two-thirds of areas with 50 percent chance FIP are connected to the river. A series of remnant gravel pit pools/ponds connect to the main channel in this reach. (Connected gravel pits can affect flows and water temperatures, disrupt sediment transport, and provide habitat for nonnative fish that compete with and prey on native species.)

Natural vegetation covers about one-quarter of the corridor along this reach, and riparian/wetland vegetation covers nearly 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, giant garter snake, colonies of bank swallows, western yellow-billed cuckoo, and Swainson's hawk. This reach also provides habitat for several sensitive fish species, including foraging adult green sturgeon; migrating, holding, spawning, and rearing fall-run

Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

More than 10 percent of the corridor along this reach of the Feather River has been conserved. Unlike most other reaches, the majority of conserved area is disconnected from the river. Conserved areas in this reach include the Oroville Wildlife Area and a portion of the Feather River Wildlife Area.

Less than 10 percent of the corridor along this reach has developed land uses, and most of this reach has only small amounts of developed land uses and major infrastructure: three gravel mines are near RMs 58 and 55 to 56, and a low, notched rock dam spans the river near RM 39. However, Yuba City and Marysville are at the downstream end of this reach, and along the river, developed land uses are extensive from about RM 31 to the end of the reach at RM 27. A number of pipelines, roads, and electrical transmission lines cross the river in this area. Also, there is a community airport at Yuba City within 1 mile of the river.

SPFC facilities in this reach include a levee throughout the reach on the west bank, the Sutter-Butte Canal Headgate, a levee extending downstream from Honcutt Creek on the east side of the river, and a ring levee around Marysville. The physical condition of these levees is of higher concern. There are also several nonproject levees.

Stakeholders identified potential restoration opportunities along this reach of the Feather River.

3.2.2 Feather River – Yuba River to Bear River

Between the Yuba and Bear rivers, most of the corridor along the Feather River has 50 percent chance FIP. More than two-thirds of these areas are disconnected from the river.

Natural vegetation covers nearly one-third of the corridor along this reach, and riparian/wetland vegetation covers approximately 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, giant garter snake, colonies of bank swallows, and Swainson's hawk. This reach also provides habitat for several sensitive fish species, including foraging adult green sturgeon; migrating, holding, and rearing fall-run Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Feather River has been conserved. A portion of the Feather River Wildlife Area is along this reach.

Developed land uses occupy about 10 percent of the corridor along this reach. The Yuba City and Marysville areas extend along the upstream end of this reach (RMs 24 to 27), and developed land uses are extensive in these areas, an electrical transmission line and a natural gas pipeline cross the river, and a power plant is adjacent to the river. Also, both the Yuba City and Yuba County airports are within 2 miles of the river. However, downstream from the Yuba City and Marysville areas, there is little developed land or major infrastructure except for an electrical transmission line that crosses the river near RM 23 and levees that extend along both banks.

SPFC levees are on both sides of the river and are spaced from about 0.5- to 1-mile apart. The physical condition of most of the west levee is of higher concern; the physical condition of the east bank levee is of lower concern.

Stakeholders identified potential restoration opportunities along this reach of the Feather River.

3.2.3 Feather River – Bear River to Sutter Bypass

From the Bear River to the Sutter Bypass, most of the corridor along the Feather River has 50 percent chance FIP. About two-thirds of these areas are disconnected from the river.

Natural vegetation covers nearly half of the corridor along this reach, and riparian/wetland vegetation covers approximately 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Antioch Dunes and Sacramento anthicid beetles, VELB, giant garter snake, western pond turtle, colonies of bank swallows, western yellow-billed cuckoo, and Swainson's hawk. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing fall-run Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Feather River has been conserved. A portion of the Feather River Wildlife Area is along this reach.

This reach has only a small amount of developed land (less than 2 percent of the corridor), primarily near Nicolaus (near RM 10). SR 99 crosses the

river near RM 9, and electrical transmission lines cross the river near RMs 9 and 10.

SPFC levees are on both banks along this reach. The physical condition of these levees is of higher concern except for approximately 2 miles of the north levee (from RM 10 to the junction with the Sutter Bypass).

Stakeholders identified potential restoration opportunities along this reach of the Feather River.

3.2.4 Feather River – Sutter Bypass to Sacramento River

Similar to upstream reaches, from the Sutter Bypass to the Sacramento River, most of the corridor along the Feather River has 50 percent chance FIP. However, this reach has more areas with 67 percent chance Sustained Spring FIP than upstream reaches (12 percent versus 1 percent or less). Connectivity of these areas to the river is also greater along upstream reaches. In this reach, the Feather River has a relatively straight channel located along the eastern edge of the floodway.

Natural vegetation covers more than 20 percent of the corridor along this reach, but riparian/wetland vegetation only covers several percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sacramento Valley tiger beetle, giant garter snake, colonies of bank swallows and tricolored blackbirds, and Swainson's hawk. Along this reach of the Feather River, there are no conserved areas. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing fall-run Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

This reach has only a small amount of developed land (less than 2 percent of the corridor), and no major infrastructure crosses the river, although an electrical transmission line is located near the east riverbank, where the Garden Highway also is located adjacent to the levee.

SPFC levees are on both river banks along this reach. The physical condition of these levees is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the Feather River.

3.2.5 Yuba River

The lower reach of the Yuba River is a relatively narrow floodplain constrained by nearby terraces and other uplands. Consequently, more than half of the corridor along the river has a greater than 10 percent chance FIP. More than 10 percent of the floodplain corridor had 50 percent chance FIP, about half of which is connected to the river. Very little floodplain had 67 percent chance Sustained Spring FIP. South of the river, a portion of the Yuba Goldfields is within the corridor. This extensive disturbed area contains numerous small water features and patches of riparian vegetation.

Natural vegetation covers approximately 60 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, western pond turtle, California black rail (*Laterallus jamaicensis coturniculus*), colonies of tricolored black birds, and Swainson's hawk. This reach also provides habitat for several sensitive fish, including migrating, holding, and rearing steelhead and fall-run Chinook; and migrating and rearing spring-run Chinook.

Approximately 7 percent of the corridor along this reach has been conserved. Conserved areas along this reach of the Yuba River are limited to several Bureau of Land Management-managed parcels (mostly upstream from RM 10) and City of Marysville open space approximately 1 mile upstream from the junction with the Feather River.

Developed land uses occupy less than 10 percent of the corridor along this reach. However, Marysville is at the downstream end of this reach where developed land uses are extensive. Upstream from Marysville, there is little developed land or major infrastructure. From about RM 8 to RM 10 there are two gravel mines and two electrical transmission lines that cross the river, and further upstream is Daguerre Point Dam.

SPFC levees are widely spaced on both sides of the river. There is also a nonproject levee around RMs 6 to 8. The physical condition of segments of these levees varies from lower to higher concern.

Stakeholders identified potential restoration opportunities along this reach of the Yuba River.

3.2.6 Bear River

Along the lowest reach of the Bear River, almost half of the corridor along the river had 67 percent chance Sustained Spring FIP or 50 percent chance FIP. Most of this area (85 percent or more) is disconnected from the river.

Natural vegetation covers nearly one-third of the corridor along this reach, and riparian/wetland vegetation covers several percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, giant garter snake, western pond turtle, and Swainson's hawk. This reach also provides habitat for migrating, holding, and rearing steelhead; and opportunistic/intermittent migrating, holding, spawning, and rearing for fall-run Chinook salmon.

Only a very small portion of the corridor along this reach of the Bear River has been conserved (approximately 1 percent of the corridor). Conserved areas along this reach are limited to several water district-owned parcels.

Developed land uses occupy less than 5 percent of the corridor along this reach, and are concentrated near Wheatland (near RMs 9 to 11). Major infrastructure includes river crossings by SRs 65 and 70 (near RMs 4 and 10, respectively), and crossings by electrical transmission lines and natural gas pipelines near those major road crossings.

There are SPFC levees on both banks for approximately the first 7 miles of this reach, and the south bank levee continues along Dry Creek. The physical condition of the north levee is of lower concern; the physical condition of the south levee is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the Bear River.

3.2.7 American River

Along the lowest reach of the American River, only about 1 percent of the corridor along the river has 67 percent chance Sustained Spring FIP, and only 14 percent has 50 percent chance FIP. Most of these areas are connected to the river.

Natural vegetation covers more than 20 percent of the corridor along this reach, and riparian/wetland vegetation covers about 8 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford's arrowhead, VELB, western pond turtle, wading bird rookeries, colonies of bank swallows, white-tailed kite, and Swainson's hawk. This reach also provides habitat for migrating, holding, and rearing steelhead; and migrating, holding, spawning, and rearing fall-run Chinook salmon.

More than 20 percent of the corridor along this reach of the American River has been conserved. This reach has the largest percentage of conserved area among reaches of the Sacramento and San Joaquin river

systems. Conserved areas along this reach of the American River include the American River Parkway and associated county parks.

Because this reach passes through the Sacramento Metropolitan Area, developed land uses occupy more than three-quarters of the land along this reach. There also is a high density of major infrastructure along the river, particularly from RMs 0 to 9. Multiple major roads and railroads, natural gas pipelines, and electrical transmission lines cross the river.

SPFC levees are on both sides of the river for the first 10 miles of this reach and extend further along the north side. The physical condition of these levees is of lower concern, except for the section of the north levee between the river and the Natomas Basin, whose physical condition is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the American River.

3.3 Sutter and Yolo Bypass Descriptions

3.3.1 Sutter Bypass

The Sutter Bypass is a wide flood channel that carries floodwater diverted from the Sacramento River at several weirs north of the Sutter Buttes to the confluence of the Feather and Sacramento rivers, and then on to the Yolo Bypass. From the west, Butte Creek (Butte Slough) enters the bypass. It is inundated in most years by water diverted out of the Sacramento River.

The Sutter Bypass is used mainly for agriculture, and there are only small amounts of natural vegetation. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, giant garter snake, western pond turtle, California black rail, yellow-headed blackbird (*Xanthocephalus xanthocephalus*), colonies of tricolored blackbirds, and Swainson's hawk. Sutter National Wildlife Refuge extends throughout this reach of the Sutter Bypass. The Sutter Bypass also provides extremely productive inundated floodplain habitat that exports nutrients and food items to the downstream river system (Sommer et al., 2001). Inundated floodplain also provides rearing habitat for steelhead and Chinook salmon, and spawning habitat for Sacramento splittail.

There is no developed land within the Sutter Bypass, and major infrastructure is limited to just several road crossings (most notably SR 113), several interconnected electrical transmission lines, and two major water supply canals, the West Borrow Canal and East Borrow Canal, which

are immediately adjacent to the waterside toes of the western and eastern Sutter Bypass levees, respectively.

The Sutter Bypass levees are project levees whose physical condition is generally of higher concern.

Stakeholders identified potential restoration opportunities in the Sutter Bypass.

3.3.2 Yolo Bypass

To the north and east, the Yolo Bypass is bordered by the natural levees of the Sacramento River and its distributary channels, on the west by the alluvial fans of Putah Creek and Cache Creek, and to the south by the tidal sloughs and islands of the Delta. During flood flows, water enters the Yolo Bypass from the Sacramento River from the north, and Cache Creek, Putah Creek, and Willow Slough from the west; and drains south to the northern Delta. During about 70 percent of years, the bypass is inundated one to several times for 0 to 135 days during May through November (DFG, 2008).

Land cover in the Yolo Bypass consists of a mosaic of agricultural and natural vegetation that includes row crops, seasonal wetlands managed as habitat (primarily for waterfowl), permanent wetlands, and uplands. Riparian and wetland-associated sensitive species documented along this reach include giant garter snake, California black rail, and Swainson's hawk. Also, as described for the Sutter Bypass, the Yolo Bypass provides extremely productive inundated floodplain habitat that benefit downstream ecosystems and provide rearing habitat for steelhead and Chinook salmon, and spawning habitat for Sacramento splittail. A substantial portion of the bypass is included in the Yolo Bypass Wildlife Area.

There is no developed land in the Yolo Bypass. Infrastructure in and adjacent to the Yolo Bypass includes levees and several major transportation features. The Sacramento Deep Water Ship Channel is east of the bypass. There are a variety of small interior levees and berms constructed for local agricultural development that prevent the inundation of particular areas from tidal fluctuations and small floods. In addition, causeways and bridge crossings of the bypass include I-80, I-5, portions of the abandoned Sacramento North Railroad, and the Southern Pacific Railroad.

The Yolo Bypass is surrounded completely on the east and partially on the west by SPFC levees. The physical condition of these levees is of higher to medium concern.

Stakeholders identified potential restoration opportunities in the Yolo Bypass.

3.4 San Joaquin River Reach Descriptions

3.4.1 Friant Dam to SR 99

Along this reach, the San Joaquin River is confined by bluffs and between the bluffs by low terraces. Consequently, the corridor along the river predominantly has greater than 10 percent chance FIP. Along the river are the pits of active and abandoned aggregate mines. A number of these pits have been captured by (i.e., become connected to) the river. (These captured pits are of conservation concern because of the potential for fish stranding and predation by warm-water fish.)

Natural vegetation covers nearly half of the corridor along this reach, and riparian/wetland vegetation covers about 8 percent of the corridor. Invasive plant species are abundant in this riparian vegetation (e.g., red sesbania (*Sesbania punicea*), blue gum (*Eucalyptus globulus*), and giant reed (*Arundo donax*)). Riparian and wetland-associated sensitive species documented along this reach include VELB and rookeries of wading birds.

More than 15 percent of the corridor along this reach has been conserved. Conserved areas include the San Joaquin River Ecological Reserve, Camp Pashayan Ecological Preserve, and several county parks and land managed by the San Joaquin River Parkway and Conservation Trust.

Developed land uses occupy nearly 30 percent of the corridor along this reach, and are most extensive south of the river. Because of its proximity to Fresno, this reach has major infrastructure throughout, particularly near SR 99, where natural gas pipelines, electrical transmission lines, and a railroad cross the river. Electrical transmission lines also cross the river near RMs 250 and 254, and SR 41 crosses the river near RM 252. In addition, there are a number of historical and several active gravel mines along this reach. Also, Sierra Sky Park Airport is within 1 mile of the river.

In addition to increasing spring–fall river flows, potential restoration actions identified for this reach by the SJRRP include isolating/eliminating selected gravel pits, modifying side channels, controlling invasive species and fish predators, modifying road crossings, and augmenting spawning gravel.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.2 SR 99 to Gravelly Ford

From SR 99 to Gravelly Ford, the San Joaquin River is confined between bluffs. At the downstream end of this reach, the bluffs diminish in height and gradually merge with floodplain surfaces. Despite this change, along this entire reach of river, the evaluated corridor primarily has greater than 10 percent chance FIP.

Natural vegetation covers only about one-eighth of the corridor along this reach, and riparian/wetland vegetation covers several percent of the corridor. Riparian and wetland-associated sensitive species have not been documented along this reach in the CNDDB.

Very little of the corridor along this reach has been conserved (less than 1 percent of the corridor). A county park (Skaggs Bridge Park) is the only conserved area along this reach of the San Joaquin River.

Developed land uses occupy less than 1 percent of the corridor along this reach. Except for a natural gas pipeline that is along the length of this reach and crosses the river twice between RMs 238 and 240, there is no major infrastructure along this reach of the San Joaquin River.

In addition to increasing spring–fall river flows, potential restoration actions identified for this reach by the SJRRP include isolating/eliminating selected gravel pits, controlling invasive plant species, and modifying road crossings. Stakeholders also identified potential restoration opportunities along this reach of the San Joaquin River. Stakeholders did not identify potential restoration opportunities along this reach of the San Joaquin River.

3.4.3 Gravelly Ford to Chowchilla Bypass

From Gravelly Ford to Chowchilla Bypass, the San Joaquin River is sand bedded and meandering. Through lateral migration and avulsion the channel actively moves within the levees. The SJRRP is restoring year-round flow to this reach that, because of diversions, has had only seasonal flow. The FIP of the corridor along this reach varies considerably, with about 40 percent having 67 percent chance Sustained Spring or 50 percent chance FIP. Most of these areas are disconnected from the river.

Natural vegetation covers more than 10 percent of the corridor along this reach, and riparian/wetland vegetation covers approximately 5 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB and Swainson’s hawk. There are no conserved areas along this reach of the San Joaquin River.

Developed land uses occupy much less than 1 percent of the corridor along this reach. There is very little major infrastructure along this reach of the San Joaquin River. A natural gas pipeline is within 1,000 feet of the river at RMs 219 to 220.

SPFC levees are along both river banks. The physical condition of these levees is of higher concern.

Stakeholders identified a potential restoration opportunity along this reach of the San Joaquin River.

3.4.4 Chowchilla Bypass to Mendota Dam

From Chowchilla Bypass to Mendota Dam, FIP varies considerably. However, nearly half of the corridor has 67 percent chance Sustained Spring or 50 percent chance FIP. Most of these areas are disconnected from the river.

The backwater of Mendota Pool occupies the lower few miles of this reach. This backwater is an extensive area of open water bordered by riparian and emergent wetland vegetation. The Mendota Pool is formed by Mendota Dam at the confluence of the San Joaquin River and Fresno Slough. The primary source of water to the Mendota Pool is conveyed from the Delta through the Delta-Mendota Canal. Most of the Mendota Pool is less than 10 feet deep, with the deepest areas no more than 20 feet deep and averaging about 400 feet wide. Inflows to and outflows from the pool are balanced so that the pool remains at a relatively constant depth. The pool must remain above 14.5 feet at the Mendota Dam gage for users at the southern end of the pool to be able to draw water.

Along this reach of the San Joaquin River, there are almost no conserved lands. However, the Mendota Wildlife Area is along the James Bypass, at the southern end of the Mendota Pool.

Natural vegetation covers nearly 15 percent of the corridor along this reach, and riparian/wetland vegetation covers about 5 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford's arrowhead, giant garter snake, western pond turtle, and Swainson's hawk.

Developed land uses occupy only about 1 percent of the corridor along this reach. Although San Mateo Road crosses the river in this reach and a natural gas pipeline repeatedly crosses the river between RMs 203 and 208, Mendota Dam and the diversions associated with Mendota Dam account for most major infrastructure along this reach. Also, there is a community airport at Mendota within 2 miles of the river.

There are nonproject levees on both banks of this reach. There are no project levees along this reach.

The SJRRP includes constructing a bypass channel around Mendota Pool, and setting back levees to create a floodplain between 500 and 3,700 feet wide. It also identifies modifying the San Mateo Road crossing as a potential restoration action. Stakeholders also identified a potential restoration opportunity along this reach of the San Joaquin River.

3.4.5 Mendota Dam to Sack Dam

Along this reach, regulated flows for water deliveries from the Delta-Mendota Canal are conveyed through the San Joaquin River channel to Sack Dam for diversion to Arroyo Canal.

From Mendota Dam to Sack Dam, about two-thirds of the corridor along the river has 50 percent chance FIP, and most of the remainder (mostly located near Firebaugh) has greater than 10 percent chance FIP. Along this reach, nearly 90 percent of areas with 50 percent chance FIP are disconnected from the river.

Natural vegetation covers about an eighth of the corridor along this reach, and riparian/wetland vegetation covers less than 4 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include giant garter snake, western pond turtle, Swainson's hawk, and western red bat. There is almost no conserved area along this reach of the San Joaquin River.

Developed land uses occupy about 5 percent of the corridor along this reach, and are extensive in the vicinity of Firebaugh on the west bank. Major infrastructure along this reach includes a crossing by Avenue 7 ½; electrical transmission line crossings near RMs 184, 185, and 195; a natural gas pipeline crossing near RM 192; and a gravel mine near RM 188. There is also a community airport at Firebaugh that is within 1 mile of the river.

For most of its length, this reach is bounded on both sides by man-made structures, including irrigation canals and project and nonproject levees. There are no project levees along this reach. At some locations, lands within the floodway are actively used for agricultural production, and are protected by local or interior levees. During the 2006 flood, a number of these parcels were inundated.

The SJRRP has not planned or identified any restoration actions along this reach other than modification of facilities to improve fish passage, and the previously described Mendota Pool Bypass, which would reconnect to the

river at the beginning of this reach. Stakeholders, however, identified a potential restoration opportunity along this reach of the San Joaquin River.

3.4.6 Sack Dam to Sand Slough Control Structure

From Sack Dam to the Sand Slough Control Structure, the geomorphology of the San Joaquin River is transitional from the meandering river channel and associated floodplain of upstream reaches to the numerous sloughs and extensive floodbasins downstream. Many sloughs originate in this and the immediately downstream reach of the San Joaquin River.

This reach normally carries only seepage water from Sack Dam and from adjacent agricultural areas. At its downstream end, any water in the channel flows through Sand Slough and into the Eastside Bypass.

Along this reach, the floodway is only about 300 feet wide. Outside of this floodway, the corridor along the river consists predominantly of areas with 50 percent chance FIP, which are disconnected from the river.

Natural vegetation covers about an eighth of the corridor along this reach, but riparian/wetland vegetation covers less than 2 percent of the corridor. Swainson's hawk has been documented along this reach. There are no conserved lands along this reach of the San Joaquin River.

The floodplain of this reach is almost entirely in agricultural use. It virtually lacks developed land uses and has relatively little major infrastructure: SR 152 crosses the river at RM 173, an electrical transmission line crosses the river at RM 173, and a natural gas pipeline crosses the river near Sack Dam.

Nonproject levees are close to the river along all of this reach except at the northern end, where there are SPFC levees. The physical condition of these project levees is of higher concern.

The SJRRP includes projects to modify Sack Dam (to improve fish passage) and to screen the intake of the Arroyo Canal. Stakeholders did not identify potential restoration opportunities along this reach of the San Joaquin River.

3.4.7 Sand Slough Control Structure to Mariposa Bypass

In this reach, the channel of the San Joaquin River historically was connected to sloughs and floodbasins. Consequently, more than two-thirds of the corridor along the river has 67 percent chance FIP, and most of the remainder has Below Baseflow FIP. This reach has the largest percentage of 67 percent chance FIP among reaches of the San Joaquin and

Sacramento river systems. About 60 percent of these areas are disconnected from the river.

Natural vegetation covers nearly 15 percent of the corridor along this reach, and riparian/wetland vegetation covers approximately 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery (*Eryngium racemosum*), giant garter snake, northern harrier (*Circus cyaneus*), and Swainson's hawk.

More than 5 percent of the corridor along this reach has been conserved. This conserved land is part of the San Luis National Wildlife Refuge.

This reach virtually lacks developed land uses. Other than the Sand Slough Control Structure and the Mariposa Bypass at the ends of this reach, and several levees, this reach also has almost no major infrastructure. SPFC levees are on both banks at the northern end of this reach, and nonproject levees are at two locations farther upstream. The physical condition of the SPFC levees is of higher concern.

The SJRRP includes increasing conveyance in this reach, potentially with setback levees, modifying road crossings, and modifying the San Slough Control Structure to improve fish passage and the San Joaquin River Headgate to allow improve conveyance.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.8 Mariposa Bypass to Bear Creek

From the Mariposa Bypass to Bear Creek, the San Joaquin River was historically connected to sloughs and floodbasins. Approximately 90 percent of the corridor along this reach has 50 percent chance FIP. Most of this area is disconnected from the river.

Natural vegetation covers more than 90 percent of the corridor along this reach, and riparian/wetland vegetation covers nearly 15 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery, northern harrier, and Swainson's hawk.

More than 70 percent of the corridor along this reach of the San Joaquin River has been conserved. Unlike most reaches, the majority of this conserved land is disconnected from the river. Conserved areas along this reach include a portion of the San Luis National Wildlife Refuge.

This reach virtually lacks developed land uses. There is very little major infrastructure along this reach other than an electrical transmission line that crosses the river at RM 142.

SPFC levees are on both banks along this reach. The physical condition of these levees is of higher concern.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.9 Bear Creek to Merced River

From Bear Creek to the Merced River, the San Joaquin River has more sinuosity than in upstream reaches; and oxbow, side channel, and remnant channel landforms are present. About half of the corridor along the river has a 50 percent chance FIP, and most of these areas are connected to the river.

Natural vegetation covers more than 70 percent of the corridor along this reach, and riparian/wetland vegetation covers nearly 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery, western pond turtle, colonies of tricolored blackbirds, northern harrier, Swainson's hawk, western red bat, and pallid bat (*Antrozous pallidus*).

More than 50 percent of this reach of the San Joaquin River has been preserved. Conserved areas along this reach include the North Grasslands Wildlife Area, Great Valley Grasslands State Park, and San Luis National Wildlife Refuge.

Developed land uses occupy only about 2 percent of the corridor along this reach. There is little major infrastructure along this reach: an electrical transmission line is located near the river at RM 116, SR 140 crosses the river near RM 123, and Lander Avenue crosses the river near RM 130.

An SPFC levee is located along the river's east side, and extends for several miles along the west side. The physical condition of the east levee is of medium concern; the physical condition of the west levee is of higher concern.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.10 Merced River to Tuolumne River

Between the Merced and Tuolumne rivers, the San Joaquin River is sinuous and in some areas is actively meandering. The corridor along this reach of the San Joaquin River includes abandoned sloughs, channel portions, and oxbow cutoffs. In this reach, more than half of the corridor along the San Joaquin River has a 10 percent chance or greater than a 10 percent chance FIP. A 50 percent chance FIP accounts for almost 40 percent of the corridor, and about half of these areas are disconnected from the river.

Natural vegetation covers more than 30 percent of the corridor along this reach, and riparian/wetland vegetation covers about 6 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery, VELB, wading bird rookeries, least Bell's vireo (*Vireo bellii pusillus*), colonies of tricolored blackbirds, Swainson's hawk, pallid bat, and western red bat. This reach also provides habitat for Sacramento splittail; and migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Only a small portion of the corridor along this reach of the San Joaquin River has been conserved (approximately 5 percent of the corridor). However, there are several conserved areas along this reach, including the West Hilmar Wildlife Area, a portion of the San Joaquin National Wildlife Refuge, and several county and regional parks and open space areas.

Developed land uses occupy about 5 percent of the corridor along this reach. However, major infrastructure is widely dispersed along this reach. Electrical transmission lines cross the river near RMs 85, 87, and 101, and pipelines cross the river near RMs 101 and 107. In addition to these crossings, a wastewater treatment facility is on the east bank at RMs 94 and 93, and an aggregate mine is near RM 107.

SPFC levees are along most of the east bank and portions of the west bank, but neither connects to other SPFC levees upstream or downstream from this reach. The physical condition of these levees is of higher concern, except for a west levee at the junction with the Tuolumne River, whose physical condition is of medium concern. There are several nonproject levees in intervening areas.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.11 Tuolumne River to Stanislaus River

The San Joaquin River is actively meandering in portions of this reach, and the river corridor includes floodplain with complex topography, including oxbows, swales, and other products of channel migration. Between the

Tuolumne and Stanislaus rivers, nearly half of the corridor along the San Joaquin River has a 50 percent chance FIP, and most of the remainder has either 10 percent chance or greater than a 10 percent chance FIP. Approximately 60 percent of areas with a 50 percent chance FIP are disconnected from the river.

Natural vegetation covers nearly half of the corridor along this reach, and riparian/wetland vegetation covers more than 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, least Bell's vireo, colonies of tricolored blackbirds, Swainson's hawk, riparian woodrat (*Neotoma fuscipes riparia*), and riparian brush rabbit (*Sylvilagus bachmani riparius*). This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

More than one-third of the corridor along this reach of the San Joaquin River has been conserved. This conserved land is part of the San Joaquin National Wildlife Refuge.

This reach virtually lacks developed land uses. Along this reach, there is little major infrastructure except for levees: between RM 78 and RM 75, Maze Boulevard, and an electrical transmission line cross the river.

There are SPFC levees on portions of both banks and nonproject levees connecting to and/or inside of the SPFC levees. The physical condition of these levees is of higher concern.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.12 Stanislaus River to Stockton

The San Joaquin River is actively migrating in portions of this reach, and the corridor along the river includes floodplains with complex topography and oxbow lakes. From the Stanislaus River to Stockton, about 40 percent of the corridor along the San Joaquin River has a 50 percent chance FIP, and most of the remainder is distributed relatively evenly between areas with Below Base Flow, a 67 percent chance Sustained Spring, and a 10 percent chance FIP. About 90 percent of areas with a 67 percent chance Sustained Spring or 50 percent chance FIP are disconnected from the river. In this tidally influenced reach, the San Joaquin River enters the legal Delta.

Natural vegetation covers approximately 10 percent of the corridor along this reach, and riparian/wetland vegetation covers approximately 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford's arrowhead, Delta button-celery, several plants associated with marshes and sloughs (e.g., slough

thistle (*Cirsium crassicaule*)), Suisun song sparrow (*Melospiza melodia maxillaris*), colonies of tricolored blackbirds, Swainson's hawk, riparian woodrat, and riparian brush rabbit. This reach also provides habitat for several sensitive fish species, including foraging adult green sturgeon; and migrating, holding, and rearing steelhead and fall-run Chinook salmon; and this reach contains delta smelt designated critical habitat.

Only a very small portion of the corridor along this reach has been conserved (approximately 1 percent of the corridor). The only conserved area along this reach is a small preserve near Vernalis.

Developed land uses are extensive, occupying more than one-quarter of the corridor along this reach. This reach of the San Joaquin River has a high density of major infrastructure that not only includes major road and railroad, natural gas pipeline, and electrical transmission line crossings, but also aggregate mines and refineries. However, there is no major infrastructure between RMs 43 and 46, RMs 47 and 56, and RMs 61 and 65.

Except for an upstream portion of the west bank, there are SPFC levees on both banks along this reach. The physical condition of these levees is predominantly of higher concern, but there are sections on both banks (that total several miles in length) whose physical condition is of medium or lower concern.

Stakeholders identified a potential restoration opportunity along this reach of the San Joaquin River.

3.5 San Joaquin River Tributary Reach Descriptions

The lowermost reach of the Merced, Tuolumne, and Stanislaus rivers were evaluated. These reaches begin approximately 1 mile upstream from the tributary's junction with the Sacramento River because the corridor along the Sacramento River extends 1 mile from the centerline of the Sacramento River.

3.5.1 Merced River

The lowermost reach of the Merced River has a relatively narrow floodplain constrained by uplands of higher elevation. Consequently, almost three-quarters of the corridor along this reach has a greater than 10 percent chance FIP. Only a very small area of floodplain has a 50 percent chance FIP or a 67 percent chance Sustained Spring FIP, most of which is connected to the river.

Natural vegetation covers nearly 10 percent of the corridor along this reach, and riparian/wetland vegetation covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, Swainson's hawk, pallid bat, and western red bat. This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Only a very small portion of the corridor along this reach of the Merced River has been conserved (less than 1 percent of the corridor). Conserved areas along this reach are limited to the George J. Hatfield State Recreation Area and a county park.

Developed land uses occupy about 8 percent of the corridor along this reach. Although dispersed throughout the reach, they are more extensive near Livingston at the upstream end of the reach. Major infrastructure along this reach includes a gravel mine near RM 17, and road crossings by Landers Avenue at RM 12 and SR 99 near RM 21. Additionally, a natural gas pipeline, an oil pipeline, and an electrical transmission line cross the river within this reach.

There also are nonproject levees on the south bank of this reach at several locations, but no project levees.

Stakeholders identified potential restoration opportunities along this reach of the Merced River.

3.5.2 Tuolumne River

Similar to the Merced River, the lowermost reach of the Tuolumne River has a relatively narrow floodplain constrained by uplands of higher elevation. Consequently, nearly 90 percent of the corridor along this reach has a greater than 10 percent chance FIP. Only a very small area of floodplain has a 50 percent chance FIP or a 67 percent chance Sustained Spring FIP, about half of which is connected to the river.

Natural vegetation covers nearly an eighth of the corridor along this reach, and riparian/wetland vegetation covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, colonies of tricolored blackbirds, and Swainson's hawk. This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Only a small portion of this reach of the Tuolumne River has been conserved (nearly 5 percent of the corridor). Conserved areas along this reach include the Tuolumne River and Ceres River Bluff regional parks.

Developed land uses occupy more than one-third of the corridor along this reach. Although located throughout the reach, developed land uses and major infrastructure are most extensive at Modesto (from RMs 10 to 22).

Major infrastructure is concentrated between approximately RM 13 and RM 22. In that stretch there are major road and railroad, electrical transmission line, and natural gas pipeline crossings. The Modesto City-County Airport is also located within 1 mile of the river in this area.

There are several nonproject levees on portions of each bank along this reach, but no project levees.

Stakeholders identified potential restoration opportunities along this reach of the Tuolumne River.

3.5.3 Stanislaus River

Similar to the Merced and Tuolumne rivers, the lowermost reach of the Stanislaus River has a relatively narrow floodplain constrained by uplands of higher elevation. Consequently, more than half of the corridor along this reach has a greater than 10 percent chance FIP, and most of the remainder has a 10 percent chance FIP. Only a very small area of floodplain has a 50 percent chance FIP or a 67 percent chance Sustained Spring FIP, more than two-thirds of which is disconnected from the river.

Natural vegetation covers more than 15 percent of the corridor along this reach, but riparian/wetland vegetation accounts for about half of that land cover. Riparian and wetland-associated sensitive species documented along this reach include VELB, Swainson's hawk, riparian woodrat, and riparian brush rabbit. This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Stanislaus River has been conserved. Conserved areas along this reach of the Stanislaus River include Caswell State Park and San Joaquin National Wildlife Refuge.

Developed land uses occupy about 9 percent of the corridor along this reach. Although some developed land uses are located throughout the reach, they are extensive at Ripon (RMs 12 to 14). Along this reach, there is little major infrastructure besides project and nonproject levees. Natural gas pipelines cross the river near RM 4 and RM 15.

SPFC levees are on both banks for about the first 10 river miles. The physical condition of these project levees is of higher concern. Nonproject levees extend upstream discontinuously along both sides of the river.

Stakeholders identified potential restoration opportunities along this reach of the Stanislaus River.

3.6 Maps and Tables of Results

This section provides a set of maps (Figures 3-2 through 3-26) and tables (Tables 3-1 through 3-12) for 2-mile-wide corridors along (1) Sacramento River reaches, (2) Sacramento River tributary and bypass reaches, (3) upper San Joaquin River reaches, and (4) lower San Joaquin River reaches. Each set includes maps of FIP, land use/land cover, conserved areas, and major infrastructure. Each set also includes a map of nonurban floodplain areas with a 67 percent chance Sustained Spring or a 50 percent chance FIP classified by their connectivity to the river system and their land use/land cover. (Areas with a 67 percent chance Sustained Spring or a 50 percent chance FIP represent those areas with the greatest potential for providing inundated floodplain habitats.) This map represents different types of restoration opportunities. Each set of tables summarizes information displayed on the maps by reach, including FIP and connectivity, and land cover and conservation status for selected areas.

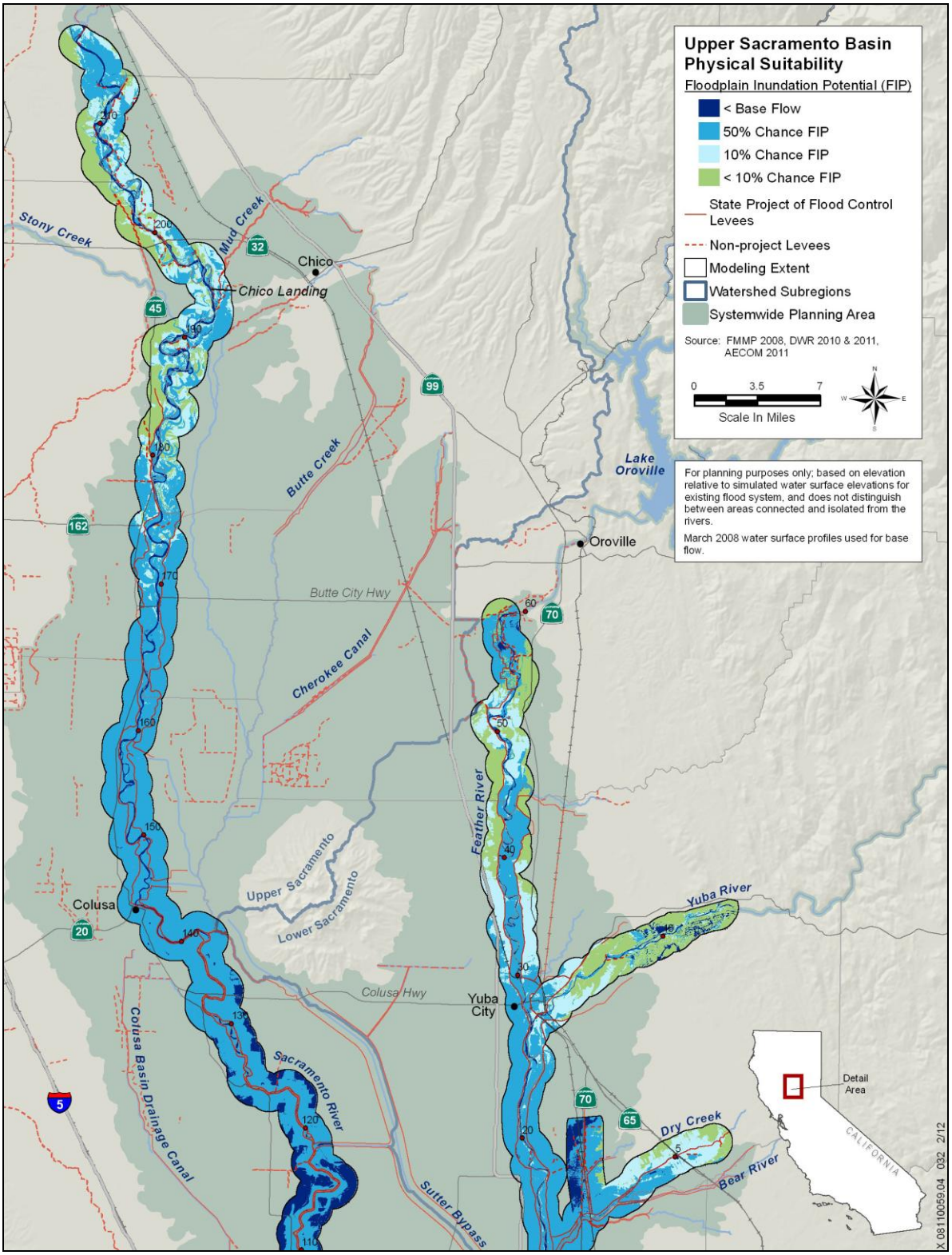

Figure 3-2. Floodplain Inundation Potential of Major River Corridors in the Upper Sacramento Basin

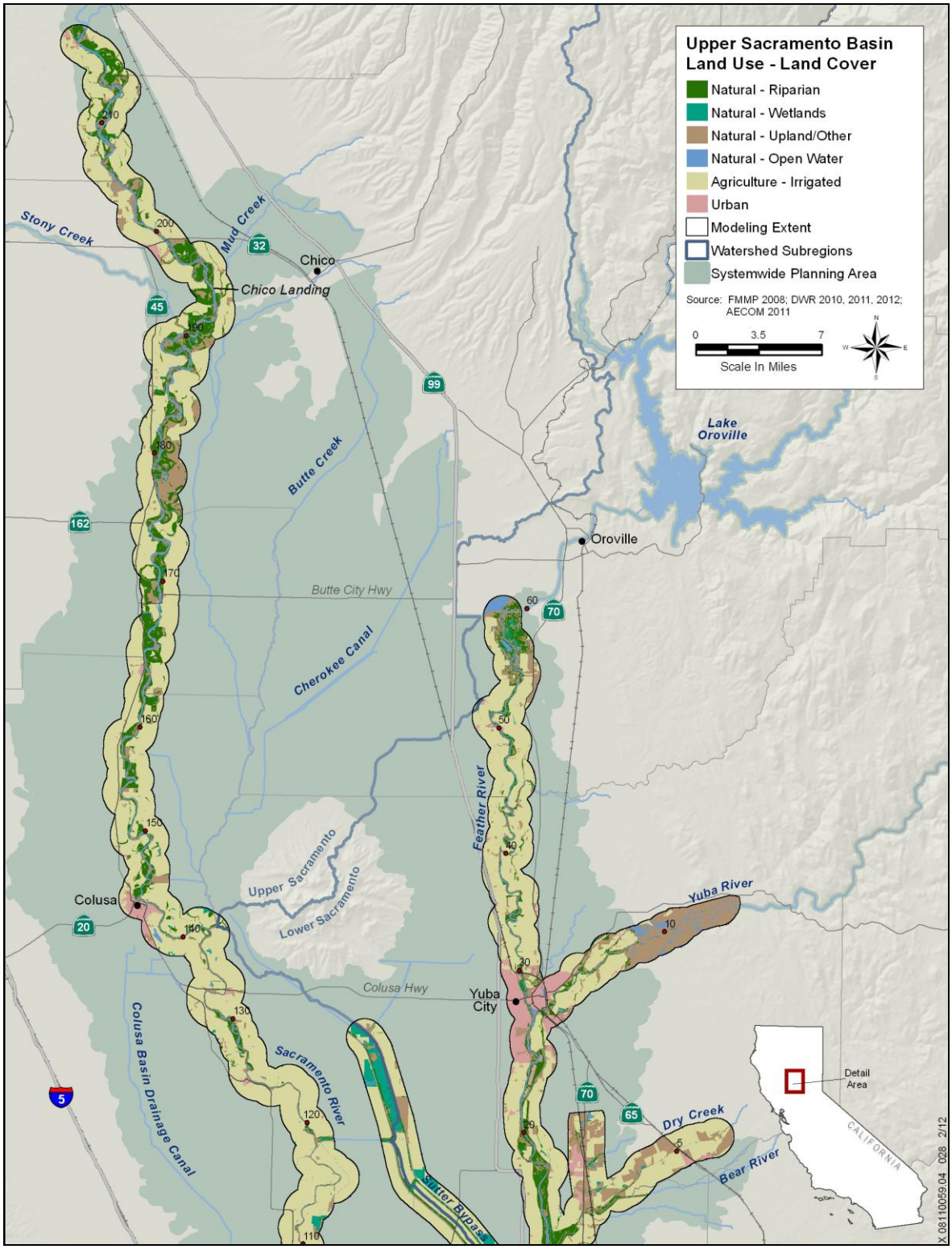

Figure 3-3. Land Use/Land Cover of River Corridors in the Upper Sacramento Basin

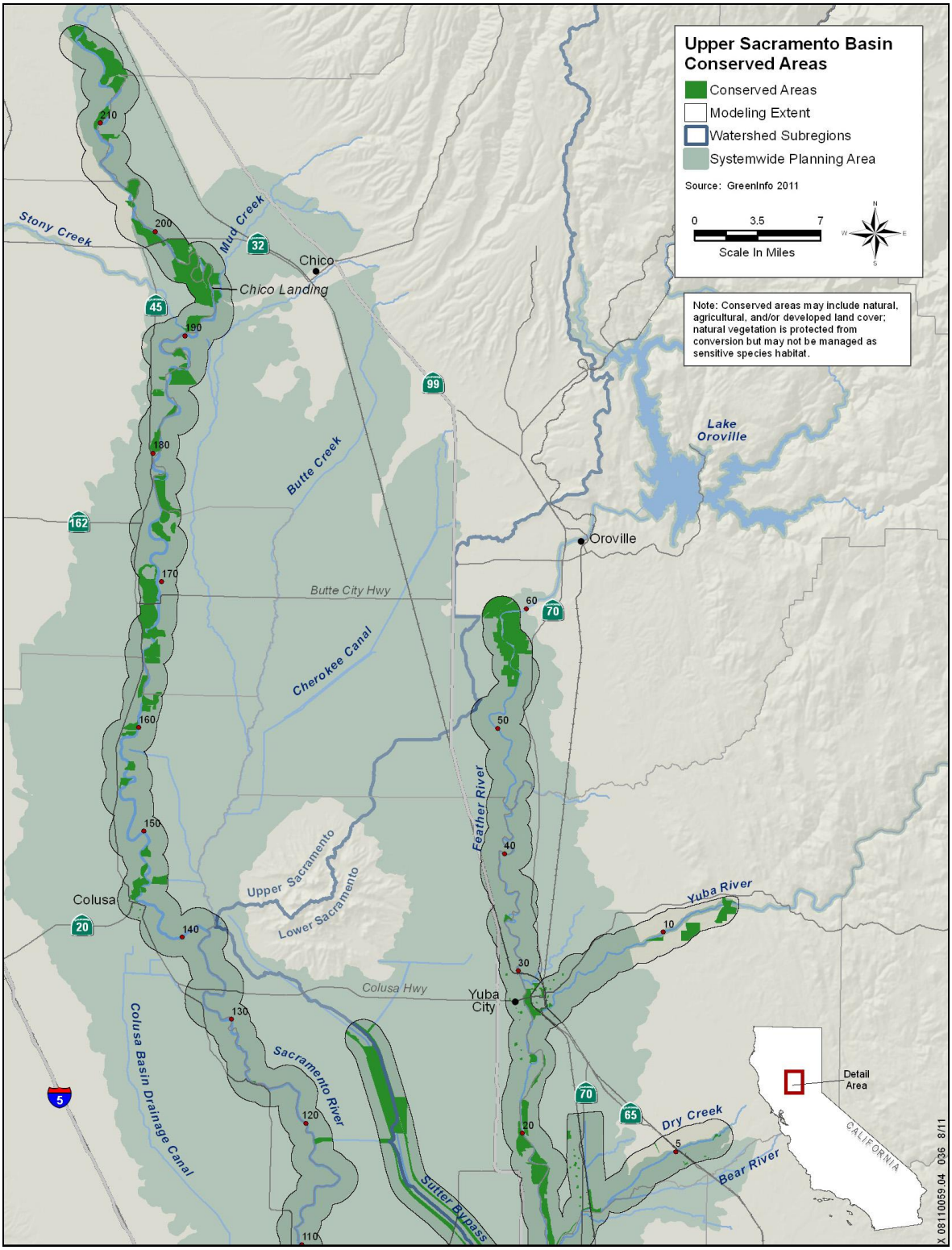

Figure 3-4. Conserved Areas of River Corridors in the Upper Sacramento Basin

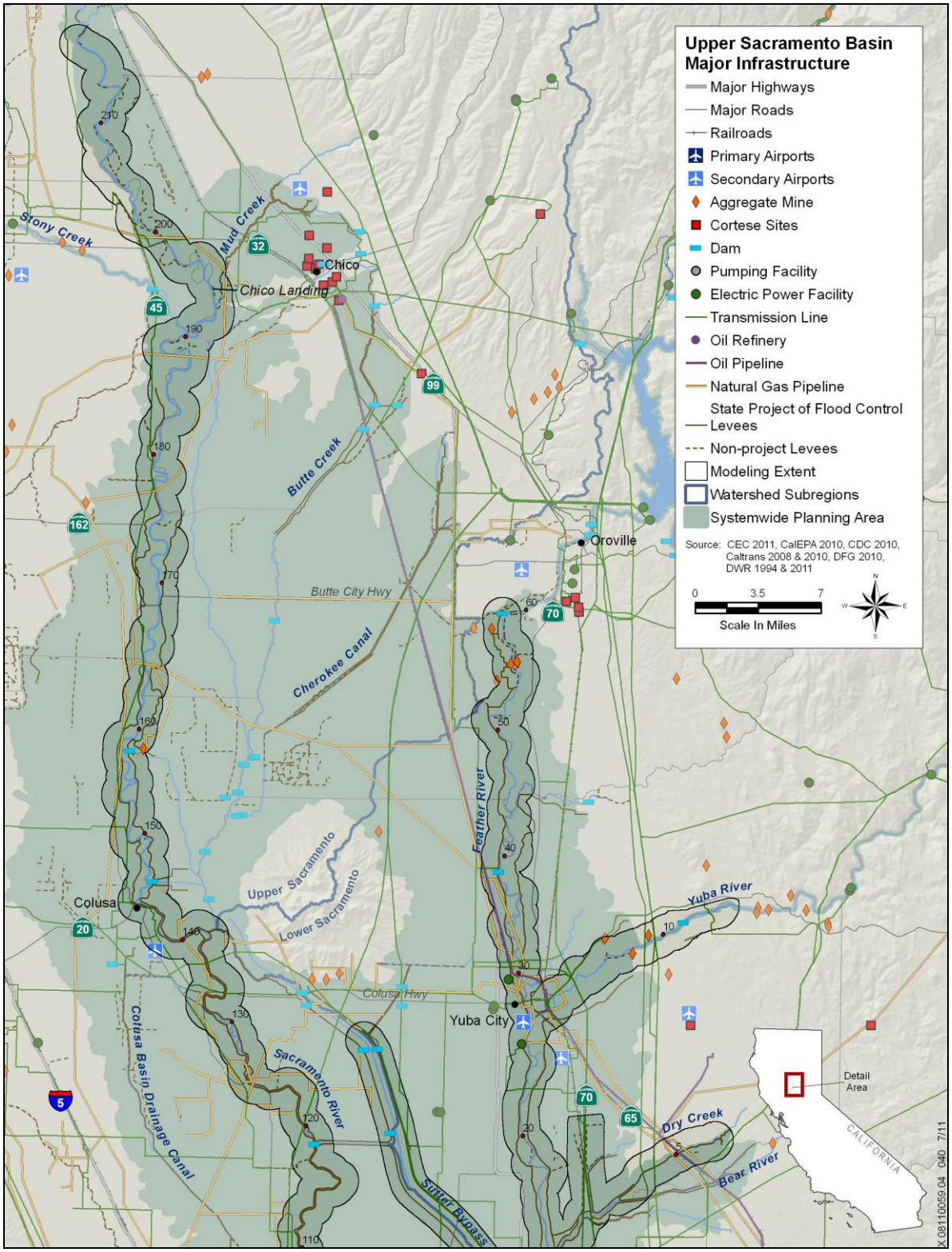

Figure 3-5. Major Infrastructure in River Corridors in the Upper Sacramento Basin

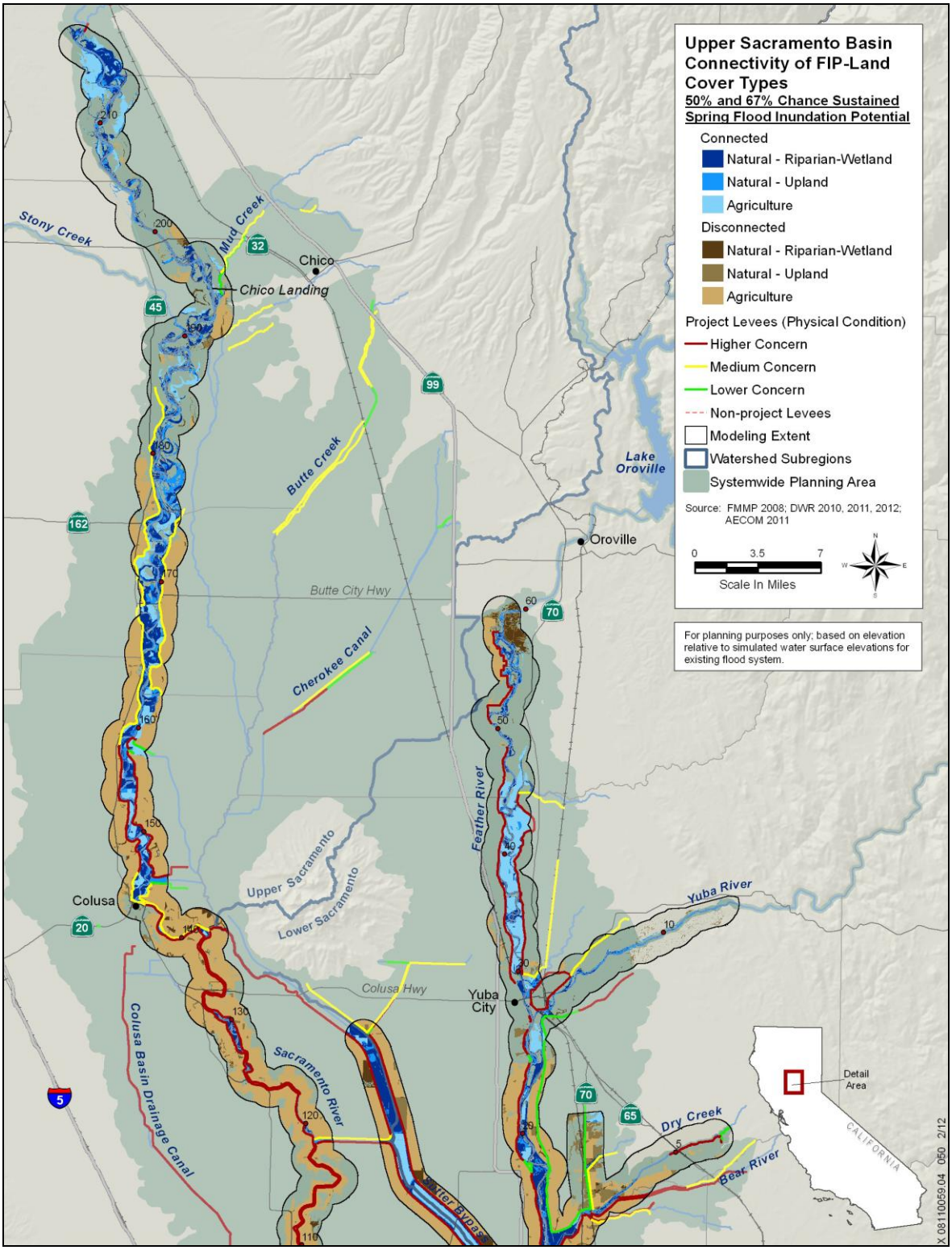

Figure 3-6. Connectivity of FIP-Land Cover Types in the Upper Sacramento Basin

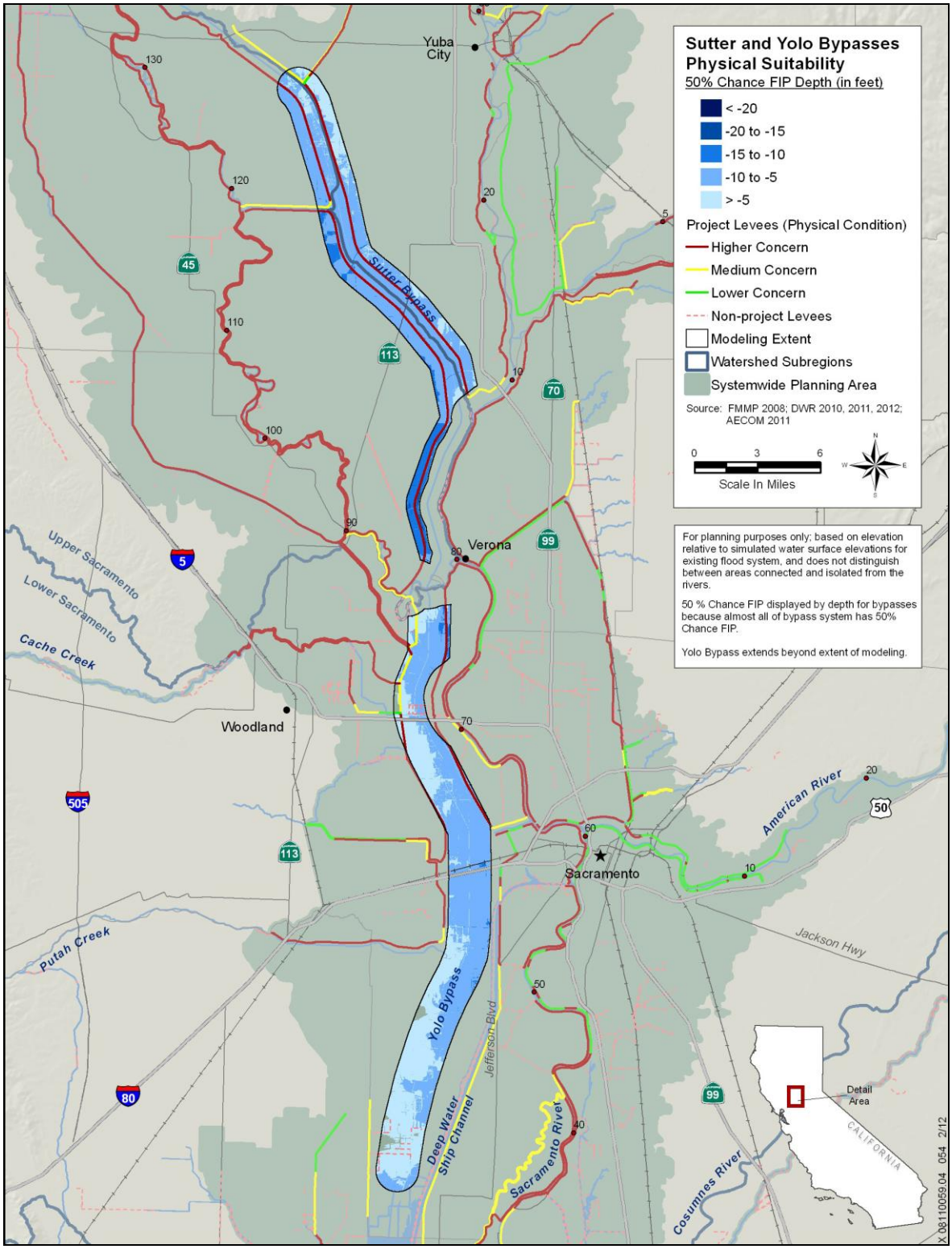

Figure 3-7. Depth of 50 Percent Chance Floodplain Inundation Potential in the Sutter and Yolo Bypasses

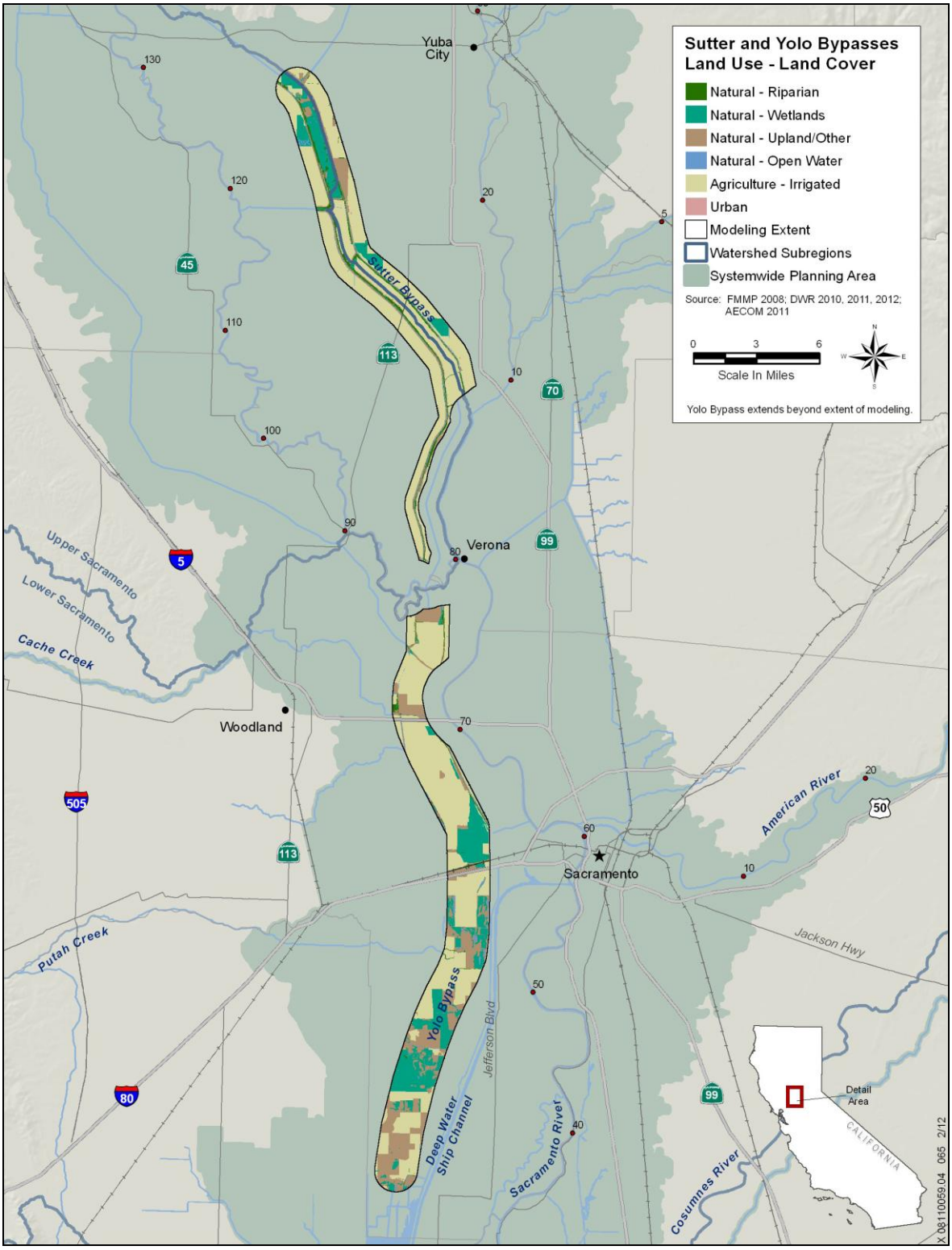

Figure 3-8. Land Use/Land Cover of River Corridors in the Sutter and Yolo Bypasses

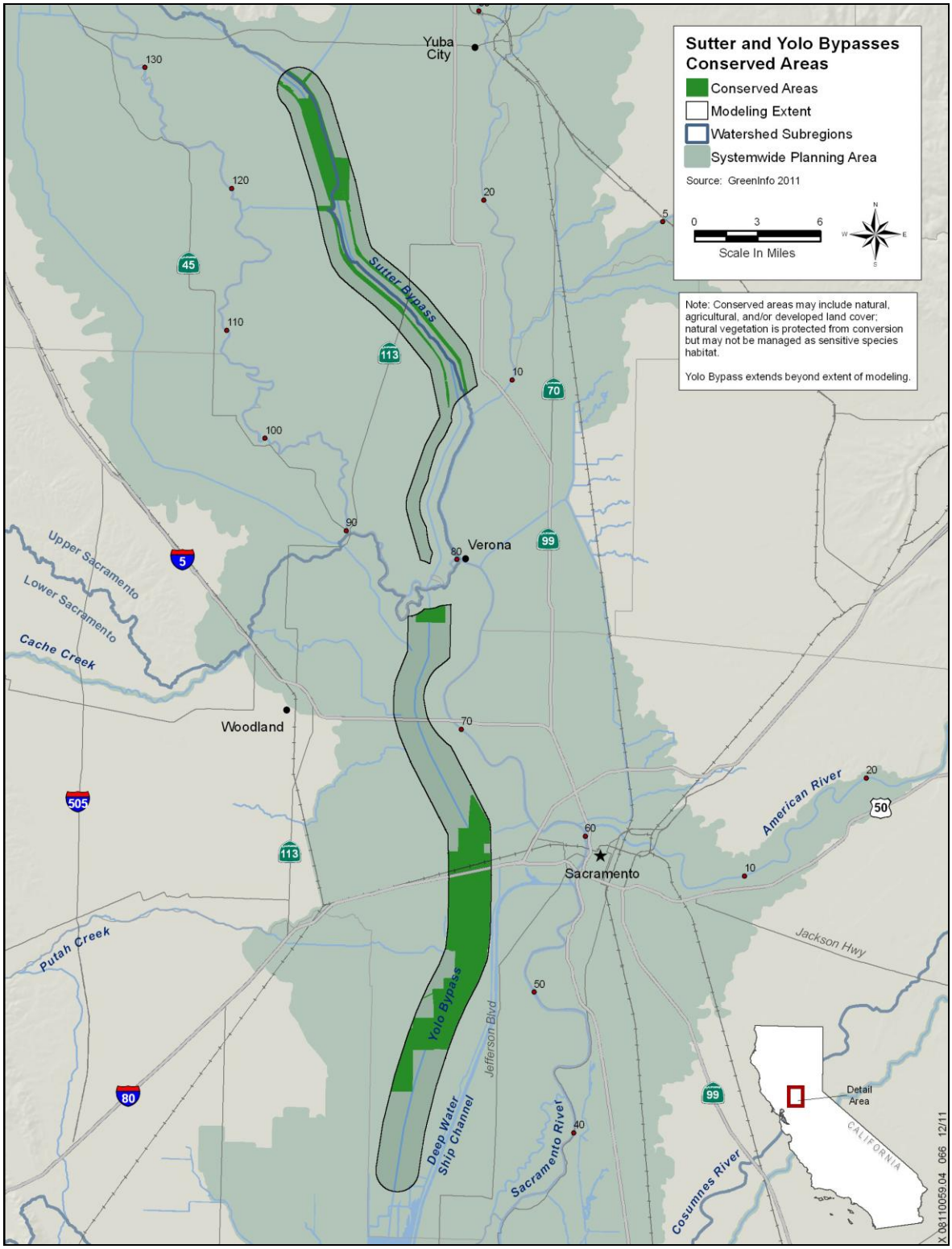

Figure 3-9. Conserved Areas of River Corridors in the Sutter and Yolo Bypasses

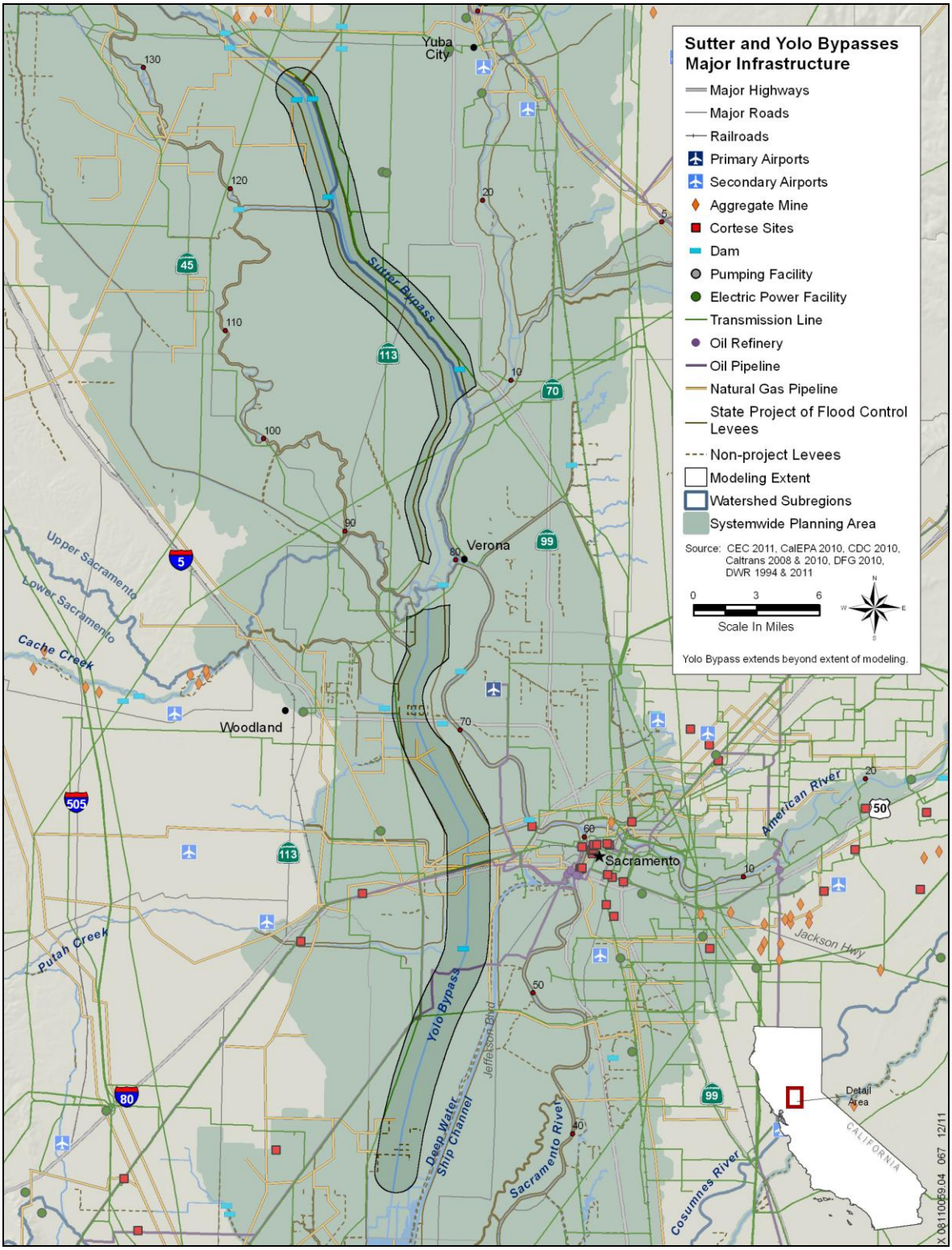

Figure 3-10. Major Infrastructure in River Corridors in the Sutter and Yolo Bypasses

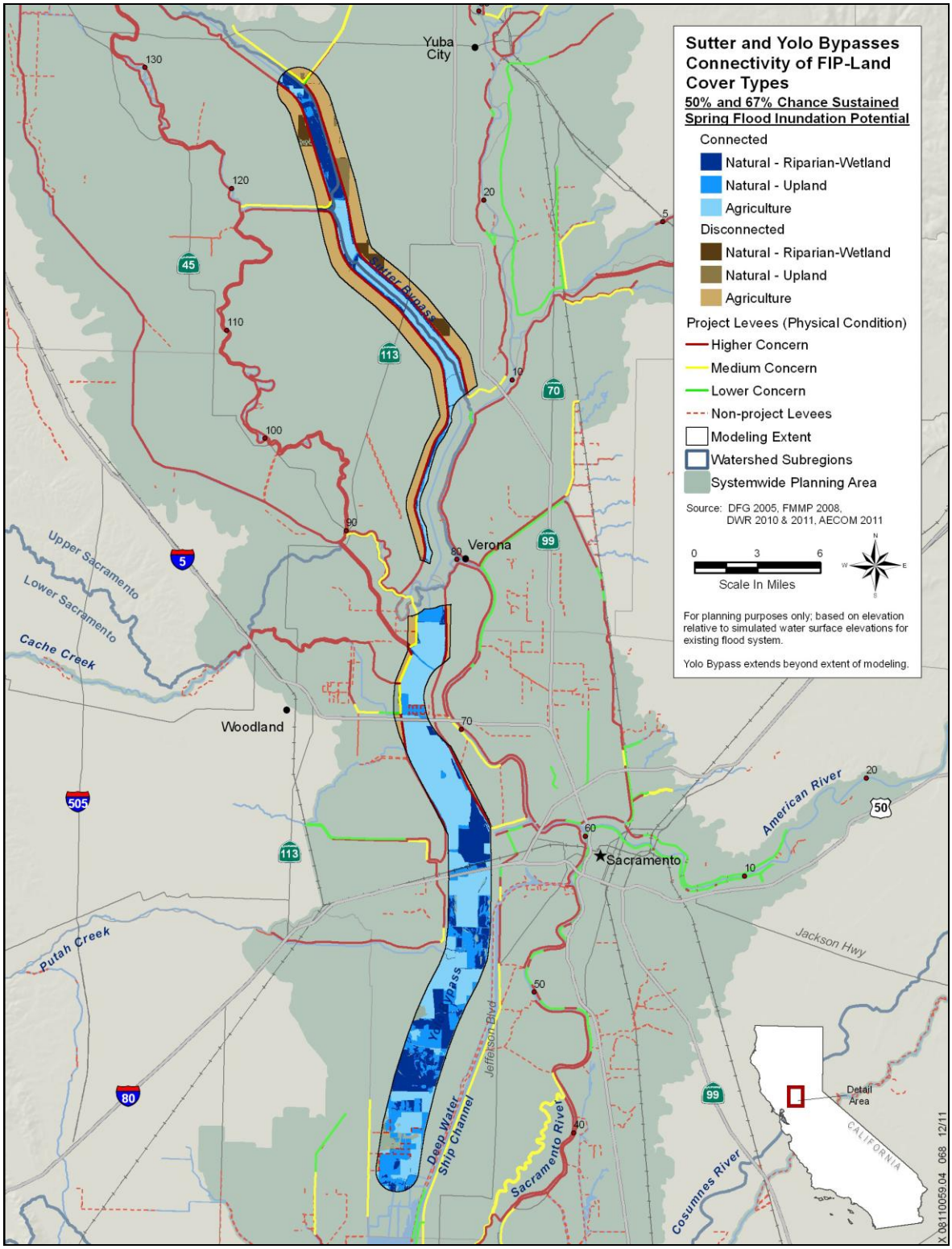

Figure 3-11. Connectivity of FIP-Land Cover Types in the Sutter and Yolo Bypasses

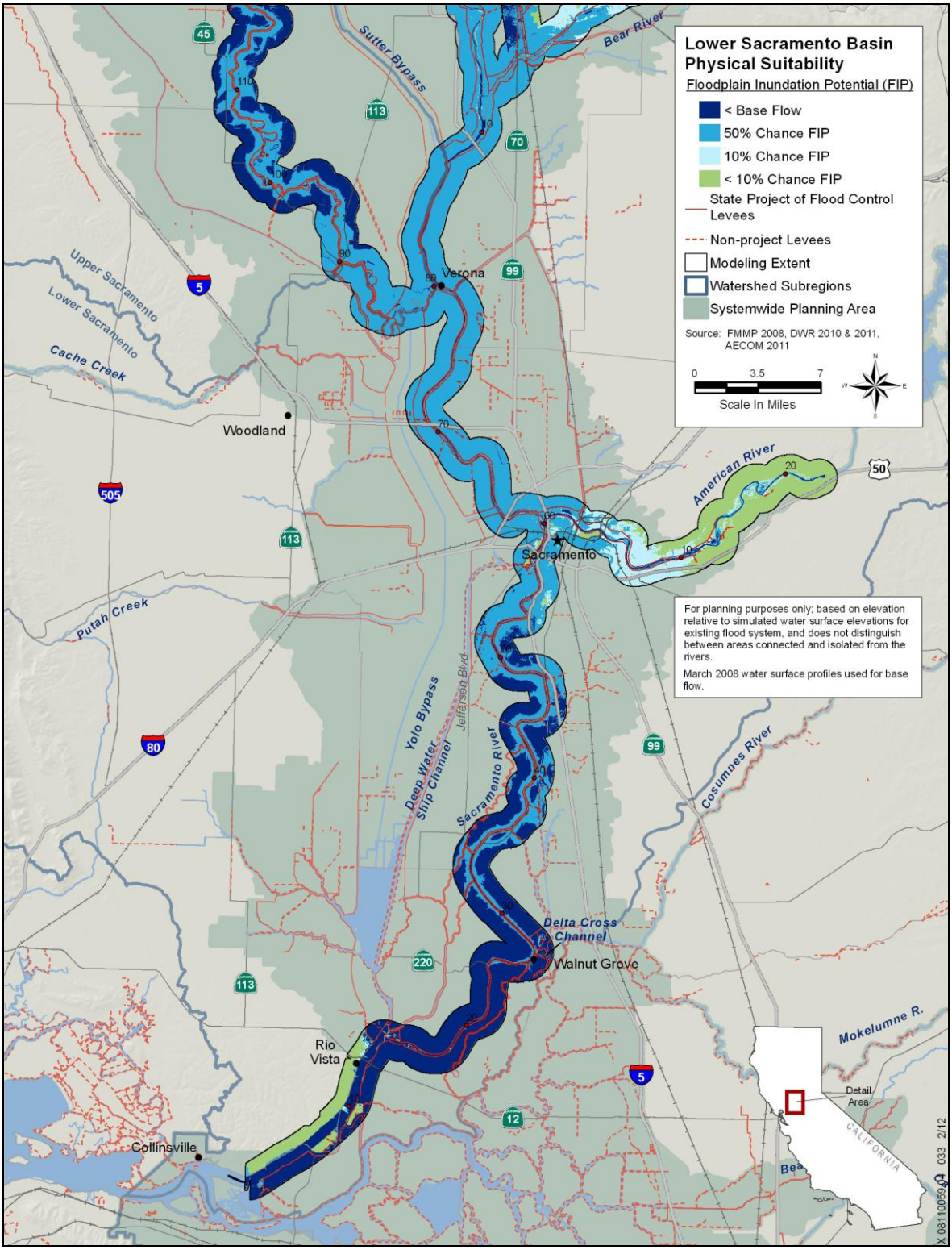

Figure 3-12. Floodplain Inundation Potential of Major River Corridors in the Lower Sacramento Basin

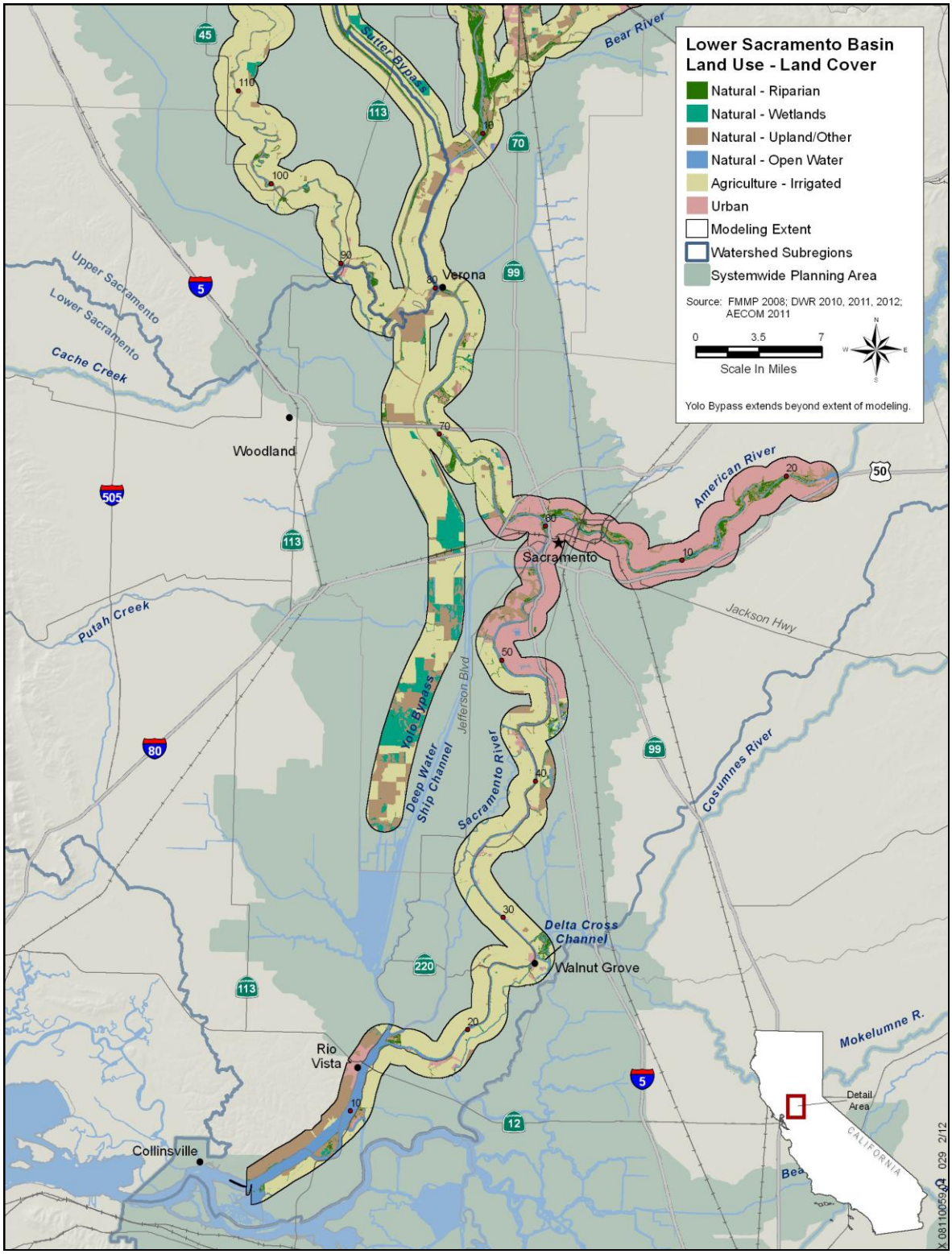

Figure 3-13. Land Use/Land Cover of River Corridors in the Lower Sacramento Basin

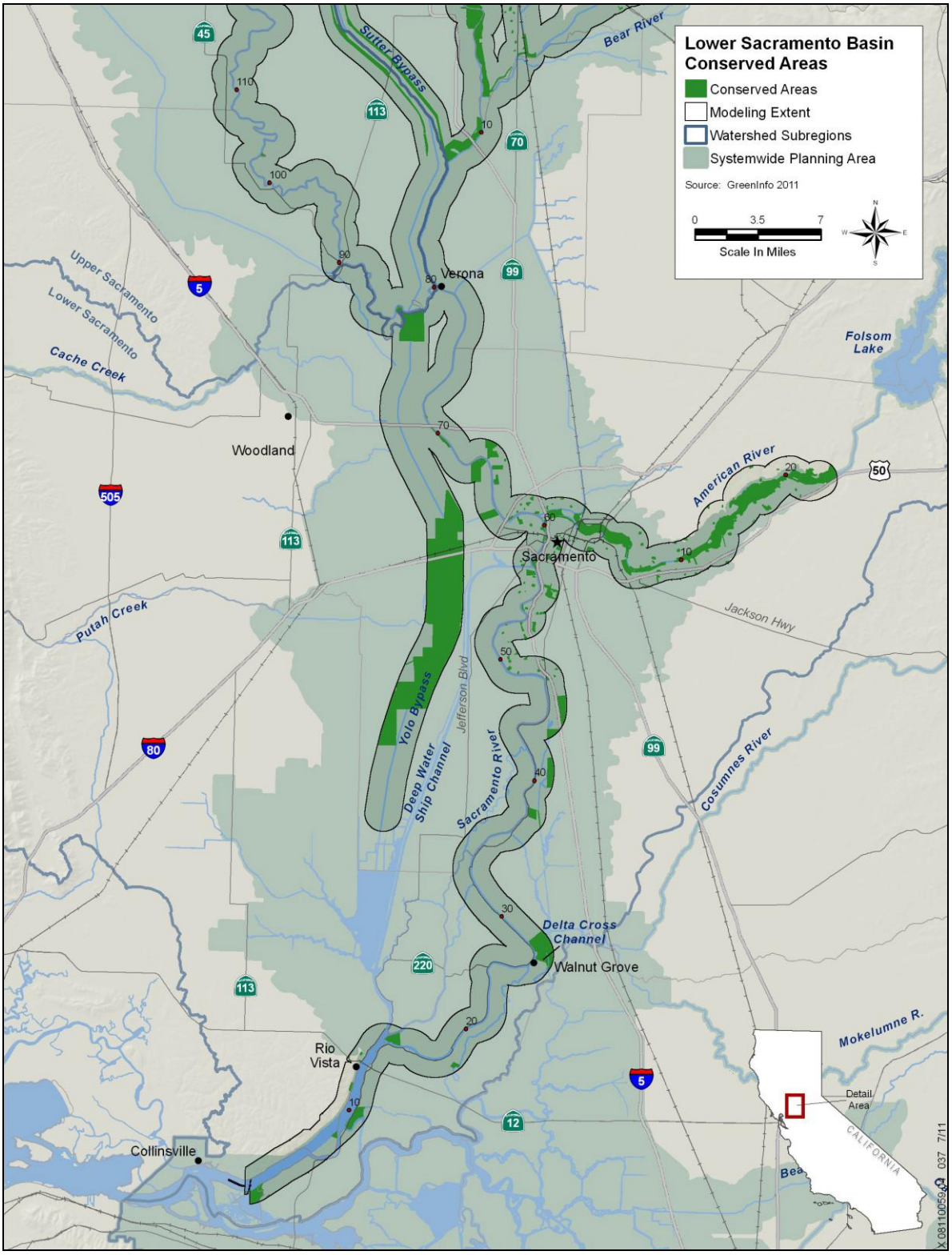

Figure 3-14. Conserved Areas of River Corridors in the Lower Sacramento Basin

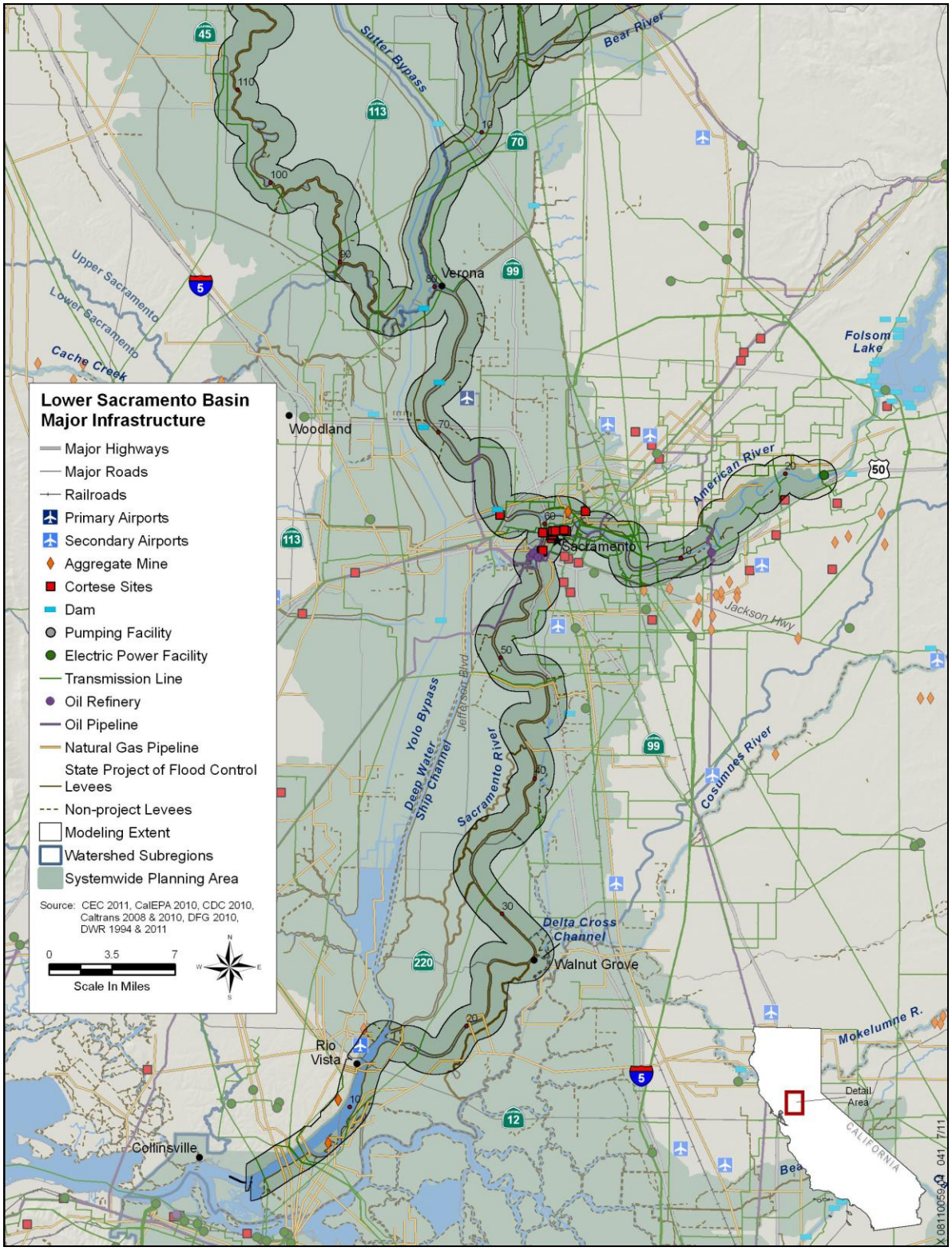

Figure 3-15. Major Infrastructure in River Corridors in the Lower Sacramento Basin

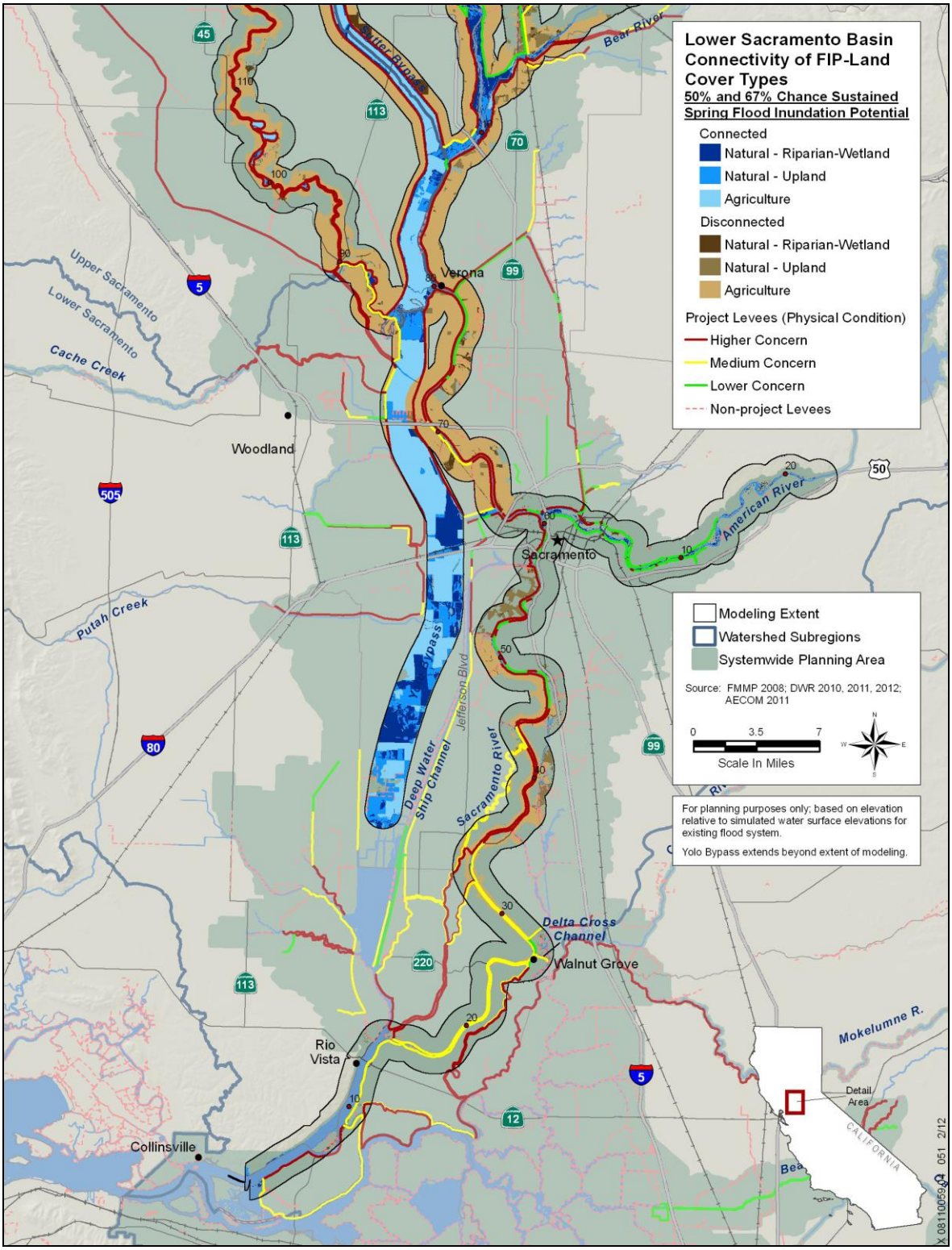

Figure 3-16. Connectivity of FIP-Land Cover Types in Lower Sacramento Basin

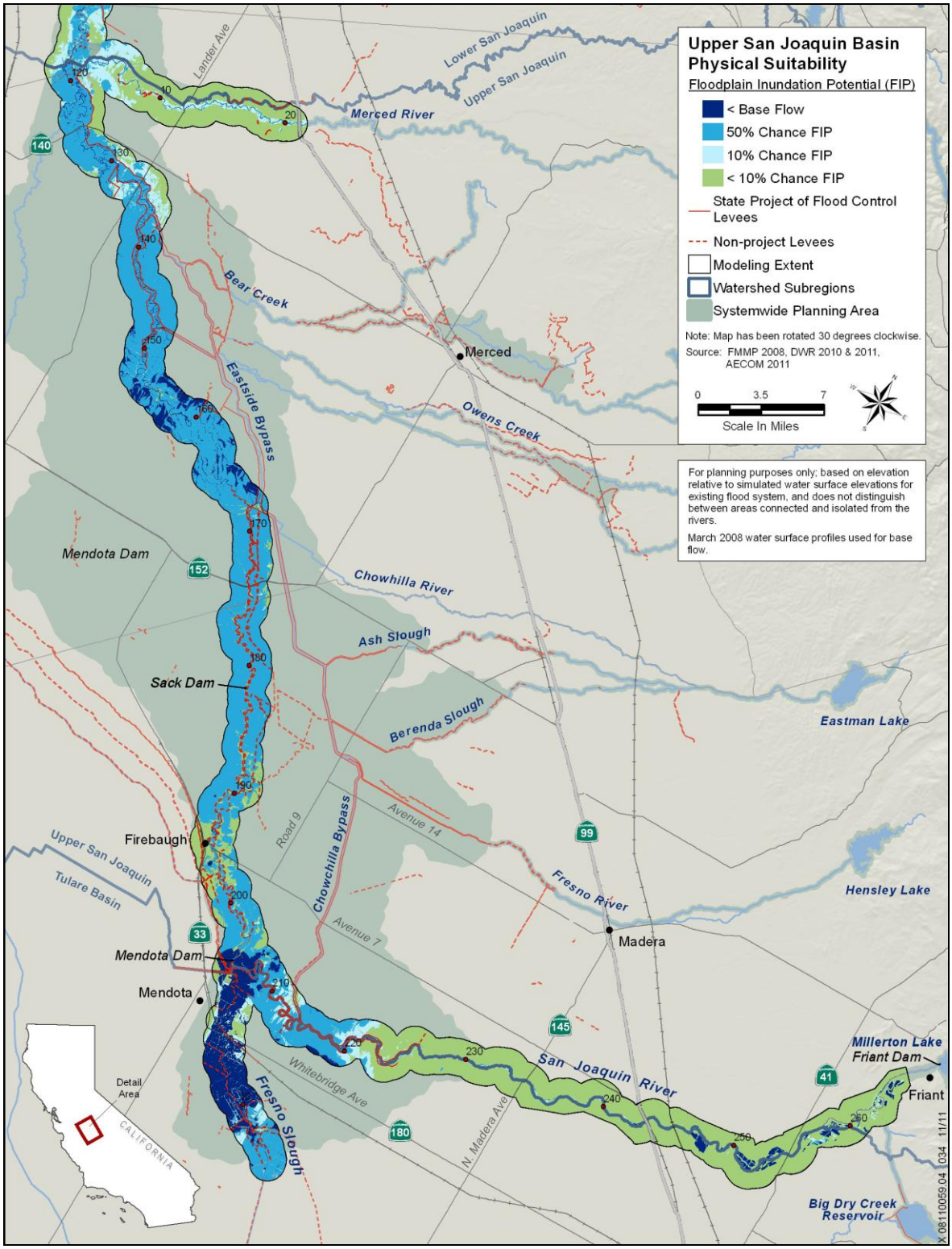

Figure 3-17. Floodplain Inundation Potential of River Corridors in the Upper San Joaquin Basin

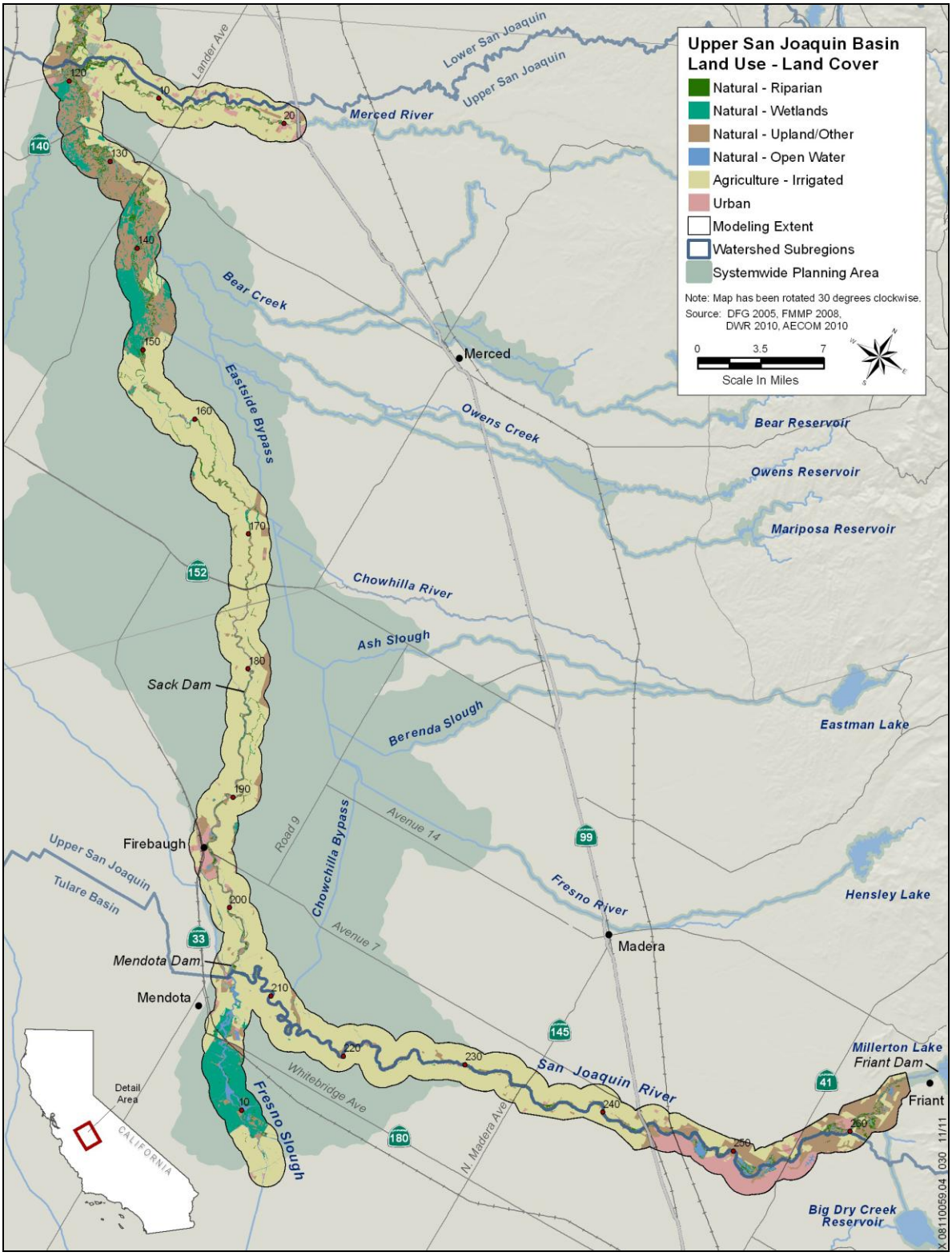

Figure 3-18. Land Use/Land Cover of River Corridors in the Upper San Joaquin Basin

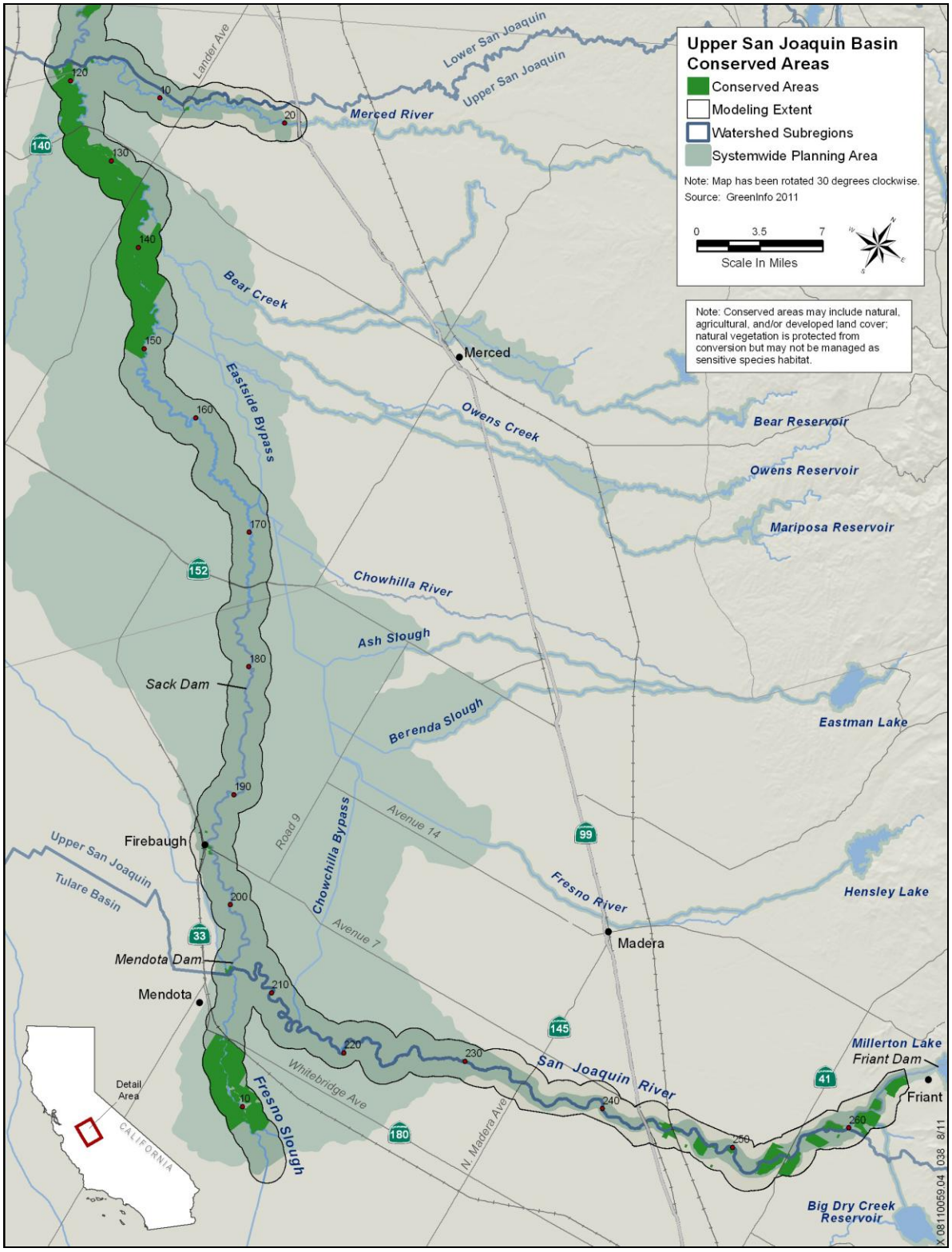

Figure 3-19. Conserved Areas of River Corridors in the Upper San Joaquin River Basin

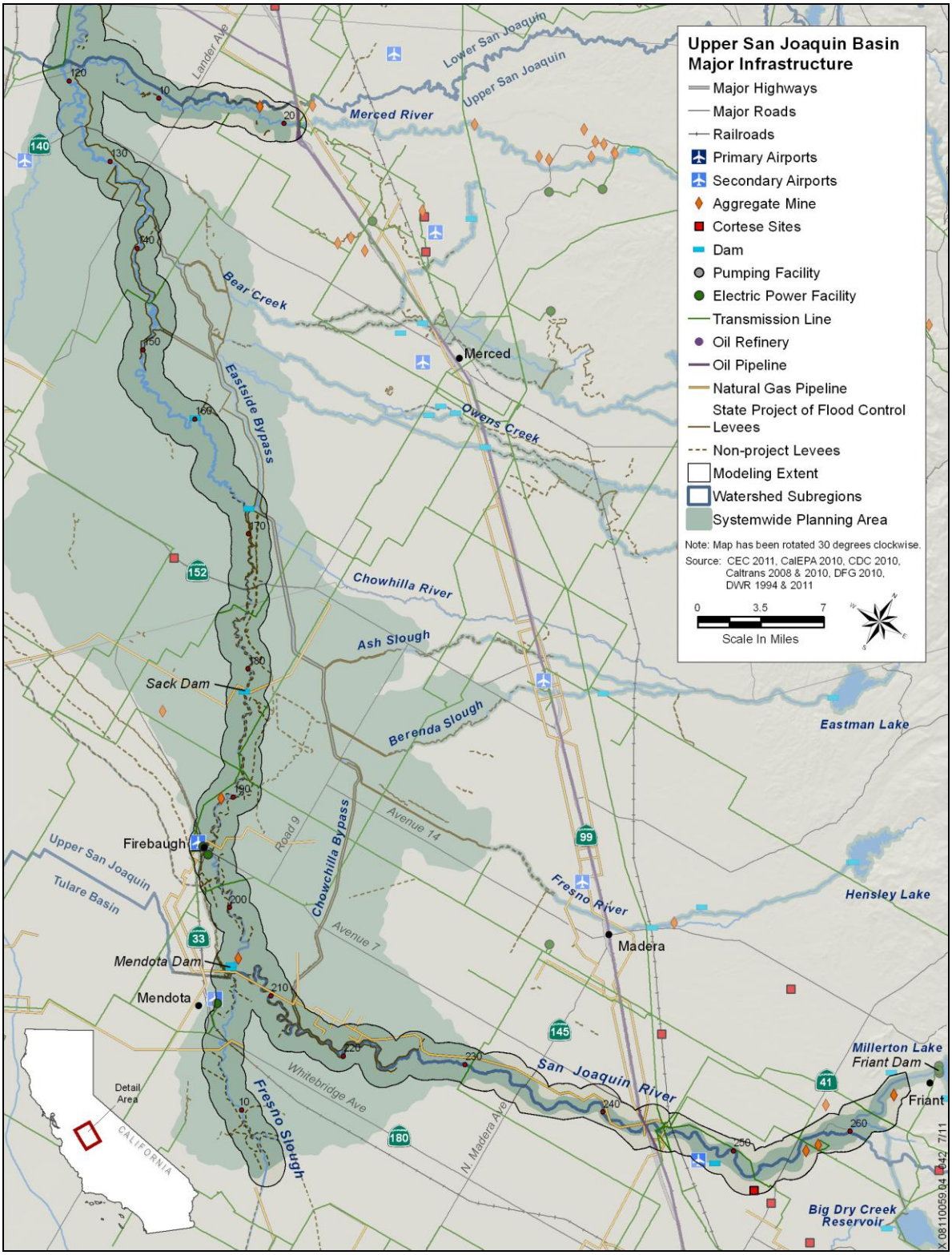

Figure 3-20. Major Infrastructure in River Corridors in the Upper San Joaquin Basin

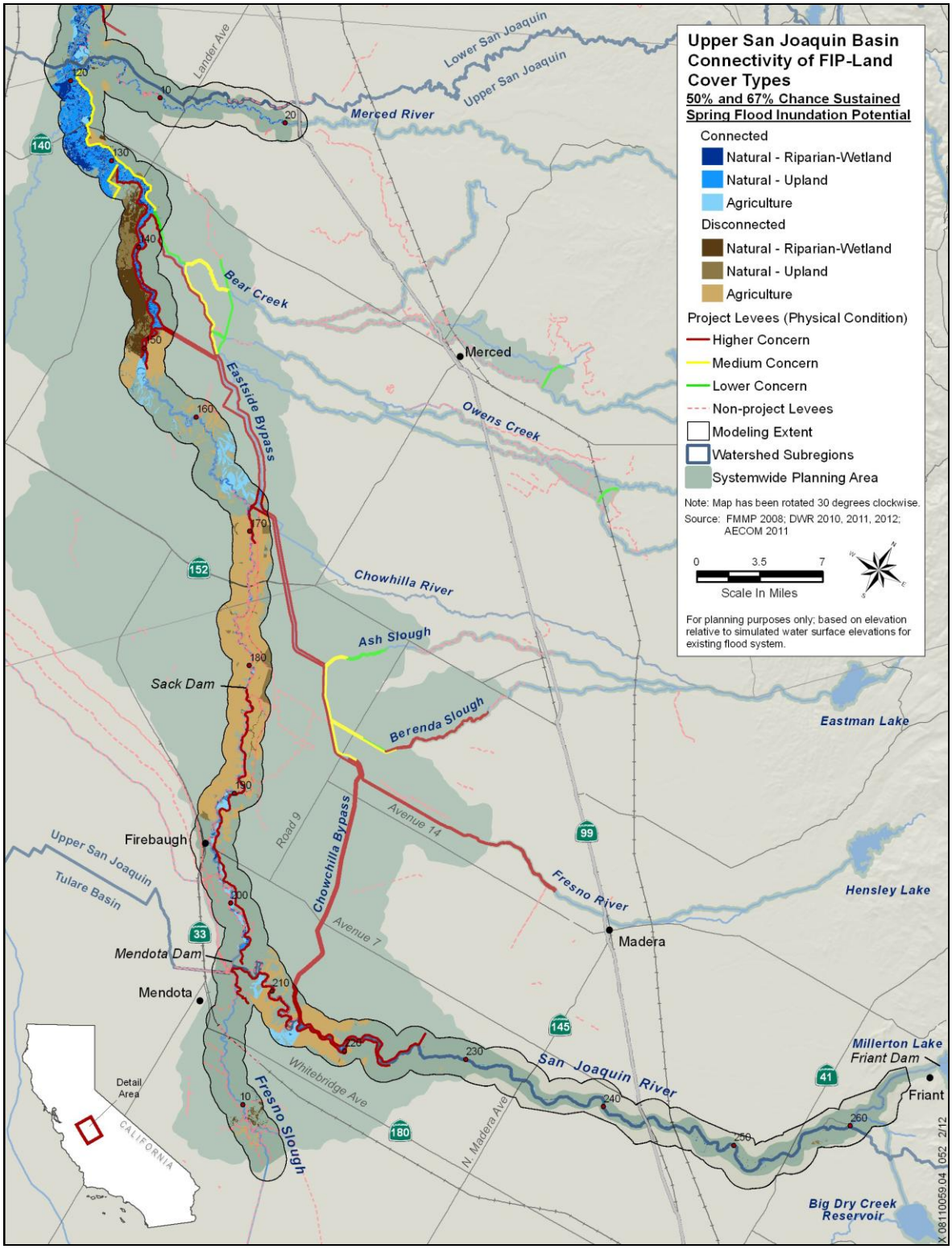

Figure 3-21. Connectivity of FIP-Land Cover Types in the Upper San Joaquin Basin

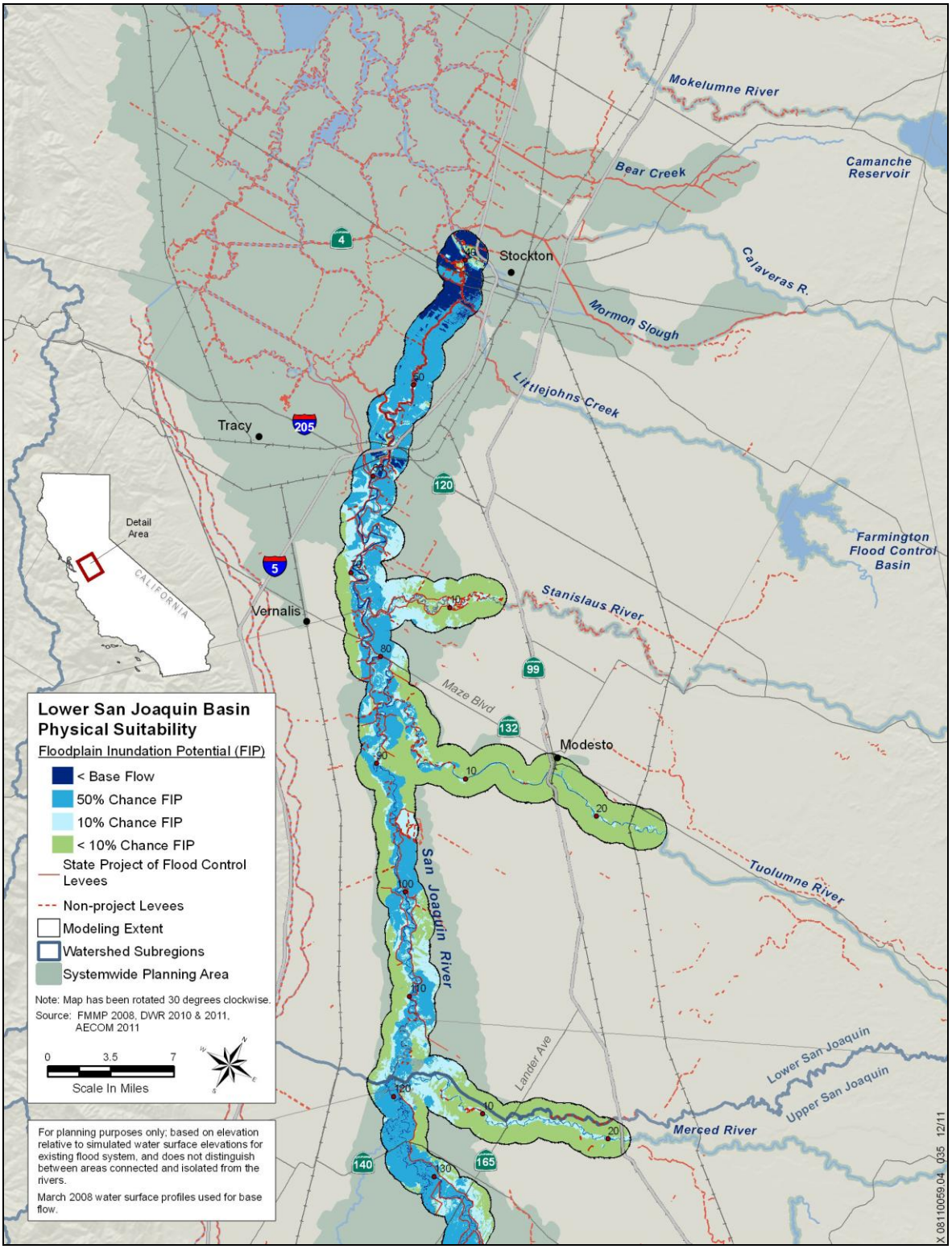

Figure 3-22. Floodplain Inundation Potential of River Corridors in the Lower San Joaquin Basin

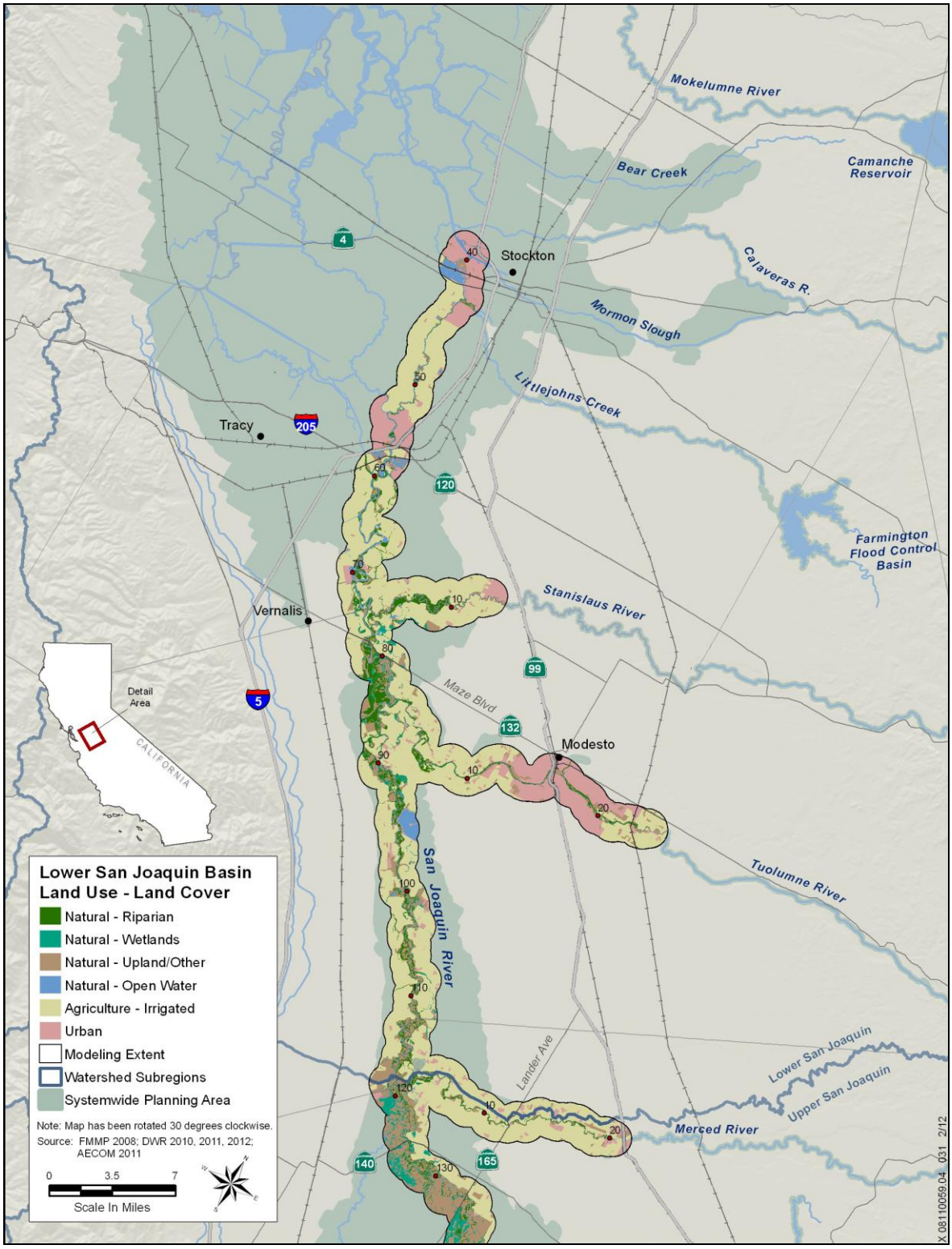

Figure 3-23. Land Use/Land Cover of River Corridors in the Lower San Joaquin Basin

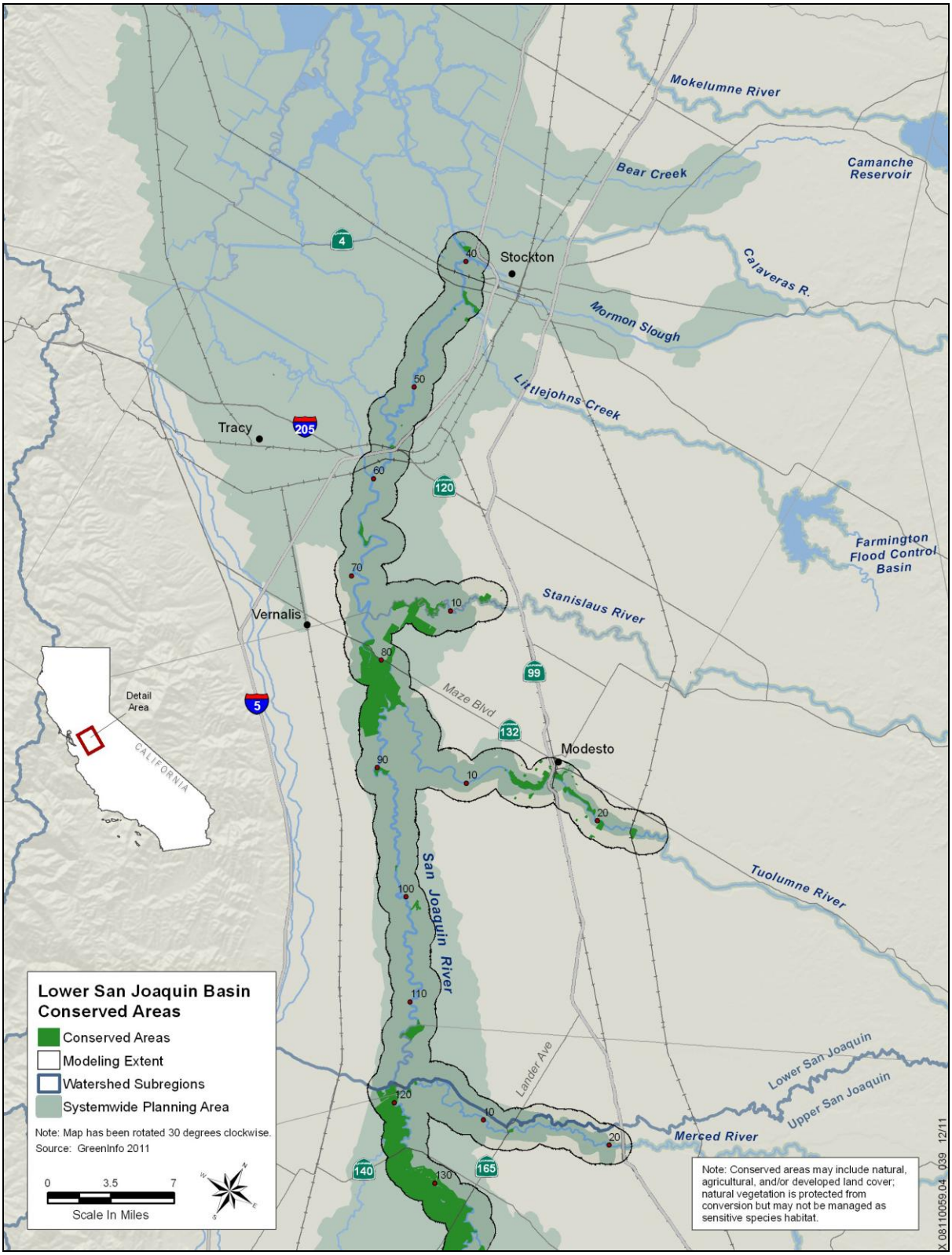

Figure 3-24. Conserved Areas of River Corridors in the Lower San Joaquin Basin

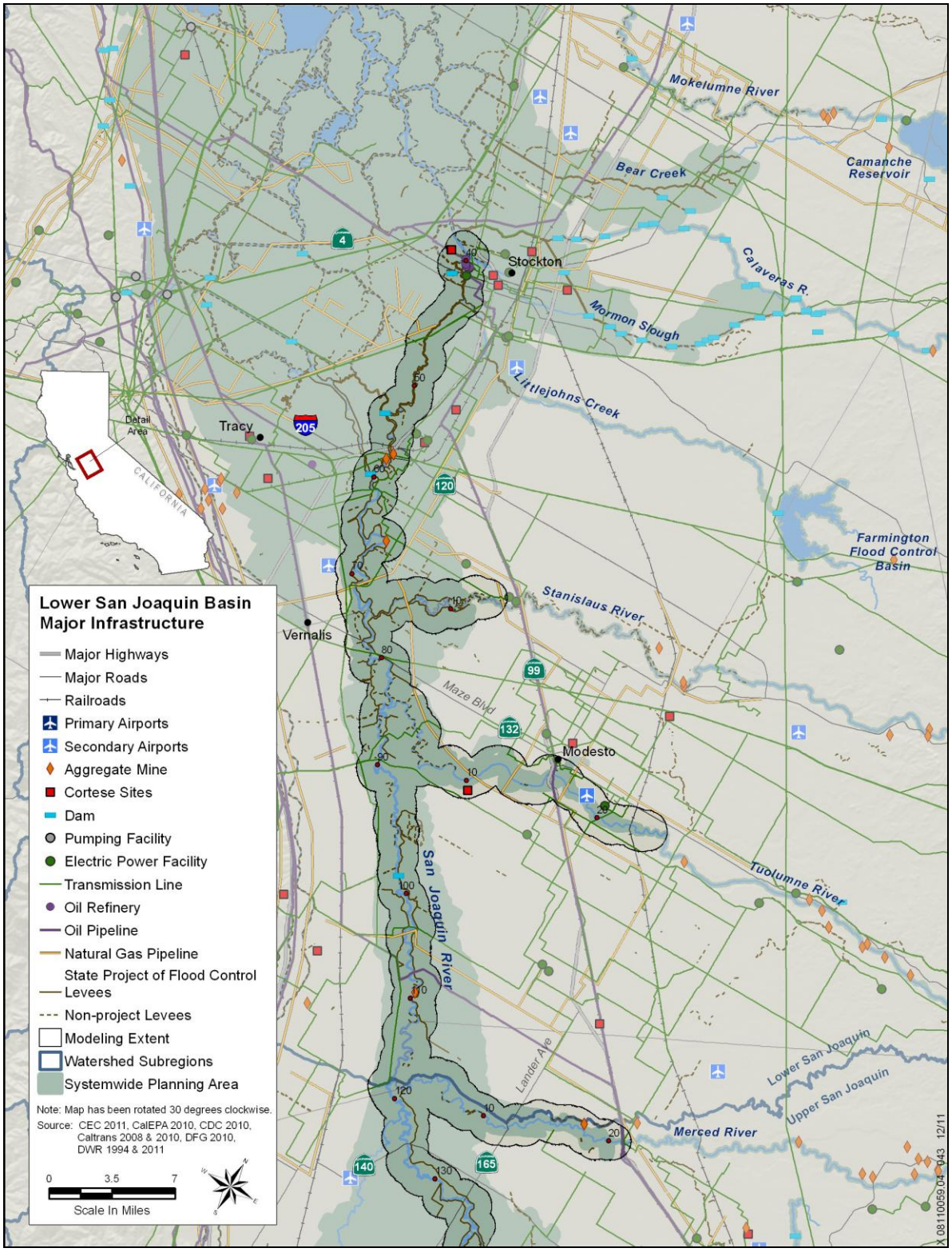

Figure 3-25. Major Infrastructure in River Corridors in the Lower San Joaquin Basin

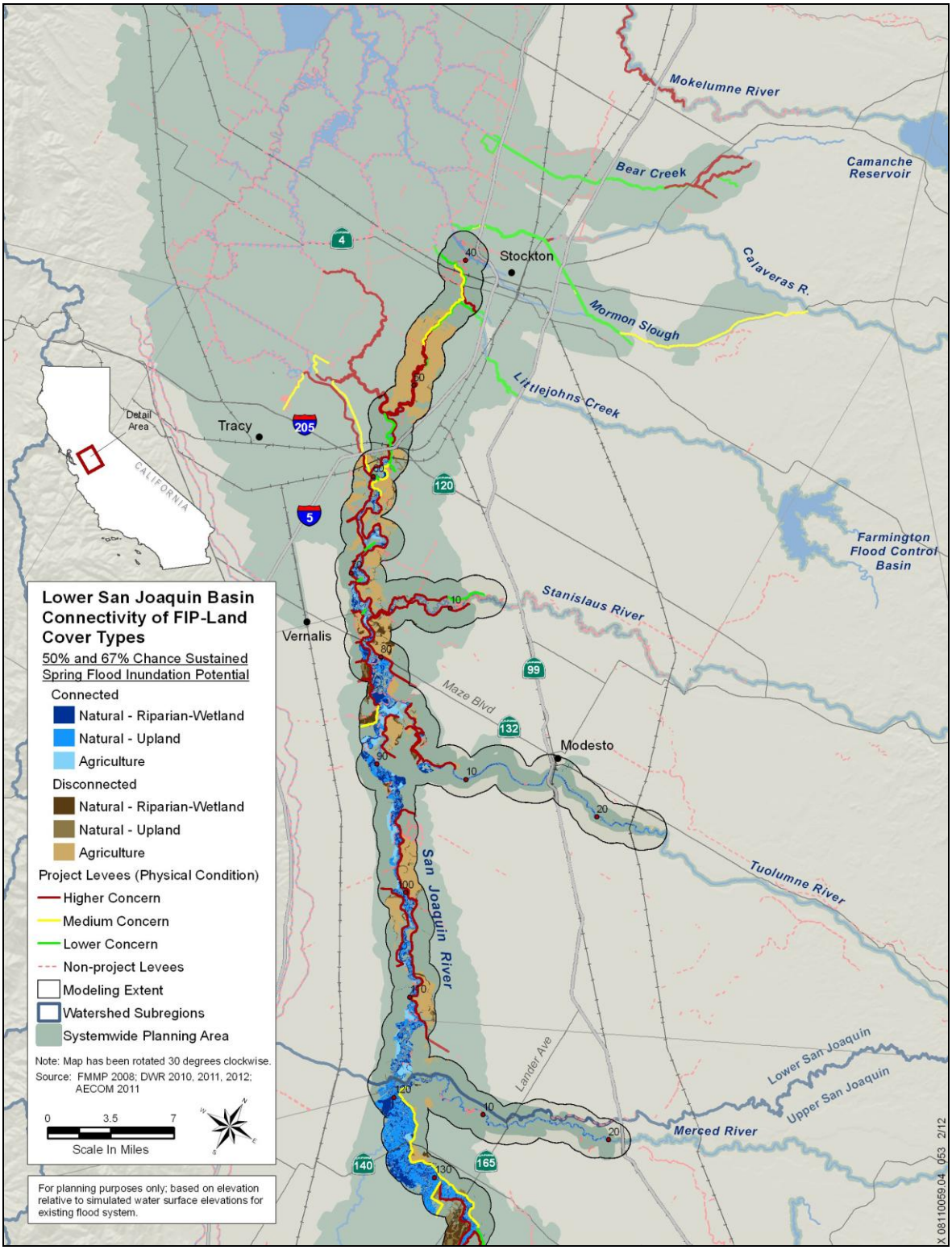

Figure 3-26. Connectivity of FIP-Land Cover Types in Lower San Joaquin Basin

Table 3-1. Floodplain Inundation Potential of Sacramento River

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance Spring[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
Upper Sacramento Valley							
Woodson Bridge State Recreation Area–Chico Landing	26,800	7	<1	32	32	28	100
Chico Landing–Colusa	56,400	6	<1	71	12	11	100
Lower Sacramento Valley							
Colusa–Verona	71,400	27	10	61	0	2	100
Verona–American River	24,700	5	25	66	1	2	100
American River–Freeport	17,000	20	28	43	4	4	100
Freeport–Delta Cross Channel	24,800	61	31	5	1	2	100
Delta Cross Channel–Deep Water Ship Channel	16,200	93	3	2	1	2	100
Deep Water Ship Channel–Collinsville	14,600	60	0	3	1	35	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

[6] Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[7] Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-2. Nonurban Floodplain Connectivity Percentages for the Sacramento River

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
Upper Sacramento Valley						
Woodson Bridge State Recreation Area–Chico Landing	<100	100	0	7,600	86	14
Chico Landing–Colusa	200	98	2	37,900	41	59
Lower Sacramento Valley						
Colusa–Verona	6,800	6	94	42,400	12	88
Verona–American River	5,600	4	96	13,400	5	95
American River–Freeport	2,200	5	95	1,600	10	90
Freeport–Delta Cross Channel	7,100	3	97	1,000	7	93
Delta Cross Channel–Deep Water Ship Channel	400	22	78	200	56	44
Deep Water Ship Channel–Collinsville	<100	75	25	400	71	29

Source: Data generated for this analysis by AECOM, 2011

Notes:

1 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

2 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

3 Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

4 Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

5 Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

6 Connected to or disconnected ("Discon.") from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under existing conditions).

Table 3-3. Sacramento River Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]							
	W. Bridge SRA–Chico Landing	Chico Landing–Colusa	Colusa–Verona	Verona–American River	American River–Freeport	Freeport–Delta Cross Channel	Delta Cross Channel–Deep Water Ship Channel	Deep Water Ship Channel–Collinsville
Connected[3]								
Conserved-Riparian/Wetland	7	5	<1	1	<1	<1	<1	<1
Conserved-Natural Upland	1	2	1	1	<1	<1	0	<1
Conserved-Agricultural	1	2	<1	<1	0	<1	<1	<1
Not Conserved-Riparian/Wetland	4	8	2	2	1	<1	<1	<1
Not Conserved-Natural Upland	2	4	1	<1	<1	<1	<1	1
Not Conserved-Agricultural	9	6	3	<1	<1	<1	<1	<1
Connected Subtotal	*24*	*28*	*8*	*4*	*2*	*1*	*1*	*2*
Disconnected[3]								
Conserved-Riparian/Wetland	<1	<1	<1	<1	<1	<1	<1	0
Conserved-Natural Upland	<1	<1	<1	<1	<1	1	<1	<1
Conserved-Agricultural	1	<1	<1	4	0	1	<1	<1
Not Conserved-Riparian/Wetland	<1	1	1	3	<1	<1	<1	<1
Not Conserved-Natural Upland	<1	<1	2	4	8	3	<1	<1
Not Conserved-Agricultural	2	37	57	61	11	26	2	<1
Disconnected Subtotal	*4*	*39*	*61*	*73*	*20*	*32*	*2*	*1*
Total	**28**	**68**	**69**	**77**	**22**	**33**	**3**	**3**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

[1] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot. and 67 percent chance Sustained Spring FIP ≤1 foot.). 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot, and 10 percent chance FIP ≤1 foot.).

[2] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

[3] Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

Table 3-4. Floodplain Inundation Potential of Sacramento River Tributaries

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance Spring[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
Feather River							
Thermalito Afterbay–Yuba River	35,800	4	0	41	28	27	100
Yuba River–Bear River	18,600	5	1	86	6	2	100
Bear River–Sutter Bypass	5,800	6	1	89	1	2	100
Sutter Bypass–Sacramento River	8,600	4	12	83	1	1	100
Other Tributaries							
Yuba River	15,400	8	1	11	26	54	100
Bear River	14,600	3	12	37	35	14	100
American River	26,500	4	1	14	28	53	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

[6] Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[7] Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-5. Nonurban Floodplain Connectivity Percentages for Sacramento River Tributaries

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
Feather River						
Thermalito Afterbay–Yuba River	100	100	<1	11,900	69	31
Yuba River–Bear River	200	70	30	14,200	31	69
Bear River–Sutter Bypass	100	87	13	5,100	35	65
Sutter Bypass–Sacramento River	1,000	57	43	7,000	57	43
Other Tributaries						
Yuba River	100	38	62	1,200	47	53
Bear River	1,200	14	86	5,200	15	85
American River	200	98	2	1,100	84	16

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

[6] Connected to or disconnected ("Discon.") from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under existing conditions).

Table 3-6. Sacramento River Tributaries Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]						
	Feather River				Other Tributaries		
	Thermalito Afterbay to Yuba River	Yuba River to Bear River	Bear River to Sutter Bypass	Sutter Bypass to Sacramento River	Yuba River	Bear River	American River
Connected[3]							
Conserved-Riparian/Wetland	1	8	4	0	<1	<1	2
Conserved-Natural Upland	1	3	9	0	<1	<1	1
Conserved-Agricultural	<1	1	<1	0	<1	<1	0
Not Conserved-Riparian/Wetland	4	7	9	6	1	3	<1
Not Conserved-Natural Upland	2	2	8	9	2	2	<1
Not Conserved-Agricultural	14	4	2	37	<1	1	<1
Connected Subtotal	*23*	*25*	*32*	*53*	*4*	7	4
Disconnected[3]							
Conserved-Riparian/Wetland	3	0	0	0	<1	<1	<1
Conserved-Natural Upland	1	<1	<1	0	<1	<1	<1
Conserved-Agricultural	<1	<1	<1	0	0	0	0
Not Conserved-Riparian/Wetland	<1	1	<1	<1	<1	1	<1
Not Conserved-Natural Upland	1	3	7	1	2	7	<1
Not Conserved-Agricultural	5	49	49	38	1	30	<1
Disconnected Subtotal	*10*	*53*	*57*	*40*	*5*	*38*	*1*
Total	**33**	**78**	**89**	**93**	**9**	**44**	**5**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

1 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot). 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

2 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

3 Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

Table 3-7. Floodplain Inundation Potential of Upper San Joaquin River

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
Friant Dam–State Route 99	22,500	9	1	1	4	85	100
State Route 99–Gravelly Ford	19,400	2	1	2	2	92	100
Gravelly Ford–Chowchilla Bypass	10,500	6	13	29	18	34	100
Chowchilla Bypass–Mendota Dam	8,400	31	26	22	14	7	100
Mendota Dam–Sack Dam	23,800	4	3	66	1	27	100
Sack Dam–Sand Slough Control Structure	14,900	2	10	83	1	5	100
Sand Slough Control Structure–Mariposa Bypass	19,200	20	69	9	0	1	100
Mariposa Bypass–Bear Creek	9,700	2	6	90	1	1	100
Bear Creek–Merced River	16,00	4	4	52	19	20	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

[5] Elevation above water surface of 67 percent chance Sustained Spring FIP but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

[6] Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[7] Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-8. Nonurban Floodplain Connectivity Percentages for Upper San Joaquin River

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
Friant Dam–State Route 99	200	69	31	200	88	12
State Route 99–Gravelly Ford	300	100	0	300	96	4
Gravelly Ford–Chowchilla Bypass	1,400	19	81	2,800	11	89
Chowchilla Bypass–Mendota Dam	2,100	35	65	900	23	77
Mendota Dam–Sack Dam	600	68	32	9,300	13	87
Sack Dam–Sand Slough Control Structure	1,100	17	83	11,700	1	99
Sand Slough Control Structure–Mariposa Bypass	5,800	39	61	1,700	10	90
Mariposa Bypass–Bear Creek	500	57	43	4,800	21	79
Bear Creek–Merced River	700	99	1	7,800	84	16

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

[6] Connected to or disconnected ("Discon.") from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under existing conditions).

Table 3-9. Upper San Joaquin Valley Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]								
	Friant Dam–SR 99	SR 99–Gravelly Ford	Gravelly Ford–Chowchilla Bypass	Chowchilla Bypass–Mendota Dam	Mendota Dam–Sack Dam	Sack Dam–Sand Slough Control Structure	Sand Slough Control Structure–Mariposa Bypass	Mariposa Bypass–Bear Creek	Bear Creek–Merced River
Connected[3]									
Conserved-Riparian/Wetland	0	0	0	<1	0	0	<1	3	12
Conserved-Natural Upland	<1	<1	0	0	0	0	<1	5	24
Conserved-Agricultural	0	0	0	0	0	0	0	<1	0
Not Conserved-Riparian/Wetland	1	1	<1	<1	2	1	1	1	2
Not Conserved-Natural Upland	<1	1	4	1	2	1	1	3	5
Not Conserved-Agricultural	<1	<1	1	10	3	<1	11	0	1
Connected Subtotal	*1*	*3*	*5*	*11*	*7*	*2*	*13*	*13*	*44*
Disconnected[3]									
Conserved-Riparian/Wetland	0	0	0	0	0	0	4	25	2
Conserved-Natural Upland	<1	0	0	0	0	0	2	16	3
Conserved-Agricultural	0	0	0	0	0	0	0	<1	<1
Not Conserved-Riparian/Wetland	0	0	<1	<1	1	1	<1	<1	1
Not Conserved-Natural Upland	<1	<1	<1	1	1	6	<1	<1	1
Not Conserved-Agricultural	<1	<1	34	24	33	77	20	0	2
Disconnected Subtotal	*<1*	*<1*	*34*	*25*	*35*	*84*	*26*	*41*	*8*
Total	**1**	**3**	**42**	**48**	**42**	**92**	**39**	**54**	**52**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

[1] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al,. 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot).

[2] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

[3] Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

Table 3-10. Floodplain Inundation Potential of Lower San Joaquin River and Tributaries

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
San Joaquin River							
Merced River–Tuolumne River	32,900	3	3	38	20	36	100
Tuolumne River–Stanislaus River	9,100	4	3	47	18	28	100
Stanislaus River–Stockton	35,200	18	15	40	19	9	100
Tributaries							
Merced River	18,800	1	1	4	21	73	100
Tuolumne River	25,700	1	1	5	5	88	100
Stanislaus River	10,700	2	<1	4	37	57	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

[6] Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[7] Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-11. Nonurban Floodplain Connectivity Percentages for Lower San Joaquin River and Tributaries

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
San Joaquin River						
Merced River–Tuolumne River	1,100	82	18	11,300	52	48
Tuolumne River–Stanislaus River	300	68	32	4,000	40	60
Stanislaus River–Stockton	4,200	9	91	9,300	11	89
Tributaries						
Merced River	100	96	4	500	38	62
Tuolumne River	200	85	15	1,000	49	51
Stanislaus River	<100	83	17	300	30	70

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

[6] Connected to or disconnected ("Discon.") from river system during a 50 percent chance flow; i.e., modeled as inundated by flood flows under existing conditions).

Table 3-12. Lower San Joaquin Valley Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]					
	San Joaquin River			Tributaries		
	Merced River–Tuolumne River	Tuolumne River–Stanislaus River	Stanislaus River–Stockton	Merced River	Tuolumne River	Stanislaus River
Connected[3]						
Conserved-Riparian/Wetland	1	9	0	<1	<1	<1
Conserved-Natural Upland	1	5	<1	<1	<1	<1
Conserved-Agricultural	0	0	<1	0	0	0
Not Conserved-Riparian/Wetland	7	3	2	1	2	1
Not Conserved-Natural Upland	6	1	<1	<1	<1	<1
Not Conserved-Agricultural	5	1	1	<1	<1	<1
Connected Subtotal	*21*	*20*	*4*	*2*	*3*	*1*
Disconnected[3]						
Conserved-Riparian/Wetland	1	3	0	0	<1	1
Conserved-Natural Upland	<1	2	<1	0	0	<1
Conserved-Agricultural	0	5	<1	0	0	<1
Not Conserved-Riparian/Wetland	1	3	1	<1	<1	<1
Not Conserved-Natural Upland	1	2	1	<1	<1	<1
Not Conserved-Agricultural	14	12	32	1	1	1
Disconnected Subtotal	*17*	*28*	*34*	*2*	*2*	*2*
Total	**38**	**48**	**42**	**4**	**5**	**3**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

[1] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.). 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[2] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

[3] Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

4.0 Floodplain Restoration Opportunities: Conclusions and Recommendations

This chapter summarizes the relative extent of potential restoration opportunities identified along river reaches based on their physical suitability and existing land cover, and makes general recommendations for the future use of FROA results.

4.1 Conclusions

Restoration opportunities are widespread throughout the 2-mile-wide corridors evaluated along the Sacramento and San Joaquin river systems. Outside of urban areas, there are more than 320,000 acres of floodplain with a 67 percent chance Sustained Spring FIP or a 50 percent chance FIP under the existing flow regime of the Sacramento River system and the flow regime planned by the SJRRP for the San Joaquin River system.

These floodplain areas (which have the potential for frequent inundation) are most limited along several of the major tributaries (e.g., the American, Merced, Tuolumne, and Stanislaus rivers), the upper San Joaquin River from Friant Dam to Gravelly Ford, and the lower Sacramento River downstream of the Delta Cross Channel. Floodplain with 67 percent chance Sustained Spring FIP or a 50 percent chance FIP accounts for less than 5 percent of the evaluated corridors along these reaches. However, because 1 percent of a 2-mile-wide corridor is comparable to corridors about 50 feet wide on each river bank, even these reaches have restoration opportunities (e.g., creation of Shaded Riverine Aquatic habitat) that could have systemwide benefits.

Floodplain with the potential for frequent inundation is much more extensive along other river reaches, providing a greater variety of restoration opportunities. In particular, river reaches differ substantially in the extent of the following combinations of hydrologic connectivity to the river system, nonurban land use/land cover, and FIP that represent different types of restoration opportunities:

- Floodplain hydrologically connected to the river, with riparian or wetland vegetation, and with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP

- Floodplain hydrologically connected to the river, without riparian or wetland vegetation, with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP

- Floodplain hydrologically disconnected from the river with a 67 percent chance Sustained Spring Flow FIP

- Floodplain hydrologically disconnected from the river with a 50 percent chance FIP

Along all evaluated reaches of the Sacramento and San Joaquin river systems, each of these types of floodplain areas exist (Tables 4-1 and 4-2) and their restoration could provide ecologically important benefits. However, those reaches having the most extensive areas of each type probably represent greater and/or more feasible opportunities for large-scale restoration of riverine and floodplain ecosystems. The types of restoration opportunities represented by these floodplain areas and their distribution among river reaches are described further below. Their distribution among river reaches is also displayed in Tables 4-1 and 4-2.

Less than 40 percent of floodplain with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP remains hydrologically connected to the river system. Hydrologically connected floodplain is most extensive along the Sacramento River from Woodson Bridge to Colusa, the Feather River from Thermolito Afterbay to the junction with the Sacramento River, and the San Joaquin River from Bear Creek to the junction with the Stanislaus River. Hydrologically connected floodplain with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP accounts for 20 percent to 53 percent of the 2-mile-wide corridor along these reaches. The majority of this floodplain has a 50 percent chance FIP and is not frequently inundated by sustained spring flows.

Riparian and wetland vegetation covers only about a third (approximately 34 percent) of the floodplain that has remained connected to the river system, including most connected floodplain with a 67 percent chance Sustained Spring Flow FIP. In many of these areas, channel migration processes have been impeded by revetment, which has reduced habitat values. Similarly, the installation of revetment has reduced the amount of Shaded Riverine Aquatic habitat, and habitat for other species (e.g., bank swallow). Thus, there is an opportunity to restore these areas by revetment removal.

Table 4-1. Restoration Opportunities Along Sacramento River System

Reach	Modeled Area[1] (Acres)	Restoration Opportunity[2] (Percent of Modeled Area)					Notes
		Connected[3]		Disconnected[3]		Total	
		Riparian/ Wetland	Other Land Use/ Land Cover	67% Chance SS FIP[2],	50% Chance FIP[2]		
Sacramento River							
Woodson Bridge–Chico Landing	26,792	11	14	0	4	28	Extensive conserved land, bank swallow, yellow-billed cuckoo
Chico Landing–Colusa	56,442	14	14	<1	39	68	Bank swallow, yellow-billed cuckoo
Colusa–Verona	71,376	3	5	9	52	69	Bank swallow, yellow-billed cuckoo
Verona–American River	24,732	2	1	22	51	77	Extensive infrastructure constraints
American River–Freeport	16,969	1	1	12	8	22	Extensive development and infrastructure
Freeport–Delta Cross Channel	24,784	<1	1	28	4	33	Tidally influenced, in legal Delta
Delta Cross Channel–Deep Water Ship Channel	16,192	<1	1	2	1	3	Tidally influenced, in legal Delta
Deep Water Ship Channel–Collinsville	14,641	1	2	<1	1	3	Tidally influenced, in legal Delta
Feather River							
Thermalito Afterbay to Yuba River	35,830	6	18	<1	10	33	Historical and active gravel pits, fall-run Chinook spawning and rearing, bank swallow, yellow-billed cuckoo
Yuba River to Bear River	18,646	15	9	<1	53	78	Bank swallow
Bear River to Sutter Bypass	5,828	13	19	<1	57	89	Bank swallow, yellow-billed cuckoo
Sutter Bypass to Sacramento River	8,643	6	47	5	35	93	Bank swallow
Other Tributaries							
Yuba River	15,390	1	3	1	4	9	Extensive disturbed area (Yuba Gold Fields)
Bear River	14,612	3		7			Fall-run Chinook spawning and rearing (intermittent)
American River	26,489	3	2	<1	1	5	Extensive development and infrastructure, extensive conserved land, bank swallow, fall-run Chinook spawning and rearing

Source: Data generated for this analysis by AECOM in 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] For nonurban areas and based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring (SS) FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study. 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[3] During 50 percent chance event, simulated under 2008 topography and infrastructure.

Table 4-2. Restoration Opportunities Along San Joaquin River System

Reach	Modeled Area[1] (Acres)	Restoration Opportunity (Percent of Modeled Area)					Notes
		Connected[3]		Disconnected[3]		Total	
		Riparian/Wetland	Other Land Use/Land Cover	67% chance SS FIP[2,]	50% chance FIP[2,]		
San Joaquin River							
Friant Dam to SR 99	22,545	1	<1	<1	<1	1	Extensive development and infrastructure, historical and active gravel pits, potential spawning habitat if salmon reintroduced
SR 99 to Gravelly Ford	19,373	1	2	<1	<1	3	
Gravelly Ford to Chowchilla Bypass	10,511	<1	5	10	24	40	
Chowchilla Bypass to Mendota Dam	8,368	<1	11	16	9	36	Mendota Pool – major infrastructure constraint
Mendota Dam to Sack Dam	23,842	2	5	1	34	42	Mendota Pool – major infrastructure constraint
Sack Dam to Sand Slough	14,895	1	2	6	78	86	
Sand Slough to Mariposa Bypass	19,180	1	12	18	8	39	Carries only local drainage, until modified
Mariposa Bypass to Bear Creek	9,689	5	8	2	39	54	Extensive conserved land
Bear Creek to Merced River	16,263	14	30	<1	8	52	Extensive conserved land
Merced River to Tuolumne River	32,861	8	13	1	17	38	
Tuolumne River to Stanislaus River	9,052	12	8	1	27	48	Riparian woodrat and riparian brush rabbit habitat, extensive conserved land
Stanislaus River to Stockton	35,191	2	2	11	23	38	Extensive development and infrastructure, riparian woodrat and riparian brush rabbit habitat, tidally influenced, in legal Delta
Tributaries							
Merced River	18,782	1	1	<1	2	2	
Tuolumne River	25,666	2	1	<1	2	2	Extensive development and infrastructure
Stanislaus River	10,672	1	<1	<1	2	2	Riparian woodrat and riparian brush rabbit habitat

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] For nonurban areas and based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study. 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[3] During 50 percent chance event, simulated under 2008 topography and infrastructure.

In many areas of floodplain hydrologically connected to the river system and lacking riparian vegetation, riparian vegetation could be established through natural processes or plantings. However, the SPFC often has insufficient capacity to allow for the increased roughness (i.e., resistance to water flow) of additional riparian vegetation. Thus, there is an opportunity to facilitate future restoration of these areas by increasing the capacity of the SPFC to allow for the increased roughness of riparian vegetation.

More than 60 percent of floodplain with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP is hydrologically disconnected from the river system by levees. Riparian and wetland vegetation cover only several percent of this disconnected floodplain. Also, less than 5 percent of this disconnected floodplain is conserved along most reaches. Reconnecting these floodplains, particularly areas with a 67 percent chance Sustained Spring FIP, to the river system could provide higher quality habitat for salmonids, and other ecological functions.

Disconnected areas with a 67 percent chance Sustained Spring Flow FIP are relatively extensive along the Sacramento River from Verona to the Delta Cross Channel, and along several reaches of the San Joaquin River: Gravelly Ford to Mendota Dam, Sand Slough to the Mariposa Bypass, and from the Stanislaus River to Stockton. However, major infrastructure constraints are also extensive along several of these reaches, in particular along the Sacramento River from Verona to Freeport. Thus, large-scale opportunities to restore these areas by setting back levees or otherwise reconnecting these areas to the river system are limited.

Extensive areas of disconnected floodplain with a 50 percent chance FIP are more widespread along the Sacramento and San Joaquin river systems than areas with a 67 percent chance FIP. Floodplain with a 50 percent chance FIP are extensive along the Sacramento River from Chico Landing to the junction with the American River; the lower Feather River, particularly from the junction with the Yuba River to the junction with the Sacramento River; and much of the San Joaquin River from Gravelly Ford to Stockton.

The feasibility, costs, and benefits of restoring any of these areas are strongly influenced by their relationship to CVFPP projects and policies, and by the content of the Central Valley Flood System Conservation Strategy (CVFSCS). Also, potential benefits differ qualitatively among reaches because sensitive species differ in their distribution. For example, reaches providing salmonid spawning habitat do not provide delta smelt habitat, and reaches providing riparian brush rabbit habitat may not provide bank swallow habitat. Consequently, the identification and prioritization of restoration opportunities are both part of the continuing development of the

overall CVFPP and of the development of species-focused conservation planning and corridor management strategies, as described in the Conservation Framework of the 2012 CVFPP.

Based in part on the results of this FROA, DWR is identifying, prioritizing, and further developing specific restoration opportunities for these river reaches. Opportunities are being identified and prioritized on the basis of their potential ecological, flood management, and other benefits (e.g., reduced maintenance and regulatory compliance costs); cost; and regulatory, institutional, technological, and operational feasibility.

4.2 Recommendations

The following are recommendations for future use of the results of this analysis for development of CVFPP projects and the CVFSCS:

- Consider FROA results during project planning as general indicators of potential ecosystem benefits.
- Conduct additional stakeholder interviews to develop a more comprehensive compilation of stakeholder-identified projects.
- Apply FROA results to evaluate the ecosystem effects of alternative actions.
- Apply FROA results to CVFSCS development as a component of baseline ecosystem conditions together with a more comprehensive summary of riverine and riparian-associated species.
- Use FROA results to identify and/or prioritize sites for preservation or restoration.
- Integrate FROA results with mapping of SRA, revetment, and natural banks to more specifically consider reach-scale opportunities for restoring channel migration.

5.0 References

AECOM. 2010a. Technical Memorandum Supplemental Data and Information Collection Summary. Prepared for the California Department of Water Resources. Sacramento, California. October 4.

———. 2010b. 2012 Central Valley Flood Protection Plan, Ecosystem Functions Model, Draft. September.

———. 2011. Technical Memorandum–Height Above River Investigation. Prepared for the California Department of Water Resources. Sacramento, California. April 14.

CBDA. *See* California Bay-Delta Authority.

California Bay-Delta Authority (CBDA). 2004. Final Database of Potential Multi-Objective Flood Damage Reduction Actions. Sacramento, California.

California Department of Conservation (DOC). 2008. Important Farmland by County as Mapped by the California Department of Conservation. Sacramento, California. Available at ftp://ftp.consrv.ca.gov/pub/dlrp/FMMP/. Accessed February 24, 2011.

———. 2011. California Farmland Conversion Report 2006–2008. Sacramento, California. Available at http://www.conservation.ca.gov/dlrp/fmmp/pubs. Accessed June 5, 2011.

California Department of Fish and Game (DFG). 2005. CalFish salmon and steelhead abundance data digital map files. Sacramento, CA. Available at: http://www.calfish.org/ DataampMaps/CalFishDataDownloads/tabid/93/Default.aspx. Last accessed: February 24, 2011.

———. 2008. Yolo Bypass Wildlife Area Land Management Plan. Prepared by EDAW, Sacramento, California.

———. 2011. California Natural Diversity Database digital map files. February. Sacramento, California.

California Department of Water Resources (DWR). 2010a. Digital Map of Urban Areas within the CVFPP Planning Area. Sacramento, California.

———. 2010b. State Plan of Flood Control Descriptive Document. Division of Flood Management, Central Valley Flood Planning Office, Sacramento, California. November.

———. 2010c. Central Valley Floodplain Evaluation and Delineation (CVFED) Data Request/Release Agreement. August 31.

———. 2011. Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area. Division of Flood Management, Central Valley Flood Planning Office, Sacramento, California. November.

———. 2012. Improving Vegetation Data. Division of Flood Management, Central Valley Flood Planning Office, Sacramento, California. January.

California Department of Transportation (Caltrans). 2009. Rail Geodatabase. CalTrans Rail Division. Available at http://www.dot.ca.gov/hq/tsip/gis/datalibrary/gisdatalibrary.html#rail. Accessed February 24, 2011.

Caltrans. *See* California Department of Transportation.

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

Dilts, T.E., J. Yang, and P.J. Weisberg. 2010. Mapping Riparian Vegetation with LiDAR Data: Predicting Plant Community Distribution Using Height above River and Flood Height. ArcUser. Winter 2010. Available at http://www.esri.com/news/arcuser/0110/files/mapping-with-lidar.pdf. Accessed February 24, 2011.

Dilts, T.E. 2011. Email communication to Jonathan McLandrich and Kevin Coulton of AECOM, Portland, Oregon. January 14.

DOC. *See* California Department of Conservation.

DWR. *See* California Department of Water Resources.

Environmental Systems Research Institute, Inc. (Esri). 2011. Riparian Topography Toolbox for ArcGIS. Available at http://arcscripts.esri.com/details.asp?dbid=16792%20

Esri. *See* Environmental Systems Research Institute, Inc.

ESSA. *See* ESSA Technologies.

ESSA Technologies. 2009. Sacramento River Ecological Flows Tool. Available: http://www.essa.com/tools/EFT/download.html. Accessed September 29, 2010.

GIN. *See* GreenInfo Network.

GreenInfo Network (GIN). 2010. California Protected Areas Database digital map files. San Francisco, CA. Available at: http://atlas.ca.gov/ download.html#/casil/planning//landOwnership. Last accessed: February 24, 2011.

MWH. 2011. Feather River Daily Flows for HEC-EFM (preliminary version)

National Oceanic and Atmospheric Administration (NOAA). 2011. Center for Operational Oceanographic Products and Services. Available: http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9415144%20Port%20Chicago,%20CA&type=Datums. Accessed: June 18, 2011.

NOAA. *See* National Oceanic and Atmospheric Administration.

Reclamation. *See* U.S. Department of the Interior, Bureau of Reclamation.

Sacramento River Conservation Area Forum. 2003. Sacramento River Conservation Area Forum Handbook. Red Bluff, California.

Sommer., T., W.C. Harrell, M.L. Nobriga, R. Brown, P.B. Moyle, W.J. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that Flood Control can be Compatible with Fisheries, Wetlands, Wildlife, and Agriculture. Fisheries 26(8): 6–16.

USACE. *See* U.S. Army Corps of Engineers.

USACE-HEC. *See* U.S. Army Corps of Engineers Hydrologic Engineering Center.

U.S. Army Corps of Engineers. 2010. Sutter Basin feasibility study.

U.S. Army Corps of Engineers and The Reclamation Board. 2002 Sacramento and San Joaquin River Basins Comprehensive Study, Technical Studies Documentation. U.S. Army Corps of Engineers and The Reclamation Board of the State of California, Sacramento, California. December.

U.S. Army Corps of Engineers Hydrologic Engineering Center (USACE-HEC). 2009. HEC-EFM Ecosystem Functions Model Quick Start Guide, Version 2.0. November. Davis, California.

U.S. Department of the Interior, Bureau of Reclamation (Reclamation). 2011. Draft Program Environmental Impact Statement/Environmental Impact Report San Joaquin River Restoration Program. Sacramento, California. April.

U.S. Census Bureau, Geography Division. 2007. TIGER/Line Shapefiles. Available at http://www.census.gov/cgi-bin/geo/shapefiles/national-files. Accessed February 24, 2011.

U.S. Geological Survey (USGS). 2010. Seamless Data Warehouse. Available at http://seamless.usgs.gov/services.php. Last accessed February 4, 2011.

———. 2011. StreamStats California. Available at http://water.usgs.gov/osw/streamstats/california.html. Accessed November 9, 2011.

USGS. *See* U.S. Geological Survey.

Williams, P.B., E. Andrews, J.J. Opperman, S. Bozkurt, P.B. Moyle. 2009. Quantifying Activated Floodplains on a Lowland Regulated River: Its Application to Floodplain Restoration in the Sacramento Valley. San Francisco Estuary and Watershed Science Vol. 7, Issue 1.

6.0 Abbreviations and Acronyms

cfs ..... cubic feet per second

CNDDB ..... California Natural Diversity Database

Comprehensive Study Sacramento and San Joaquin River Basins Comprehensive Study

CVFED ..... Central Valley Floodplain Evaluation and Delineation

CVP ..... Central Valley Project

CVFPP ..... Central Valley Flood Protection Plan

CVFSCS ..... Central Valley Flood System Conservation Strategy

Delta ..... Sacramento-San Joaquin Delta

DEM ..... digital elevation model

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

DWR ..... California Department of Water Resources

EFR ..... Ecosystem Function Relationship

ESRI ..... Environmental Systems Research Institute, Inc.

FIP ..... floodplain inundation potential

FROA ..... Floodplain Restoration Opportunity Analysis

GIS ..... geographic information system

HAA ..... Habitat Analysis Areas

HAR ..... Height Above River

HEC-DSS ..... Hydrologic Engineering Center's Data Storage System

HEC-EFM ..... Hydrologic Engineering Center's Ecosystem Functions Model

HEC-GeoRAS ..... Hydrologic Engineering Center's River Analysis System

HEC-RAS ..... Hydrologic Engineering Center's River Analysis System

LiDAR ..... Light Detection and Ranging

MTL ..... Mean Tidal Level

MWH ..... MWH Americas, Inc.

NAVD88 ..... North American Vertical Datum 1988

NGVD29 .....National Geodetic Vertical Datum of 1929

NOAA .....National Oceanic and Atmospheric Administration

RM .....River Miles

SacEFT.....Sacramento River Ecological Flows Tool

SJRRP .....San Joaquin River Restoration Program

SPFC .....State Plan of Flood Control

SR.....State Route

SRA .....State Recreation Area

UPID .....Union Pacific Interceptor Canal

USACE .....U.S. Army Corps of Engineers

USACE-HEC.....U.S. Army Corps of Engineers Hydrologic Engineering Center

USGS .....U.S. Geological Survey

VELB .....Valley elderberry longhorn beetle

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DEPARTMENT OF WATER RESOURCES

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix A. Floodplain Inundation and Ecosystem Functions Model Pilot Studies

January 2012

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Table of Contents

1.0 Overview 1-1
2.0 Floodplain Inundation Pilot Study 2-1
2.1 Overview 2-1
2.2 Identify Pilot-Study Area 2-2
2.3 Compile and Review Data 2-3
2.4 Generate Stream Raster 2-7
2.5 Calculate Floodplain Inundation Potential 2-8
2.6 Calculate Flood Height 2-13
2.7 Calculate Inundation Area 2-13
2.8 Levee Realignment Methodology 2-14
2.9 Height Above River Results 2-15
2.10 Inundation Area Results 2-16
2.11 Conclusions 2-20
3.0 Hydrologic Engineering Center's Ecosystem Functions Model Pilot Study 3-1
3.1 Methods 3-1
3.1.1 Selection of the Pilot-Study Area 3-1
3.1.2 Data Collection and Review 3-2
3.1.3 Identification of Habitat Analysis Areas 3-9
3.1.4 HEC-RAS Modeling 3-12
3.1.5 HEC-EFM Modeling 3-12
3.2 Results and Sensitivity 3-15
3.2.1 SacEFT-Defined EFRs 3-16
3.2.2 Modified EFRs 3-18
3.3 Mapping 3-23
3.3.1 Mapping Approaches 3-23
3.3.2 Refinement of Mapping Products 3-32
3.4 Conclusions 3-32
4.0 Acronyms and Abbreviations 4-1

List of Tables

Table A-1. Areas of Inundation Depths at 50% and 10% Chance Flood Events 2-20

Table A-2. USGS Gages Within the Pilot-Study Area..... 3-7

Table A-3. Habitat Analysis Areas 3-10

Table A-4. Summary of Ecosystem Functional Relationships 3-13

Table A-5. HEC-EFM Results – RS 26.25–RS 22.50 3-17

Table A-6. HEC-EFM Results—RS 19.00–RS 13.25 3-17

Table A-7. HEC-EFM Results—RS 11.00–RS 8.50 3-18

Table A-8. Cottonwood Seedling Germination Sensitivity – RS 26.25–RS 22.50 3-18

Table A-9. Cottonwood Seedling Germination Sensitivity – RS 19.00–RS 13.25 3-19

Table A-10. Cottonwood Seedling Germination Sensitivity – RS 11.00–RS 8.50 3-19

Table A-11. Salmonid Rearing Habitat Sensitivity – RS 26.25–RS 22.50 3-22

Table A-12. Salmonid Rearing Habitat Sensitivity – RS 19.00–RS 13.25 3-22

Table A-13. Salmonid Rearing Habitat Sensitivity – RS 11.00–RS 8.50 3-23

Table A-14. HEC-RAS-Derived Stages for Salmonid-Rearing Habitat – RS 9.75–RS 11.00 3-30

List of Figures

Figure A-1. Proposed Approach for CVFPP Floodplain Restoration Opportunity Analysis 2-1

Figure A-2. Lower Feather River Pilot-Study Area..... 2-4

Figure A-3. Central Valley NGVD29 to NAVD88 Vertical Datum Conversion (NAVD88 elevations are higher than NGVD29 elevations)..... 2-6

Figure A-4. Toolbox Folder Structure 2-8

Figure A-5. Output Stream Raster (5a) and Output Stream Line (5b) 2-9

Figure A-6. HAR Tool Methodology..... 2-10

Figure A-7. Raster to Point 2-11

Figure A-8. HAR Closeup (8a) and Pilot Study Reach (8b) 2-12

Figure A-9. Calculate Inundation Area..... 2-14

Figure A-10. LiDAR Water-Surface Profile FIP Output 2-15

Figure A-11. 50 Percent Chance Water-Surface Profile FIP Output..... 2-17

Figure A-12. 10 Percent Chance Water-Surface Profile FIP Output..... 2-18

Figure A-13. Cross Section of 50 Percent Chance Flood Profile (RS 19.00).. 2-19

Figure A-14. Lower Feather River Pilot-Study Area..... 3-3

Figure A-15. Revised HEC-RAS Model .....**Error! Bookmark not defined.**

Figure A-16. Synthetic vs. Observed Daily-Averaged Flow – Nicolaus 3-7

Figure A-17. Synthetic vs. Observed Flow Duration Curve – Nicolaus..... 3-8

Figure A-18. Revised Daily Flow Time Series Hydrographs..... 3-10

Figure A-19. Habitat Analysis Areas..... 3-11

Figure A-20. Comparison of Rating Curves – RS 11.00 3-15

Figure A-21. Comparison of Rating Curves Showing HEC-EFM Results – RS 11.00 3-16

Figure A-22. Salmonid Rearing Habitat for Various Frequency Events in HAA 11.00 3-24

Figure A-23. Salmonid-Rearing Habitat Areas Mapped Using HEC-GeoRAS in HAA 11.00 3-25

Figure A-24. Cottonwood Seedling Germination Habitat Areas Mapped Using FIP and HEC-GeoRAS in HAA 11.00 3-29

Figure A-25. Salmonid-Rearing Habitat Areas Mapped Using FIP and ArcGIS in HAA 11.00 3-31

1.0 Overview

This appendix provides the methods, results, and conclusions of two pilot studies conducted on the lower Feather River to evaluate the suitability of floodplain inundation potential (FIP) (also known as Height Above River (HAR)) (Dilts et al., 2010) and U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's Ecosystem Functions Model (HEC-EFM) analyses for use in the Floodplain Restoration Opportunity Analysis (FROA). Each pilot study is discussed in a separate section:

- 2.0, Floodplain Inundation Pilot Study
- 3.0, Hydrologic Engineering Center's Ecosystem Functions Model Pilot Study

The approach of the FROA was developed in part from the results and conclusions of these pilot studies.

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2.0 Floodplain Inundation Pilot Study

2.1 Overview

This pilot study is a test of the proposed approach for the FROA displayed on Figure A-1. This approach uses readily available topographic and hydrologic data sets, and straightforward geographic information system (GIS) analyses to identify floodplains inundated under more frequent, ecologically valuable flow events (e.g., 50 and 10 percent chance events). The HAR tool (Dilts et al., 2010) was identified as a method that could potentially be adapted for use in this FIP analysis. GIS layers based on the results of this analysis would show floodplains that could be more readily reconnected to the river during specific flow events. The specific method of this approach is described in the following sections.

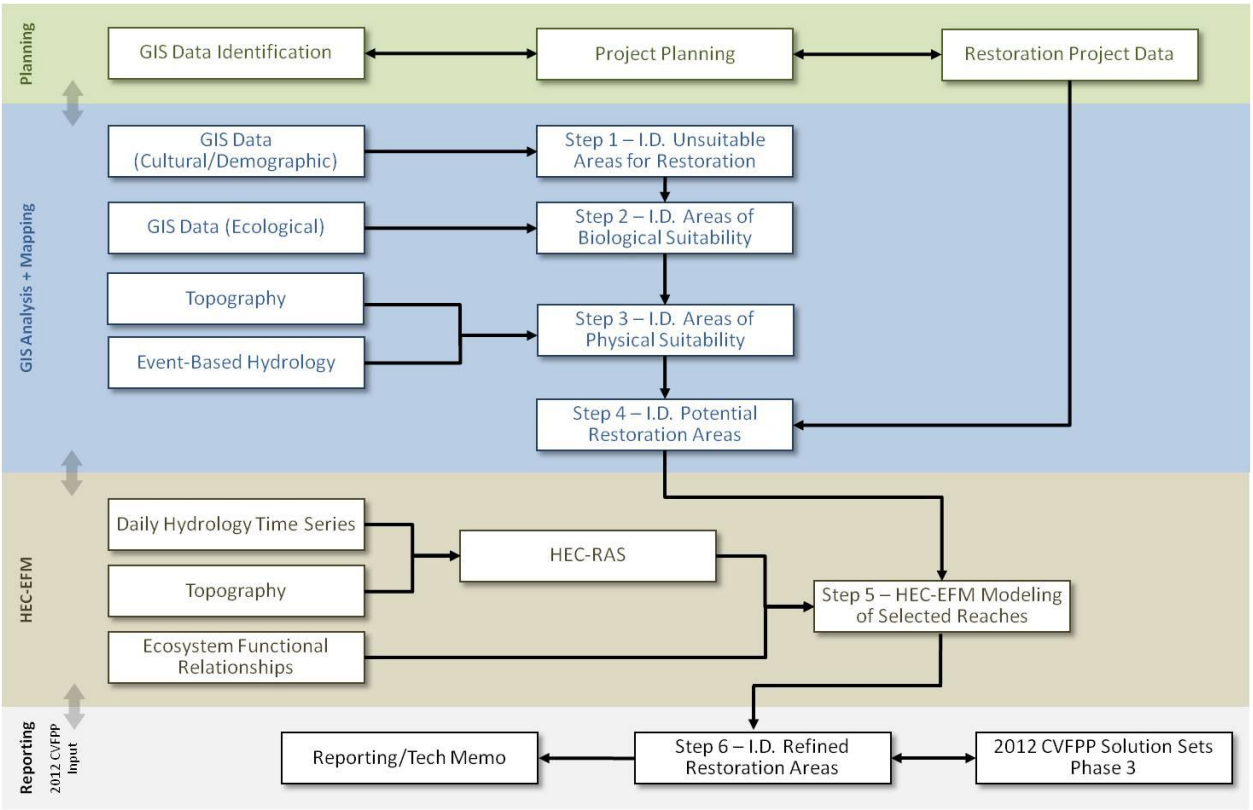

Figure A-1. Proposed Approach for CVFPP Floodplain Restoration Opportunity Analysis

For the purpose of this work, the "FIP method" is the term used to describe a series of GIS tools provided within the Riparian Topography Toolbox, as described by Dilts et al. (2010). These tools are distributed as the ArcGIS Riparian Topography Toolbox by Environmental Systems Research Institute, Inc. (ESRI) (ESRI, 2011).

Through our review and application of the publically available tools in this toolbox, and with the use of unpublished tools provided by Mr. Dilts, we have established a series of steps that constitute the FIP method. These steps are described in the following sections:

- 2.2, Identify Pilot-Study Area
- 2.3, Compile and Review Data
- 2.4, Generate Stream Raster
- 2.5, Calculate Flooplain Inundation Potential
- 2.6, Calculate Flood Height
- 2.7, Calculate Inundation Area

The Riparian Topography Toolbox tools were developed for application to actual river water surface conditions at the time of a Light Detection and Ranging (LiDAR) flight. Since an objective of this pilot study was to investigate the application of these tools to hypothetical flood conditions, other than observed water surface conditions, some deviations were made in the application of the tools; however, the Generate Stream Raster tool was common to all applications.

Section 2.8 describes notes that data were modified to account for two locations in the pilot study area, two locations where levees had been set back after the March 2008 date of the LiDAR flight. Sections 2.9 through 2.11 provide the height above river results, inundation area results, and the conclusions of this pilot study, respectively.

2.2 Identify Pilot-Study Area

An approximately 20-mile reach of the Feather River was selected for the pilot study from the confluence with the Sutter Bypass, upstream to Yuba City at River Station (RS) 27.75 (Figure A-2); the purple rectangle shown on Figure A-2 indicates the specific subreach to which the FIP method was applied.

2.3 Compile and Review Data

The following data were compiled and reviewed in preparation for the application of the HAR tool to the pilot-study area.

1. Terrain Data – Central Valley Floodplain Evaluation and Delineation (CVFED) preprocessed LiDAR and breakline data were obtained and processed into 25-foot digital elevation models (DEM).

2. Water-Surface Profiles – The following water-surface profiles were used in the pilot study:

    a. March 2008 LiDAR water-surface profiles – The river water surfaces at the time of the LiDAR flight were used for initial investigations of the relationship of water levels to floodplain inundation.

    b. Ten- and 20-foot test profiles – Arbitrary heights of 10 and 20 feet above the LiDAR water surface were used initially to evaluate floodplain inundation areas from higher water levels; these heights were replaced by the Sacramento and San Joaquin River Basins Comprehensive Study (Comprehensive Study) (USACE and The Reclamation Board 2002) 50 and 10 percent chance water-surface profiles for further investigations.

    c. Comprehensive Study 50 and 20 percent chance event water-surface profiles – Water-surface profiles for these two return period flood events were obtained by running the Comprehensive Study's model derived from the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) for the pilot study river reach.

    d. Vertical datum conversion – Water surface elevations from the HEC-RAS models are in the older National Geodetic Vertical Datum of 1929 (NGVD29) vertical datum and were converted to the current North American Vertical Datum 1988 (NAVD88) vertical datum to match the vertical datum of the terrain data. Figure A-3 summarizes the spatial variation of the conversion factors in the Central Valley. An average of the conversion factors along the pilot-study stream reach was estimated and this value of +2.335 feet was applied to the HEC-RAS NGVD29 elevations to estimate the NAVD88 elevations.

Figure A-2. Lower Feather River Pilot-Study Area

The vertical datum conversion was cross-checked by identifying the latitude/longitude of the pilot-study reach and entering this into the National Geodetic Survey (NGS) on-line tool VERTCON (NGS, 2011) to perform the conversion, and the results were similar.

ArcGIS Riparian Topography Toolbox – The Riparian Topography Toolbox for ArcGIS was downloaded from the ESRI Web site (ESRI, 2011). The HAR tool is one of the tools contained within the Riparian Topography Toolbox and includes tools for calculating FIP, inundation area for a given FIP, and flood height.

The FIP method requires the use of a DEM terrain surface. Two sources of DEMs were evaluated for use in the pilot study: (1) U.S. Geological Survey (USGS) 10-meter DEMs (USGS, 2010), and (2) CVFED preliminary DEMs (DWR, 2010b).

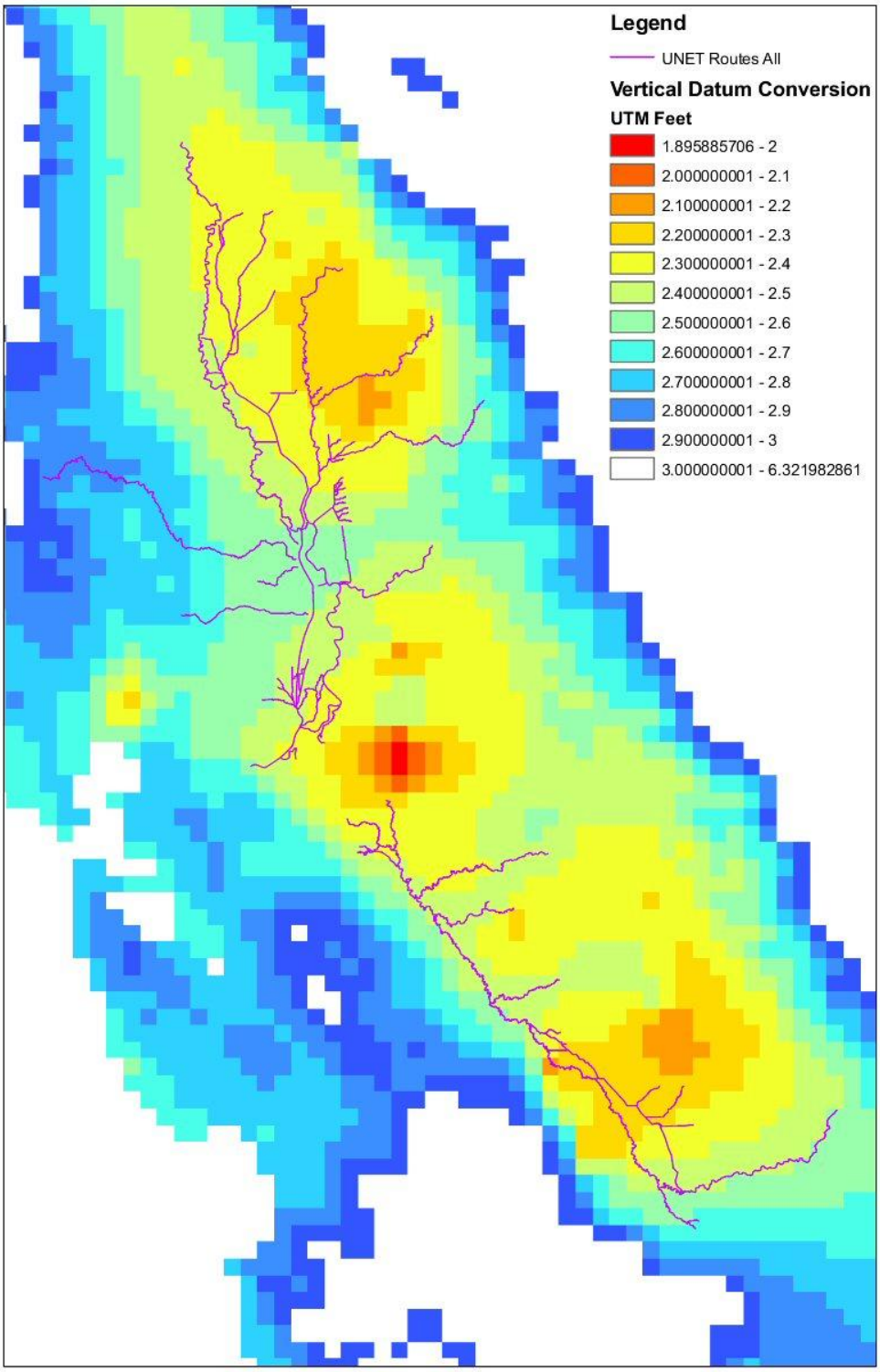

Figure A-3. Central Valley NGVD29 to NAVD88 Vertical Datum Conversion (NAVD88 elevations are higher than NGVD29 elevations)

USGS 10-meter DEMs (USGS, 2010) were obtained and evaluated for their appropriateness of use in the pilot study. Appendix D6-B provides the methods and results of a brief assessment of the data, which led to the decision not to use the USGS data because of the significant inaccuracies found in the delineation of project levees and ground elevations.

New DEMs are being prepared as part of the CVFED program, though the final DEMs have not been completed. Available preliminary CVFED terrain data were obtained for the pilot-study area in October 2010, for use in preparing a DEM for the pilot-study area. The DEM preparation involved incorporating/building breaklines and filling in void areas found in these preliminary CVFED data. The LiDAR data had data voids where water and dense vegetation restricted the triangular irregular network (TIN) from triangulating, essentially leaving large gaps in the TIN. Points were created in those areas to help complete the TIN.

A brief comparison was done to determine the level of effort and resulting data file sizes for the preparation of a DEM with a 5-, 25-, 50-, and 100-foot grid cell resolution (Appendix D6-C). Based on the results of this comparison, DWR decided to develop a 25-foot DEM using preprocessed CVFED data in the pilot-study area. The use of a 25-foot-resolution DEM was determined to provide a reasonable balance between the preparation time, resolution (usability), and file sizes with the intended level of detail for the final products from this planning-level exercise.

2.4 Generate Stream Raster

One of the first tasks required for the FIP analysis was the generation of the Stream Raster. This was previously accomplished through a series of steps using ArcHydro and Arc Map; however, a new unpublished tool “Derive Stream Raster” replaces the previous process and the tool was obtained from Mr. Dilts, the HAR author (Dilts, 2011). The Derive Stream Raster tool was located by navigating through the Topography Tools toolbox as follows: Topography Tools → Riparian Tools → Transverse → 2_Derive Stream Raster. The following steps were taken to complete the generation of the stream raster using Derive Stream Raster, and the input menu is shown on Figure A-4:

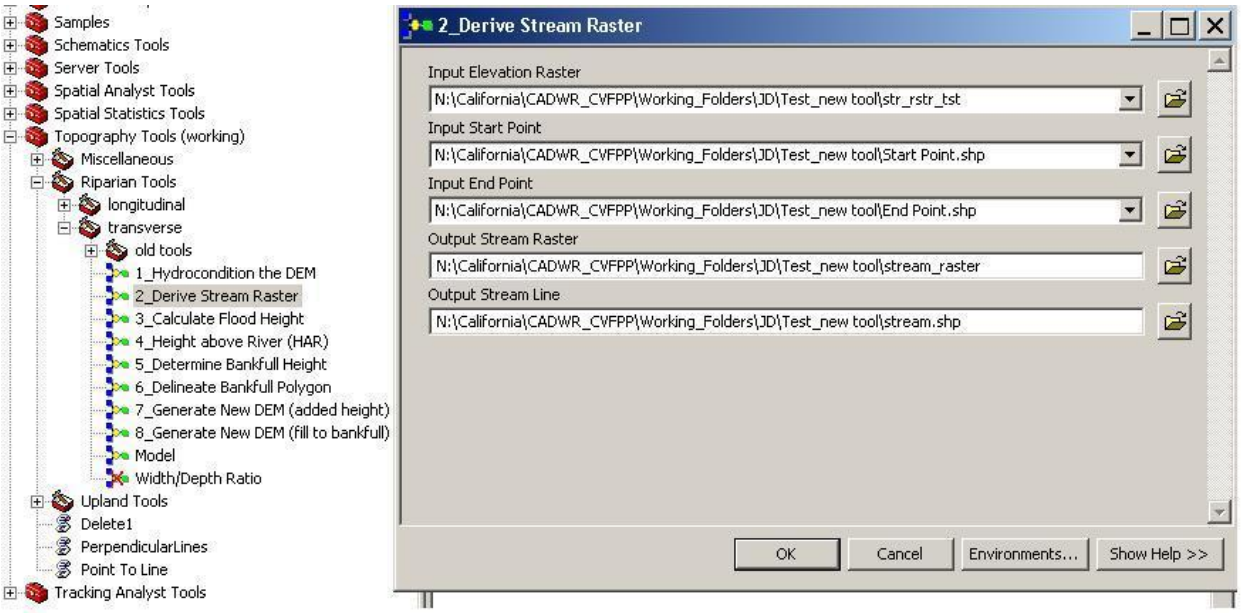

Figure A-4. Toolbox Folder Structure

1. **Input Elevation Raster** – Enter the file location for the 25-foot DEM.

2. **Input Start Point and Input End Point** – Create two new shapefiles, each consisting of one point named "Start Point" and the other "End Point." In the Start Point shapefile, a point was placed at the start (upstream limit) of the pilot-study stream reach of interest. In End Point shapefile, a point was placed at the end (downstream limit) of the pilot-study stream reach of interest. The DEM was used as a visual aid to locate these points along the centerline of the stream channel.

3. **Output Stream Raster** – Assign name and location to place output stream raster grid cells (Figure A-5a).

4. **Output Stream Line** – Assign shapefile location and filename for stream raster grids converted to polyline (Figure A-5b).

2.5 Calculate Floodplain Inundation Potential

The HAR tool was located by navigating through the Topography Tools toolbox as follows: Topography Tools → Riparian Tools → Transverse → 2_HAR → right-click → Edit. The HAR tool methodology is shown in a flow chart on Figure A-6, where blue ovals indicate data entry steps, the yellow boxes are tool processes, and the green ovals are outputs from processes.

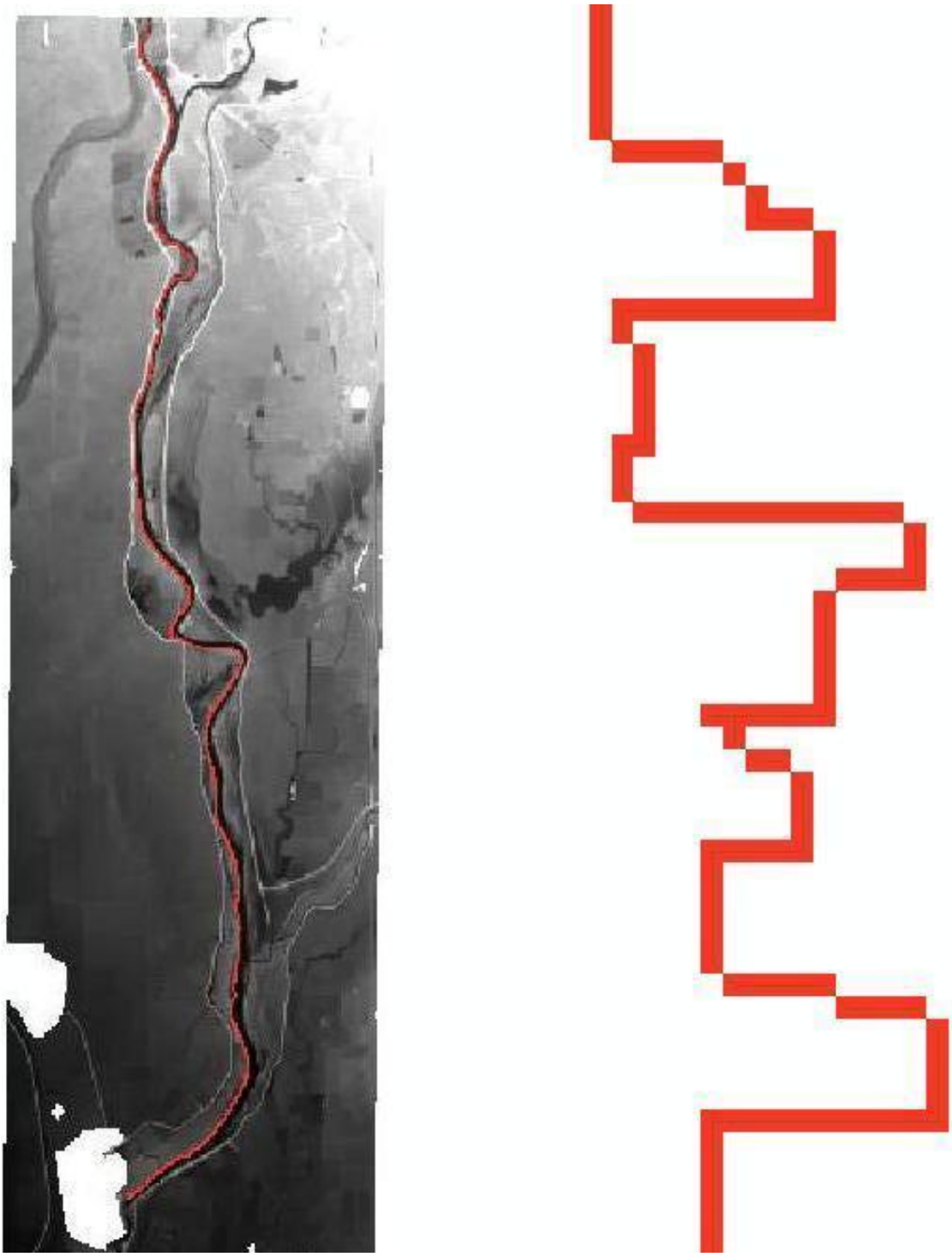

Figure A-5. Output Stream Raster (5a) and Output Stream Line (5b)

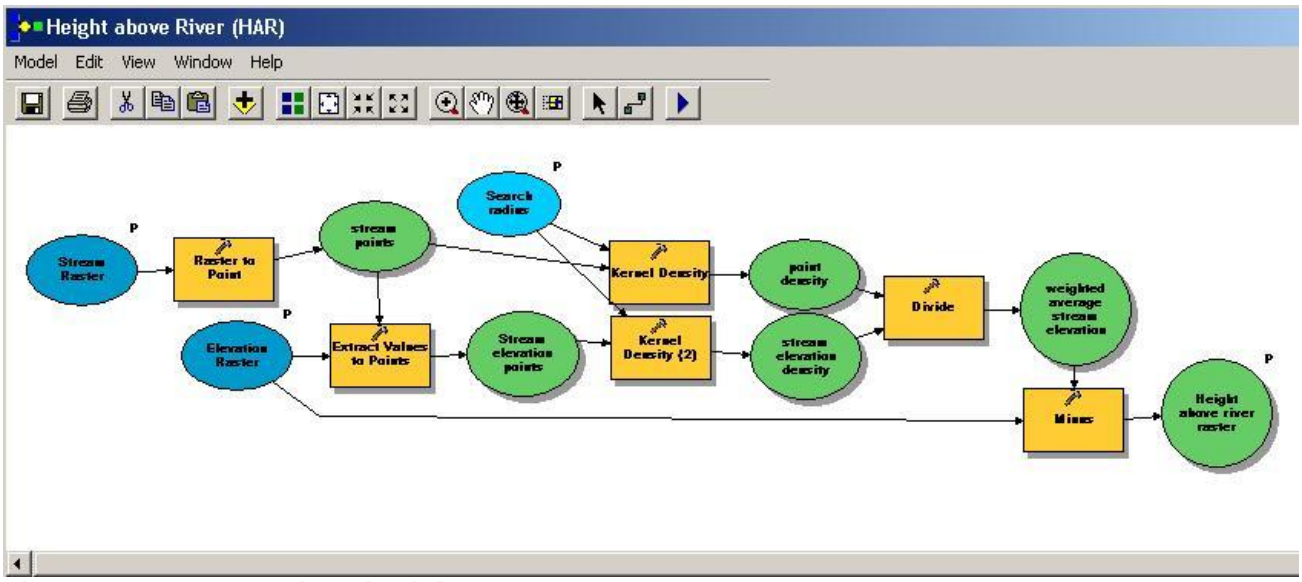

Figure A-6. HAR Tool Methodology

The significant steps in the methodology (indicated by the yellow boxes) are described as follows in the order that they were accomplished during the pilot study:

1. **Stream Raster** – Browse to the location of the output stream raster and input the file path.

2. **Elevation Raster** – Browse to the location of the DEM and input the file path. The first raster used in this process was derived from the LiDAR terrain model. To investigate the conditions associated with the 50 and 10 percent chance flood in the pilot-study reach, the initial LiDAR DEM was modified by adding the 50 and 10 percent chance water-surface profiles from the HEC-RAS model. This was done by extracting the LiDAR water surface elevations (WSEL) and inserting the HEC-RAS 50 and 10 percent chance WSELs, creating an artifically raised surface within the banks of the river channel. The remaining steps in this methodology remain the same and were applied three times to the LiDAR water-surface profile, and the 50 and 10 percent chance water-surface profiles.

3. **Search Radius** – Enter search radius (in feet only). This is the radius that was applied to each point on the stream line created in the next step and establishes the spatial extent of the FIP analysis; during the pilot study, the search radius was increased from 5,280 feet to 7,000 feet after a preliminary review of the output indicated the initial radius length did not capture all of the levees adjacent to the stream reach.

4. **Raster to Point** – The HAR tool pulls the output stream raster and converts it to points and asssigns a new filename with file location assigned by user (Figure A-7).

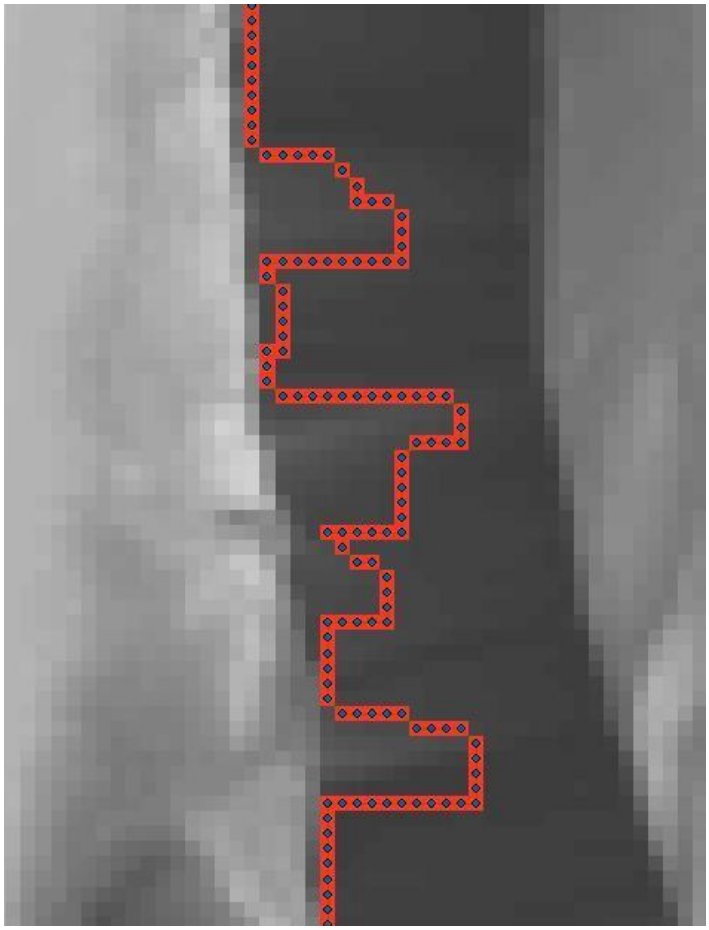

Figure A-7. Raster to Point

5. **Extract Values to Points** – The stream points (Step 4) and elevation raster (Step 2) are identifed, and the filename and file location assigned in Step 4 are assigned again by the user. Note that the HAR tool saves files to the last saved filepath and filename; thus, these default filenames and locations may need to be replaced with the correct values.

6. **Kernel Density** – The HAR tools pulls stream points (Step 4), and the population field is set at "NONE." The filename and file location assigned in Step 4 are assigned again by user. Output cell size (optional) was changed to "25" to match the DEM grid size (in feet). Search radius is pulled from Step 3 and area units was left as default "SQUARE_MAP_UNITS." The output from this process is the stream point density.

7. **Kernel Density 2** – The HAR tools pulls stream elevation points (Step 4), and the population field is set at "RASTERVALU," which was manually entered into the population field. The filename and file location assigned in Step 4 are assigned again. Output cell size (optional) was changed to "25" to match the DEM grid size (in feet). Search radius was pulled from Step 3 and area units was left as default "SQUARE_MAP_UNITS." The output from this process is the stream elevation density.

8. **Divide** – The HAR tool pulls the stream elevation density file (Step 7) and point density file (Step 6) into the Input raster or constant value 1 and 2, respectively, and divides the values of the two rasters on a cell-by-cell basis. The output is the weighted average stream elevation.

9. **Minus** – The HAR tool takes the elevation raster (Step 2) and the weighted average stream elevation (Step 8) and subtracts the value of the weighted average stream elevation from the elevation raster on a cell-by-cell basis. The output is the HAR raster. A closeup of the HAR raster for the LiDAR water-surface profile is shown on Figure A-8a, with the HAR raster for the entire pilot-study reach shown on Figure A-8b.

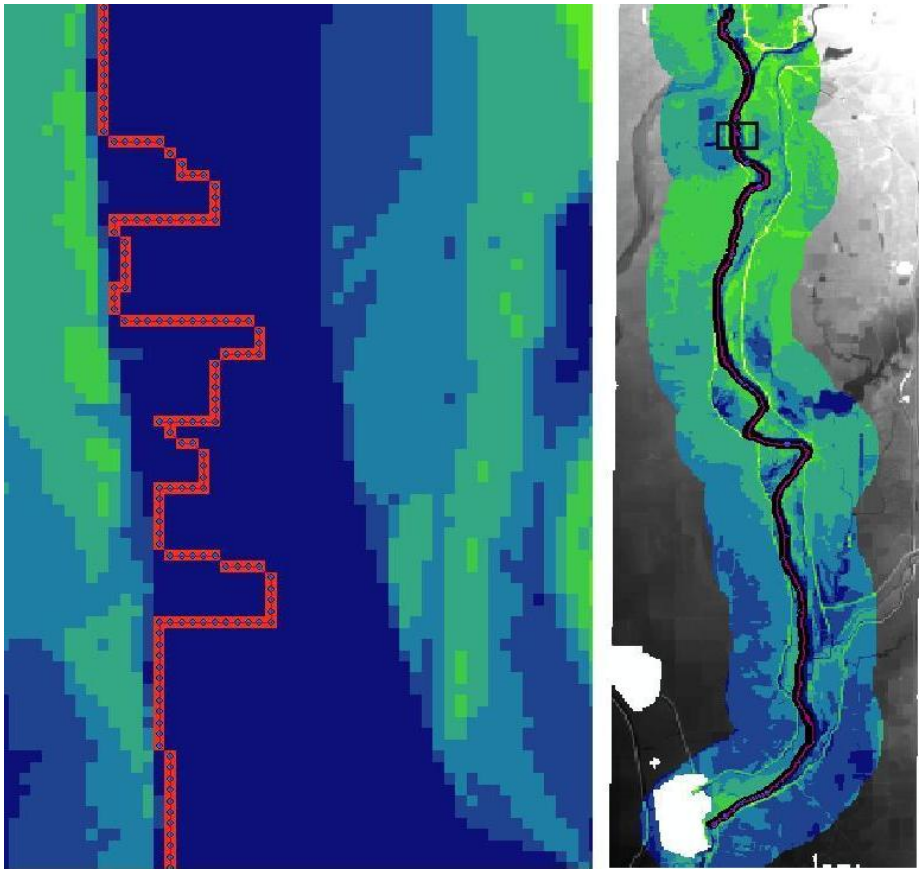

Figure A-8. HAR Closeup (8a) and Pilot Study Reach (8b)

2.6 Calculate Flood Height

A Calculate Flood Height tool is provided in the Riparian Topography Tools toolbox; however, in lieu of this approach, flood height was estimated by changing the symbology of the HAR raster. This method proved to be quicker, provided equivalent results, and involved the following steps:

1. The HAR raster was brought into ArcMap. Pyramids were built when prompted to improve image quality.

2. The HAR raster Properties were selected by right-clicking the HAR raster and clicking Properties.

3. Layer Properties – The Symbology tab was selected and the Show entered "Classified" was choosen and Compute Histogram was activated by clicking Yes when prompted.

4. Classification – The Natural Breaks (Jenks) – The Classify button was clicked to open the Classification menu box. User selects number of Breaks.

5. Break Values – These values were set so the lowest value in the HAR raster was in the same Break Value range as the height of the flooding. No other values were changed because the flood height was the only value necessary. The OK button was selected when values were set.

6. Layer Properties – Color Ramp – Symbol, Range, Label – The symbol for the range containing the lowest HAR raster value and the flood height value was changed to a color different from the rest of the ranges.

2.7 Calculate Inundation Area

The "Calculate Inundation Area" tool was located by navigating through the Riparian Topography Tools toolbox as follows: Riparian Topography Tools → Calculate Inundation Area→ right-click → edit. The "Calculate Inundation Area" tool methodology is shown in a flow chart on Figure A-9, where blue ovals indicate data entry steps, the yellow boxes are tool processes, and the green ovals are outputs from processes. The steps in the methodology are described as follows in the order that they were accomplished during the pilot study:

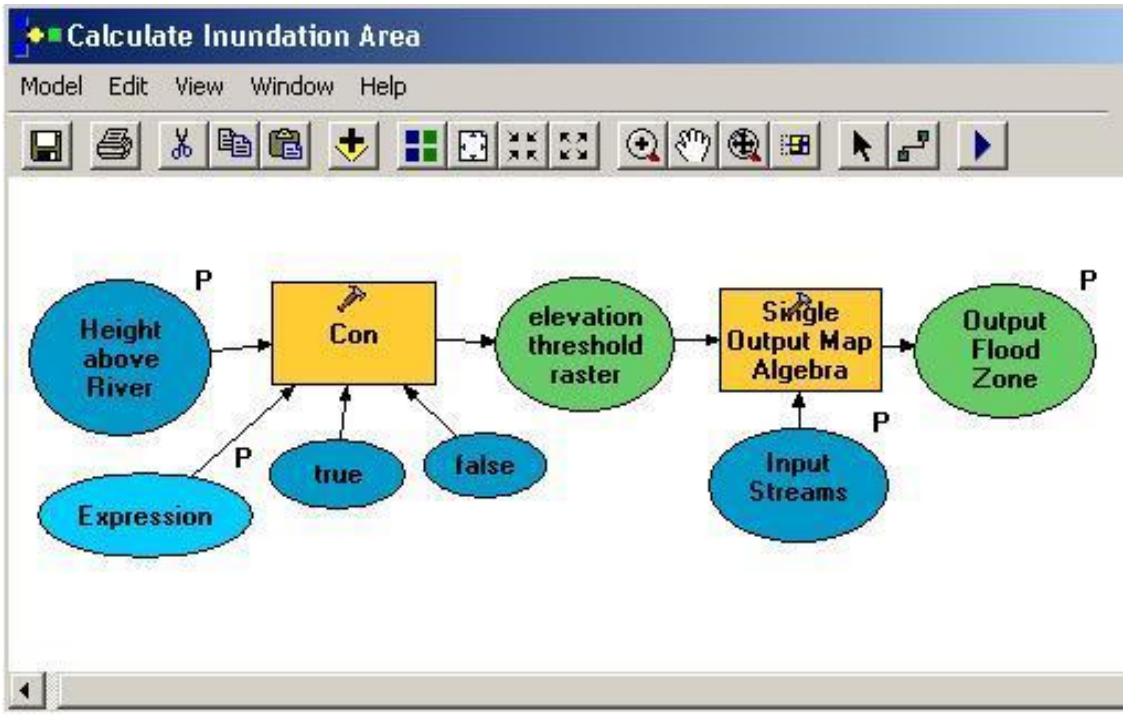

Figure A-9. Calculate Inundation Area

1. **Height above River Raster** – Browse to location of HAR raster and input file path.

2. **Input streams** – Browse to location of stream raster and input file path.

3. **Expression (optional)** – The value entered here is the height above the FIP water-surface profile, and it sets threshold elevation and code values either above or below this surface, with the cells below the FIP value directly connected to the river. Through trial and error we determined that the minimum value to enter here is 1.0 foot owing to the elevation variability imposed on the true water surface by the FIP method.

4. **Output flood zone** – Assign raster location and filename for inundation area.

2.8 Levee Realignment Methodology

Within the Feather River pilot-study reach, the project team noted that there were two locations where levees had been set back after the March 2008 date of the LiDAR flight. This resulted in a need to adjust the DEM terrain surface to show actual current topographic conditions. While the FIP output in this technical memorandum still shows the March 2008 levee

positions, a separate effort was made to determine a reasonable methodology to adjust levee locations for subsequent FIP analyses. This methodology is described in Appendix D6-D.

2.9 Height Above River Results

The LiDAR water-surface profile FIP results are shown on Figure A-10, together with an aerial photograph of the same location in the pilot study reach. Only heights above the river (water surface) are shown with increasingly lighter colors representing land areas higher above the water surface.

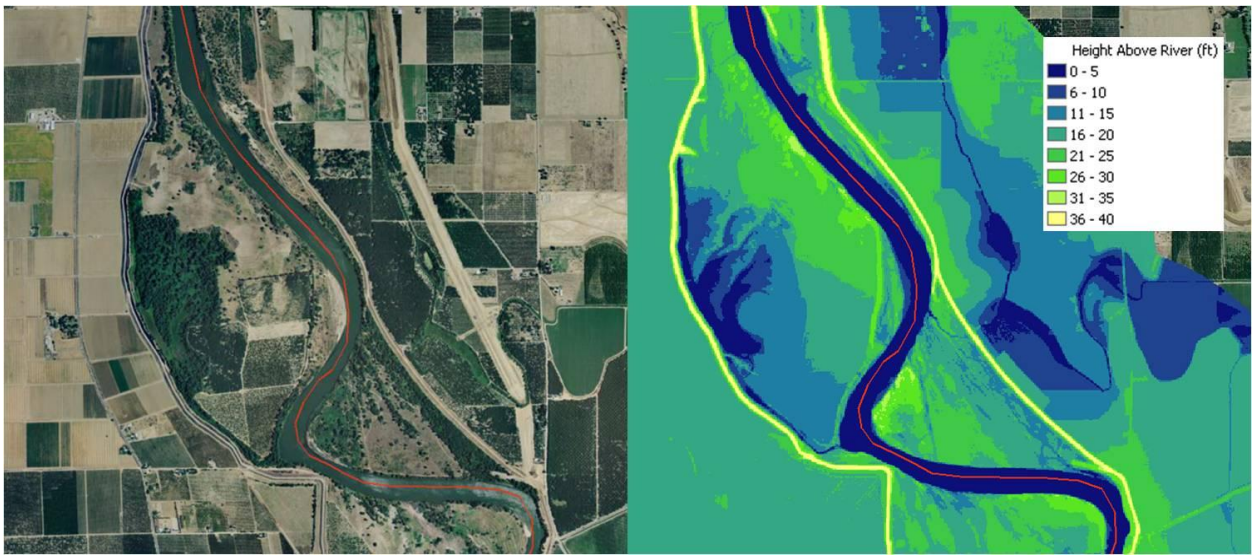

Figure A-10. LiDAR Water-Surface Profile FIP Output

This initial FIP analysis used the actual WSEL at the time of the CVFED LiDAR flights to define the FIP. The CVFED LiDAR data was flown between March 17, 2008, and March 31, 2008, when the flow was approximately 660 to 670 cubic feet per second (cfs).

The FIP output allows for a quick assessment of adjacent floodplain lands at or below the water surface of the river and above the water surface. In this particular location, the relative extent of low-lying lands west of the river is apparent (where the forested area is shown on the aerial photograph), and it is clear that this area is hydraulically connected only at the downstream end.

Other low-lying land areas are east of the river, immediately landward of the east levee. However, it is noted that in this particular reach of the Feather River, levee setbacks have occurred since the LiDAR flight date,

and a portion of the levee locations shown on Figure A-10 are outdated. A technique was developed to realign levees on the DEM; this method was discussed in Section 2.2.8 and will be applied to levee sections where recent restoration projects have resulted in a change in levee alignments since the LiDAR flights in March 2008.

The 50 percent chance water-surface profile (corresponding to a discharge of approximately 80,258 cfs) was added into the DEM and run through the HAR tool. The results shown on Figure A-11 now include depths below the 50 percent chance water-surface profile, as well as above. Land elevations within +/-1 foot of the 50 percent chance water-surface profile are shown in the lightest shade of blue, with depths below this surface shown as increasingly darker shades of blue and heights above this surface shown in white. A +/- 1-foot height was used to approximate a given water surface for mapping purposes because the kernel density radius interpolation of elevation points at hydraulic model cross sections that was used to calculate the water surface resulted in an undulating surface (i.e., the interpolation routine between points of known elevation resulted in estimated elevations that varied within 1-foot of true values). The mapped area includes land area within a 7,000-foot search radius from the stream centerline, with blue shading indicating inundation areas connected to the river and gray shading indicating inundation areas disconnected from the river.

At a glance, it is clear that much of the floodplain land area in this portion of the pilot-study reach is below the 50 percent chance water-surface profile, except for the upper portion of the reach, as shown on Figure A-11.

Figure A-12 provides similar FIP output for the 10 percent chance water-surface profile (corresponding to a discharge of approximately 159,912 cfs). The color ramping of the depth increments below and of the height increments above the water surface and the scaling is consistent between the 50 and 10 percent chance FIP results, and it indicates that floodplain land area throughout the pilot-study reach is significantly below the 10 percent chance water-surface profile, with the levees being the only land features above the water surface.

2.10 Inundation Area Results

The Calculate Inundation Area tool floods all raster cells below a user-specified FIP and shows flooded land areas that are directly connected to the river. The connected and disconnected inundation areas for a portion of the pilot-study reach are shown on Figures A-11 and A-12. The connected and disconnected inundation areas for the entire pilot-study reach for the LiDAR flight (March 17 to 31, 2008), the 50 percent chance, and

10 percent chance flood profiles are provided in Appendix D6-E. As expected, the inundation areas for the return period flood events are contained within the levees.

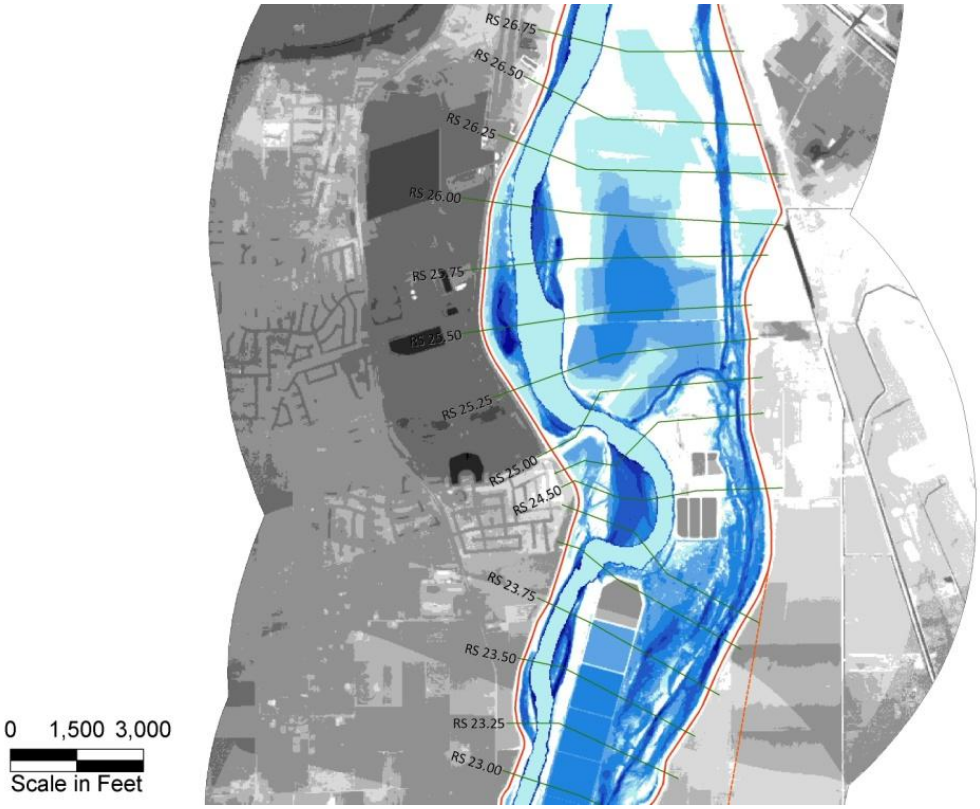

Figure A-11. 50 Percent Chance Water-Surface Profile FIP Output

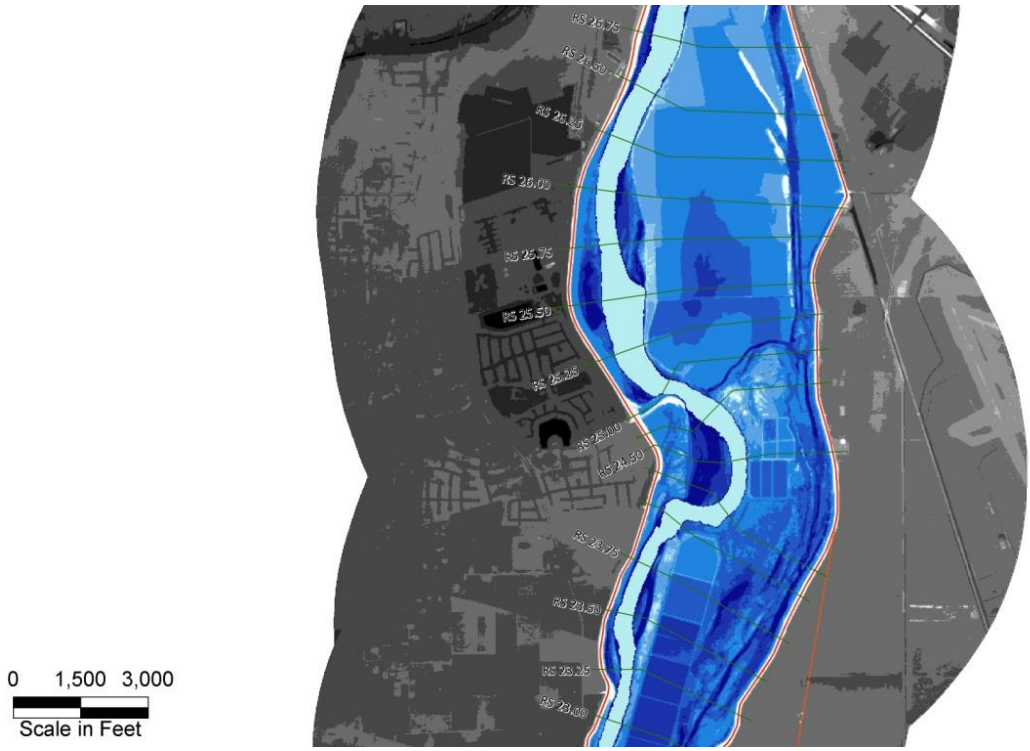

Figure A-12. 10 Percent Chance Water-Surface Profile FIP Output

After a review of these figures, a question arose as to whether the 50 percent chance flood would actually flood most of the land areas between the levees. The HEC-RAS modeling was reviewed to confirm the lateral extent of the 50 percent chance flood. Figure A-13 shows a representative cross section of the 50 percent chance flood stage at RS 19.00 on the Feather River, between the Yuba and Bear river confluences. The 50 percent chance discharge is 80,258 cfs, and the associated 50 percent chance water surface elevation is 47.99 feet. The LiDAR-based water surface elevation at the same location is between 26 feet and 27 feet, or approximately 20 feet lower than the 50 percent chance flood stage.

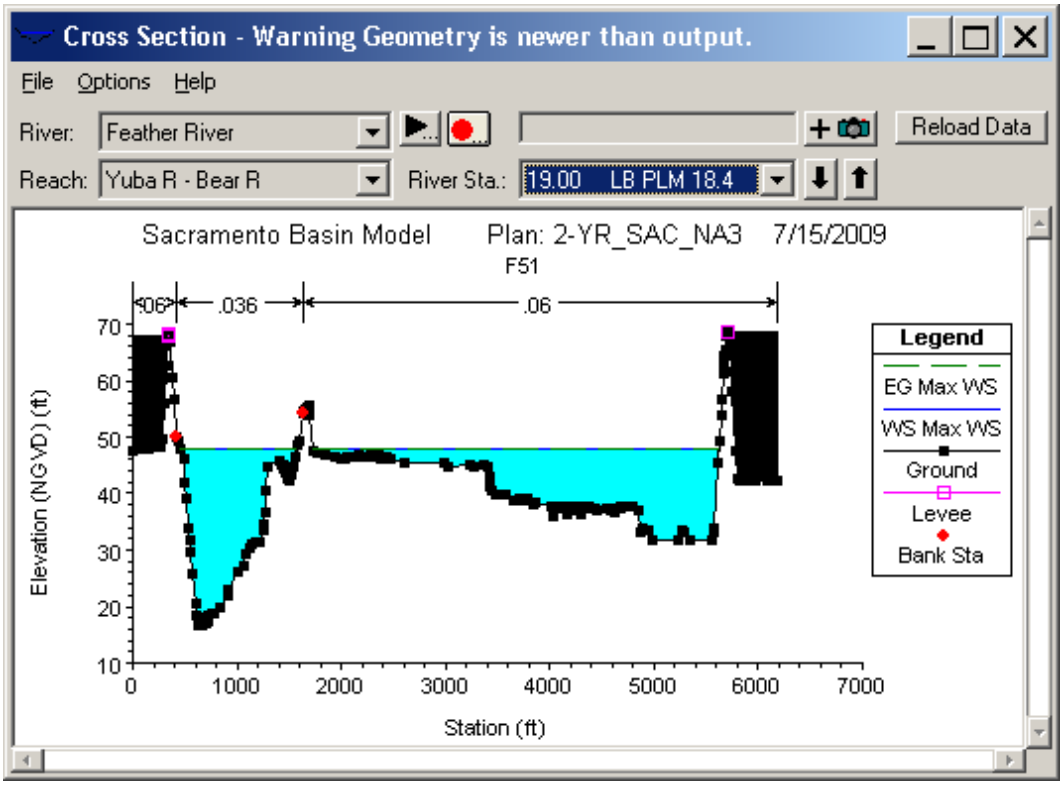

Figure A-13. Cross Section of 50 Percent Chance Flood Profile (RS 19.00)

While the right overbank area appears to be disconnected from the channel, based on the cross-section plot alone, it is possible that this overbank area is connected to the main channel upstream or downstream. Based on the results of the FIP mapping, areas were classified as either "connected" or "disconnected" to the main channel. Disconnected areas do not directly connect to the main channel.

The spatial data on inundation depths for the 50 percent chance and 10 percent chance flood events were summarized in a tabular format and are provided in Table A-1. Recognizing that the connected areas are constrained by the physical presence of levees and the disconnected areas are constrained between the levees and an imposed 7,000-foot search radius from the stream centerline, the relative change in inundation areas by depth was reviewed. For the 50 percent chance flood, the majority of the inundation area falls within the minus 2-foot to minus 9.9-foot depth classes and, as expected, the 10 percent chance inundation area falls within the deeper minus 5-foot to minus 19.9-foot depth classes. Looking at the totals, the 10 percent chance flood only inundates 3,200 additional areas than the 50 percent chance flood, about a 7 percent increase.

Table A-1. Areas of Inundation Depths at 50% and 10% Chance Flood Events

Depth Range	Areas of Inundation Depths at 50% and 10% Chance Flood Events (Acres)			
	50% Chance Connected	50% Chance Disconnected	10% Chance Connected	10% Chance Disconnected
< - 20 feet	200	300	900	1,900
- 15.0 to - 19.9 feet	400	1,100	1,400	7,800
- 10.0 to - 14.9 feet	900	4,600	2,600	15,200
- 5.0 to - 9.9 feet	2,200	13,100	2,600	6,400
- 2.0 to - 4.9 feet	1,800	7,400	700	1,100
- 1.0 to - 1.9 feet	600	1,800	100	200
1 to - 0.9 foot	2,100	3,500	1,300	1,400
Total	**8,200**	**31,800**	**9,600**	**34,000**

2.11 Conclusions

The FIP method is a relatively effective way to quickly and easily find features on the land surface that are either above or below a specified water-surface profile.

The GIS spatial output from the FIP method can provide a benefit for the visualization of floodplain restoration opportunities for planning or reconnaissance-level investigations, including the following specific considerations:

1. Color ramping of FIP output showing height increments both above the river (water surface) and below can provide a rapid visualization of the low-lying land areas physically connected to a river channel, or capable of being connected, and the relative depth of these topographic depressions.

2. The relative depth of adjacent topographic depressions can also be referenced to qualitatively assess the level of effort (e.g., earthwork) necessary for setback levees and/or floodplain terracing as a floodplain restoration technique; for example, setback levees aligned across a topographic depression will require a greater amount of fill to maintain a certain levee crest elevation than if the levee was aligned around the topographic depression on higher ground.

3. The Comprehensive Study HEC-RAS models are limited in extent, in that the model cross sections of the floodplain only extend between the levees (USACE and The Reclamation Board, 2002). The FIP output

provides estimates of flood profile elevations and flood depths beyond the levees, and this information can be used to guide qualitative investigations into potential levee setback locations. Although the FIP method is not a substitute for detailed hydraulic modeling, it does provide an ability to relatively quickly understand flood characteristics across the floodplain landscape.

Mr. Dilts has recently begun to update his tools and has provided his unpublished versions for use on this pilot study. Because of this, the generation of the Stream Raster, which is a very important component to the FIP, is now automated and can be applied more quickly to future FIP investigations.

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3.0 Hydrologic Engineering Center's Ecosystem Functions Model Pilot Study

This section summarizes the HEC-EFM pilot study in four sections:

- 3.1, Methods
- 3.2, Results and Sensitivity
- 3.3, Mapping
- 3.4, Conclusions

3.1 Methods

This section describes the methods and approaches used to perform the HEC-RAS/HEC-EFM (RAS/EFM) analysis on the lower Feather River near Yuba City, California. As discussed, the goal of this study was to document the standard methods and approaches required for a RAS/EFM analysis and to identify potential issues, if any, and/or alternative approaches. The following tasks were conducted as part of the RAS/EFM analysis:

- Selection of the pilot-study area
- Data collection and review
- Identification of Habitat Analysis Areas (HAA)
- HEC-RAS modeling
- HEC-EFM analysis

The remainder of this section describes these tasks in more detail.

3.1.1 Selection of the Pilot-Study Area

The pilot study was conducted on a 21-mile reach of the lower Feather River, from the confluence with the Sutter Bypass, upstream to Yuba City at RS 27.75 (see Figure A-14). The area was chosen for the availability of data and the project team's familiarity with the area. Within the study area, the lower Feather River maintains levees along both banks and receives

flow from the Yuba and Bear rivers. It also maintains inflows and outflows resulting from agricultural and groundwater sources.

3.1.2 Data Collection and Review

A steady-state, geo-referenced HEC-RAS model of the Feather River, from the confluence with the Sutter Bypass to the Thermalito Afterbay, and synthetic daily flow hydrographs from October 1, 1921, to September 30, 2003, were provided to AECOM by MWH Americas, Inc. (MWH).

The HEC-RAS model was developed by MWH based on the Feather River Sacramento-San Joaquin Comprehensive Study UNET hydraulic model (USACE and The Reclamation Board 2002). MWH converted the original Comprehensive Study UNET model to HEC-RAS, geo-referenced the model, and calibrated the model to low-flow conditions. The model files were provided via FTP on November 30, 2010.

The Feather River synthetic daily flow hydrographs were developed by MWH from monthly flow hydrographs computed by the CalSim model. Hydrographs were provided by MWH via e-mail on December 8, 2010. Development methodology for the synthetic daily flow hydrographs was

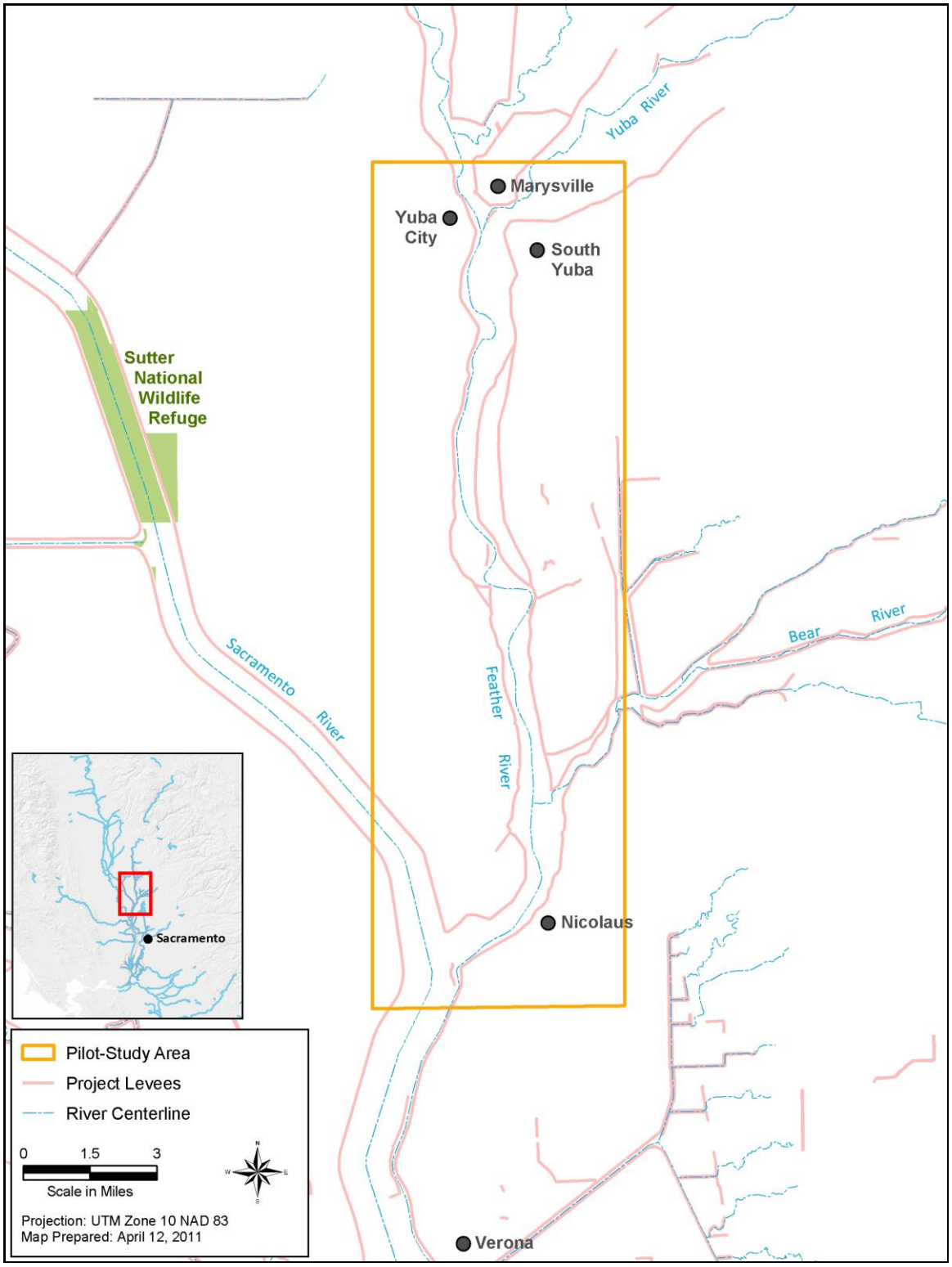

Figure A-14. Lower Feather River Pilot-Study Area

outlined in a draft document prepared by MWH, titled *Feather River Daily Flows for HEC-EFM* (2011). This document is currently being finalized by MWH and will be submitted to California Department of Water Resources (DWR) separately from this report.

The following actions were performed during the review and application of the HEC-RAS model and synthetic daily flow hydrographs.

1. The model was reviewed briefly to confirm its appropriateness for this study and to review the geo-referencing, reach lengths, and Manning's *n* values. Detailed features or assumptions, such as the value of coefficients, the stations, and elevations of levees and ineffective flows areas, and other detailed aspects of the model were not reviewed.

2. Areas of the model upstream from the Feather River and Yuba River confluence were removed and the upstream boundary was set to RS 27.75. This was done to remove unnecessary complexities upstream from the study area. Figure A-15 shows an overview of the revised HEC-RAS model.

3. An unsteady-state version of the model was developed, requiring the following actions:

    a. Modification of the model geometry

    An inline weir was added at RS 24.00 to improve model stability at the Shanghai Bend Falls, where a sudden change in the channel invert can produce super-critical and unstable conditions. The model was adjusted from the original NGVD29 datum to match the terrain datum, NAVD88, by adding 2.335 feet (see AECOM's Technical Memorandum (TM) – Height Above River Investigations (AECOM, 2011a)). The model geometry was not updated using the LiDAR-derived DEMs as described in the Scope of Sub-Consultancy Services Subtask 3.3.1.d, "recut floodplain cross-section data, combine with channel geometry." This task was not performed because official DWR review of LiDAR-derived DEMs was not complete.

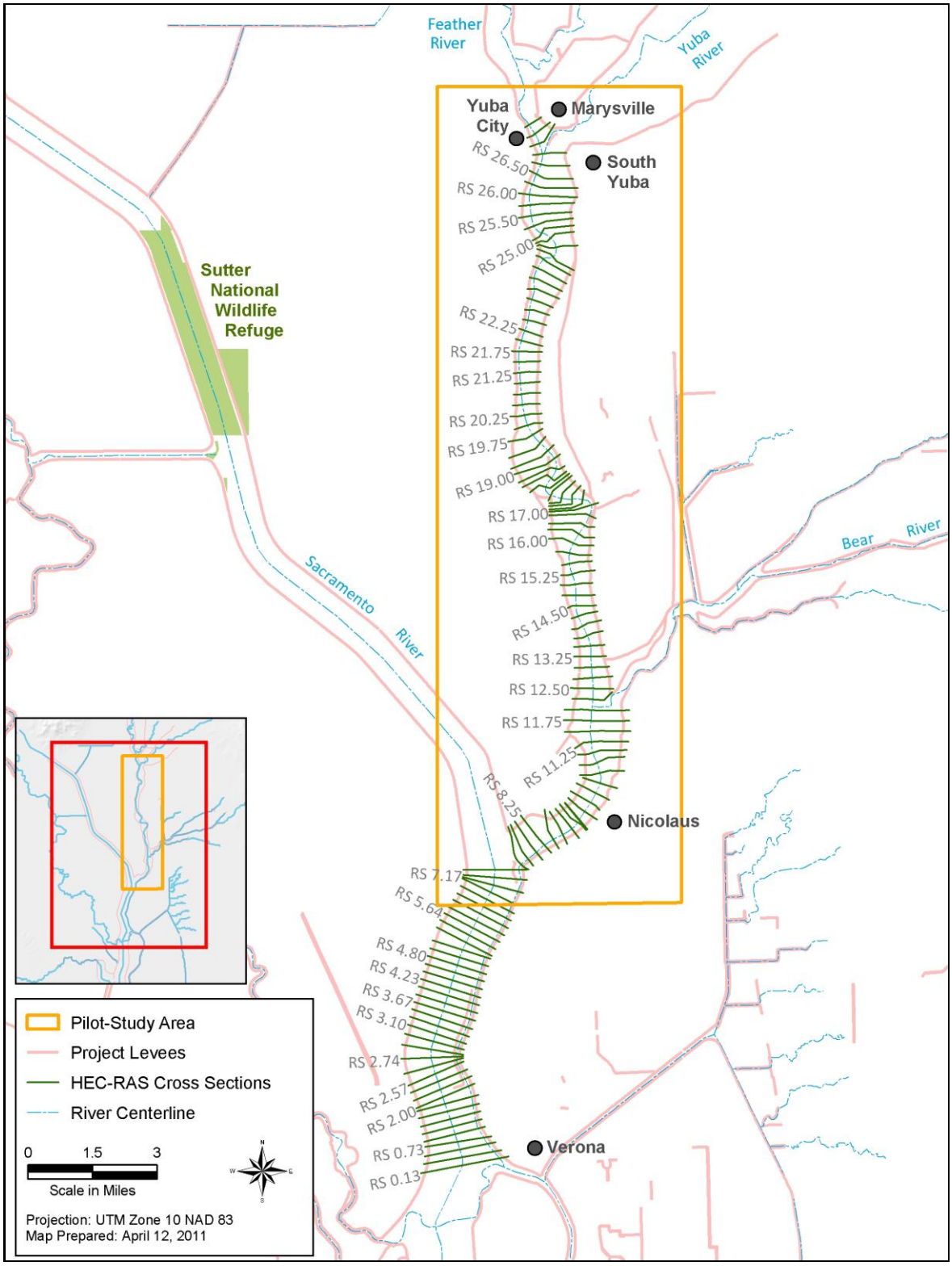

Figure A-15. Revised HEC-RAS Model

b. Development of unsteady-state boundary conditions

Unsteady-state boundary conditions were developed to simulate the synthetic period. The downstream boundary condition at RS 0.13 was set to normal depth with a friction slope of 0.0002 (0.02 percent). The upstream boundary condition at RS 27.75 was set to read the daily synthetic flow hydrograph provided by MWH at Yuba City. Inflows and outflows between Yuba City and the Sutter Bypass were applied based on the synthetic daily flow hydrographs provided by MWH.

c. Review of synthetic hydrographs

The hydrographs provided by MWH included synthetic daily-average flows from October 1, 1921, to September 30, 2003, at locations along the Feather River. The flows were developed from the CalSim State Water Project (SWP)/Central Valley Project (CVP) monthly simulation model.

The flow in the Feather River is controlled by water operations at the upstream Oroville Reservoir. Because of changes in Oroville operations to meet increasing demands both for water supply and environmental purposes, historical flows may not provide the best representation of future flows in the Feather River.

The CalSim model is specifically designed to evaluate the operations of Oroville Reservoir, and the flows in the Feather River, under potential conditions assuming that the historical precipitation from October 1921 through September 2003 reoccurs. The resulting flows may provide a better representation of expected future flows than historical flows.

The synthetic daily average flows provided by MWH to observed daily average flows at USGS flow gages (see Table A-2) were compared to determine whether the synthetic flows provided reasonable values. Figures A-16 and A-17 compare daily averaged flows and resulting flow duration curves for the period of October 1, 1969, through September 30, 1976, (Water Year (WY) 1970 through WY 1976) at Nicolaus (see Figures E-1 through E-4 in Appendix D6-E for the Yuba City and Shanghai Bend locations). The selected period of record represents a time frame when the USGS gages were all in operation.

The comparison illustrates that while the synthetic daily averaged flows often do not reproduce individual daily averaged flows, they do reproduce the various high- and low-flow events. This is

confirmed by the flow duration curves, which closely match the observed flow duration curves, although flows are consistently lower than observed.

Table A-2. USGS Gages Within the Pilot-Study Area

USGS Gage No.	Name	Period of Record
11407700	Feather River at Yuba City	10/01/1964–9/30/1976
11421700	Feather River below Shanghai Bend, near Olivehurst, California	10/01/1969–9/30/1980
11425000	Feather River near Nicolaus, California	10/01/1943–9/30/1983

Source: Data downloaded by AECOM in 2011 from USGS, 2011
Key:
USGS = U.S. Geological Survey

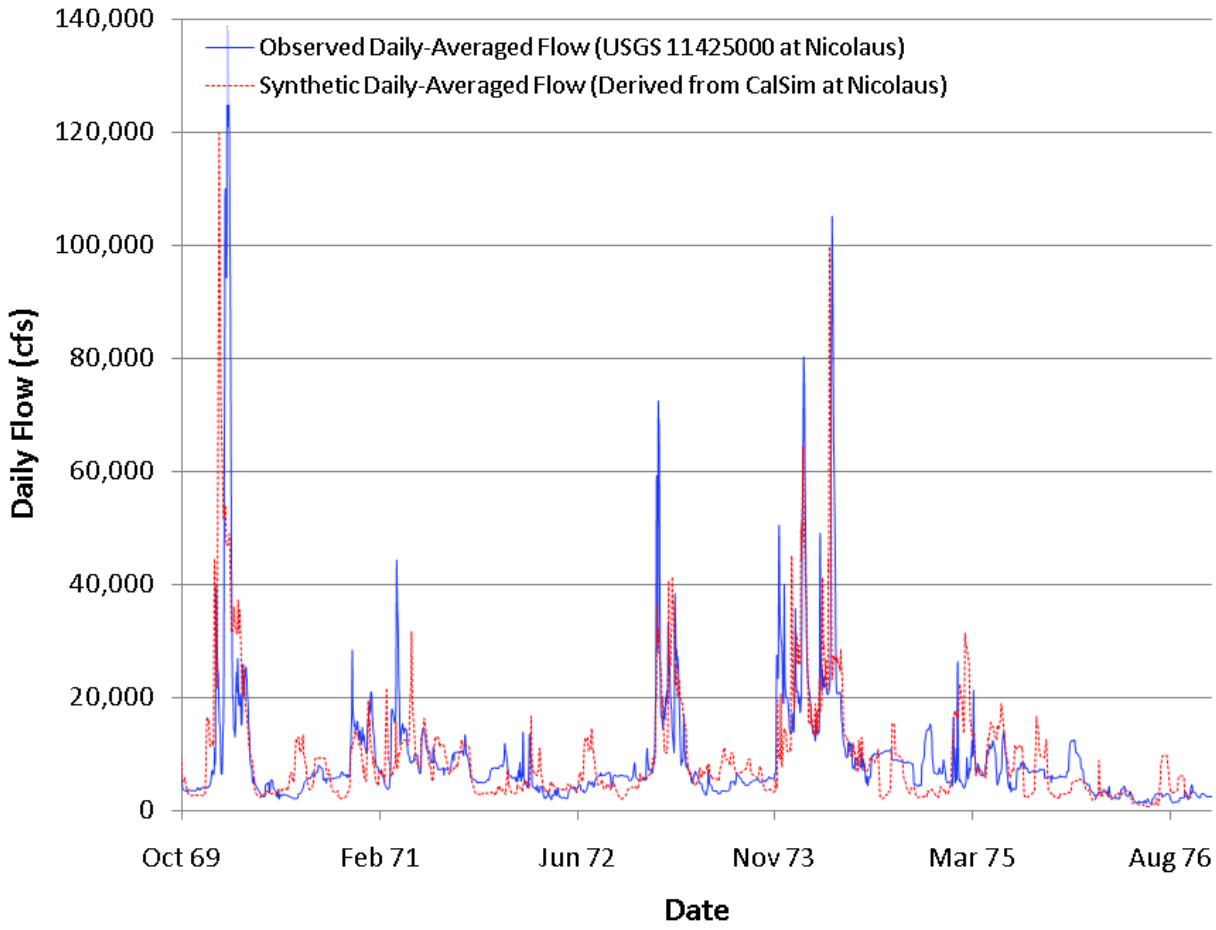

Figure A-16. Synthetic vs. Observed Daily-Averaged Flow – Nicolaus

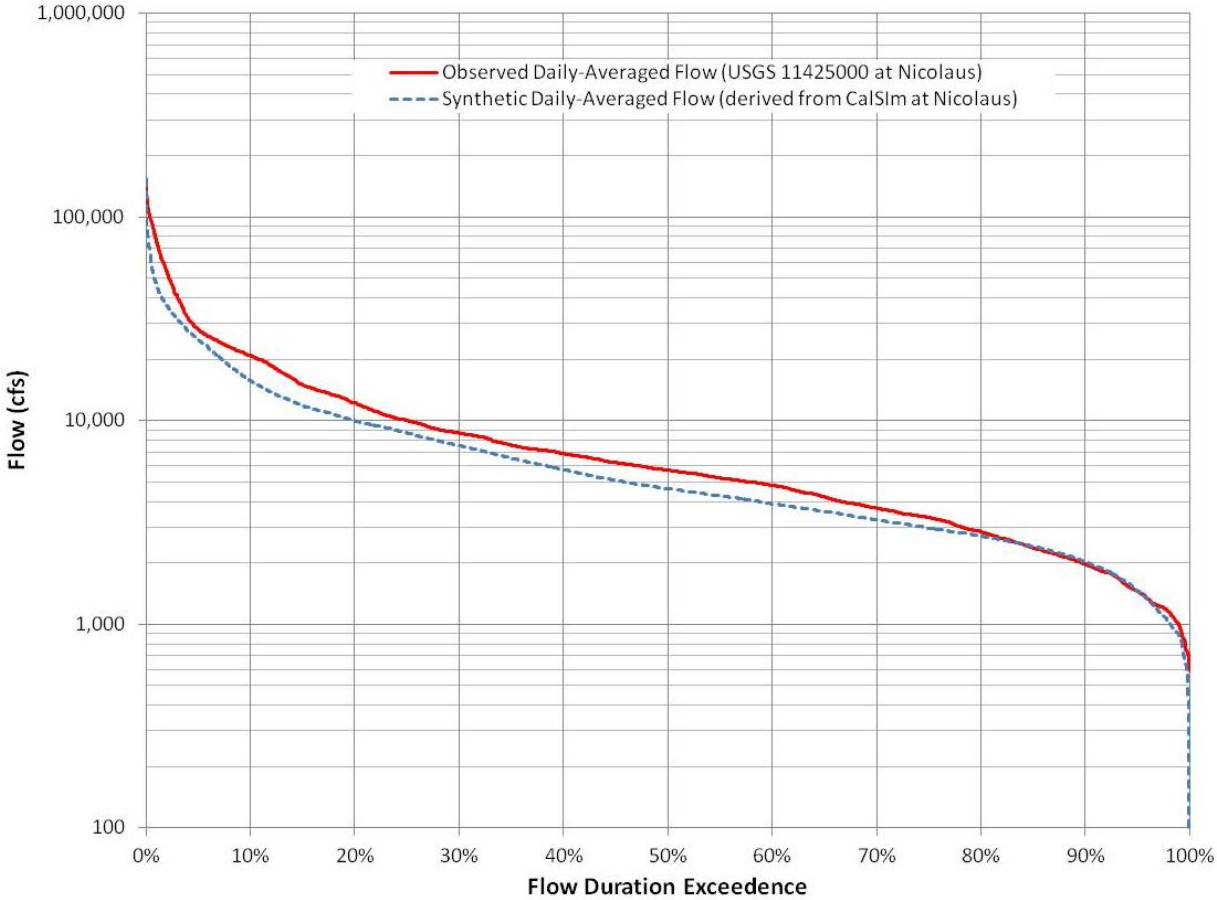

Figure A-17. Synthetic vs. Observed Flow Duration Curve – Nicolaus

d. Modification of synthetic hydrographs for HEC-RAS

The synthetic daily flow hydrographs provided by MWH were modified to be used in the HEC-RAS unsteady-state model. Since each synthetic hydrograph corresponded to the entire channel flow and not the individual inflows and outflows from tributaries, groundwater, agriculture, or other sources, the hydrographs could not be applied directly to the model.

Each Feather River flow hydrograph was subtracted from the upstream hydrograph to produce a hydrograph representing the net accretion (Feather River flow increase) or depletion (Feather River flow decrease) between Feather River flow hydrographs. For example, to estimate the accretion or depletion between the upstream boundary of the model at Yuba City (RS 27.75) and the Yuba River confluence (RS 27.25), flows at Yuba City were subtracted from the flows at the Yuba River confluence. This provided a daily time series of the total net change in flow between Yuba City and the Yuba River confluence. In general, the majority

of this change can be attributed to the Yuba River, so the daily time series was applied as the Yuba River inflow hydrograph. This process was repeated at the Bear River confluence (RS 12.25) and at Nicolaus (RS 9.75).

Figure A-18 shows the synthetic daily flow at Yuba River and Nicolaus, as well as the hydrographs produced using the approach above. As shown, this process sometimes results in depletions (see time series "Net Change in Flow from Bear River to Nicolaus"). These depletions correspond to losses in flow between the Bear River and Nicolaus as a result of groundwater and agricultural withdrawals. HEC-RAS handles depletions by removing the flow from the system, which often causes instabilities for unsteady-state models. In this example, the model failed near Nicolaus when the depletions resulted in zero flow at the downstream end. Since the downstream boundary is based on normal depth, which is based in part on flow, the model failed to converge on a solution. To maintain positive flow at the downstream end, a constant flow of 50 cfs was added at RS 9.50. While this introduces a fictitious flow to the system, it is relatively small and does not significantly impact modeled stages or flows.

3.1.3 Identification of Habitat Analysis Areas

The pilot-study area was subdivided into regions, defined as HAAs. For each HAA, a RAS/EFM analysis was performed and the results were mapped in GIS. Table A-3 and Figure A-19 show each HAA, their upstream and downstream bounding cross sections, and a single "representative" cross section. Defining HAAs is critically important to the RAS/EFM analysis because HAAs are viewed by HEC-EFM as maintaining homogenous hydraulic and ecological properties. For example, HEC-EFM assumes that the flow and stage relationship at RS 11.00 is the same for all cross sections between RS 9.75 and RS 12.00. HAAs were therefore subdivided where flow changes occur, where hydraulic structures control, or where the water surface slope was significant. HAAs were subdivided at the Yuba and Bear rivers, upstream from bridges, and at Shanghai Bend.

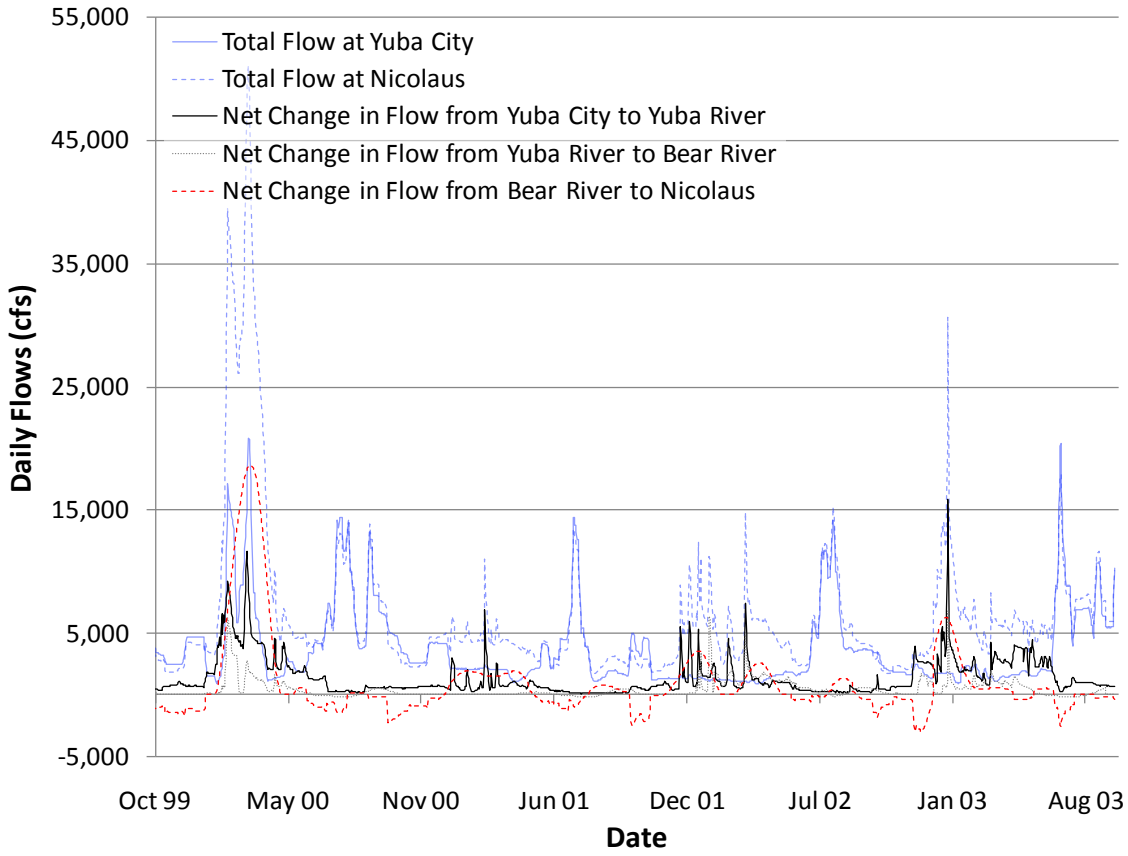

Figure A-18. Revised Daily Flow Time Series Hydrographs

Table A-3. Habitat Analysis Areas

Bounding Cross Sections	Representative Cross Sections
7.55–9.50	8.50
9.75–12.00	11.00
12.25–14.50	13.25
14.75–16.75	15.75
17.00–21.00	19.00
21.25–23.75	22.50
24.00–25.25	24.50
25.50–27.00	26.25

Source: Data generated by AECOM for this report in 2011

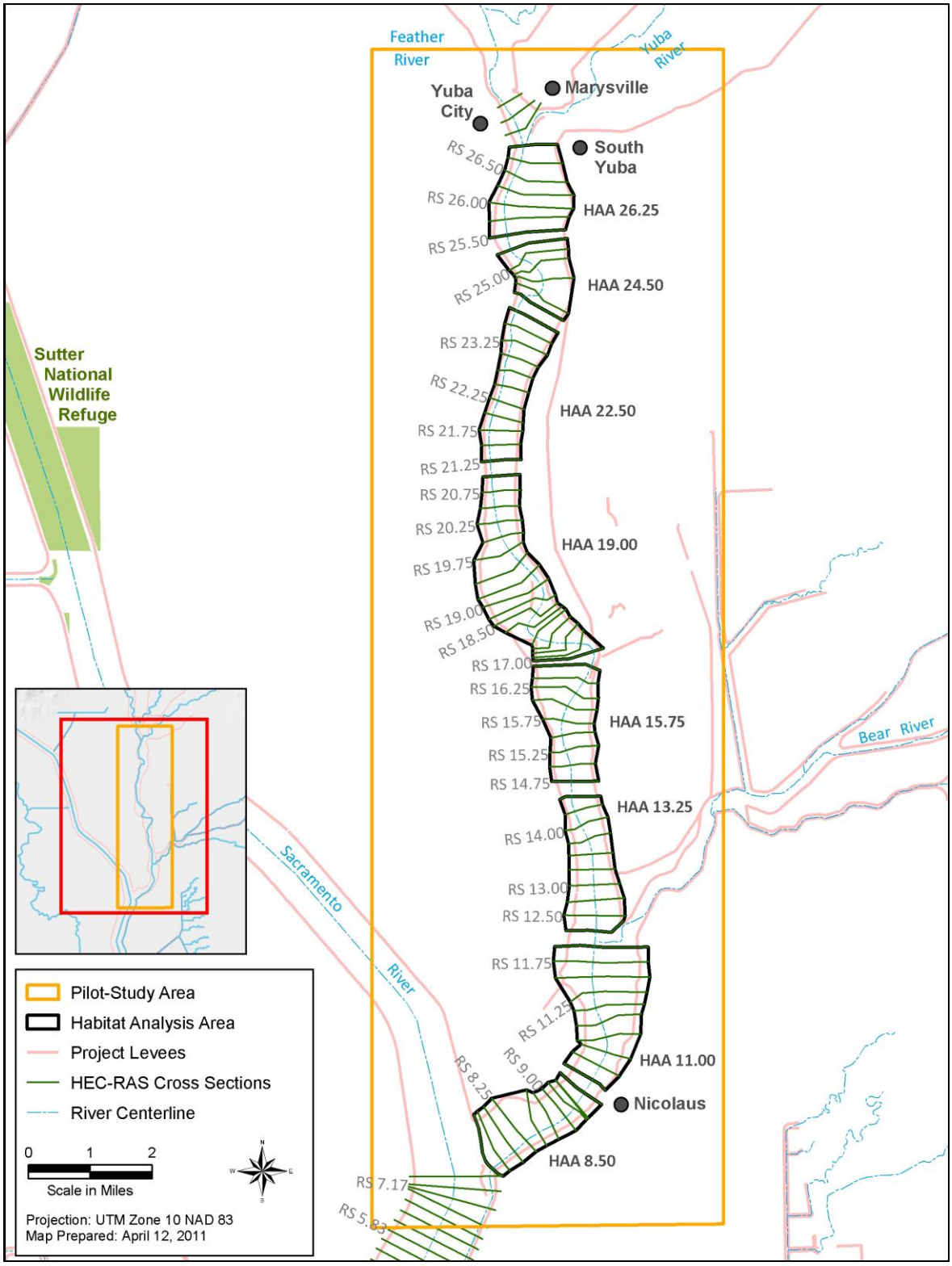

Figure A-19. Habitat Analysis Areas

3.1.4 HEC-RAS Modeling

Once HAAs were identified, the HEC-RAS unsteady-state model was used to produce synthetic stage and flow hydrographs at each representative cross section. These hydrographs were stored in a HEC Data Storage System (HEC-DSS) format database and used as input to HEC-EFM. In addition, a series of steady-state flow profiles was simulated to produce rating curves at each representative cross section. These rating curves were then used during the HEC-EFM modeling, as discussed in the following section.

3.1.5 HEC-EFM Modeling

The HEC-EFM portion of the RAS/EFM analysis consisted of analyzing synthetic stage and flow hydrographs produced by HEC-RAS to determine if and when HEC-EFM Ecosystem Function Relationship (EFR) conditions were met. These conditions, defined by the user, include seasonality, duration, rate of change, and/or return frequency as a function of stage and flow.

Using the stage and flow hydrographs developed by the HEC-RAS unsteady-state model, a HEC-EFM "flow regime" was created for each HAA. These flow regimes identify the flow and stage hydrographs that correspond to each HAA. EFRs were obtained from Table 3 in the September 2010 draft of *2012 Central Valley Flood Protection Plan—Ecosystem Functions Model* (AECOM, 2010b). A summary of each EFR, directly from the above report, is provided in Table A-4. The EFRs used in this study included Salmonid-Rearing Habitat Formation, riparian Cottonwood Seedling Germination, riparian Cottonwood Seedling Inundation (death), and riparian Cottonwood Recruitment. Each EFR was added to HEC-EFM and is shown on Figures F-1 through F-4 in Appendix D-9F.

HEC-EFM was then used to analyze each EFR and HAA. HEC-EFM first performs a statistical analysis on each stage and flow hydrograph for each EFR to determine if and when conditions of the EFRs are met. During this analysis, HEC-EFM produces a stage-flow rating curve for each flow regime based on a statistical sampling of the stage and flow hydrographs. If conditions of the EFR are met, the flow or stage that meets the conditions is then used in conjunction with the rating curve to determine the corresponding flow or stage.

Table A-4. Summary of Ecosystem Functional Relationships

Ecological Process	Summary of Ecosystem Functional Relationship	Flow Parameters			
		Season	Duration	Rate of Change	Event Probability
Riparian Habitat Recruitment	Seedling germination of cottonwood and other early-seral riparian vegetation requires moist soil from April through early June for at least 2 weeks. The river stages must decline at a rate of not more than 1 inch per day to allow newly developing roots to extend with receding river stages. Germination events should occur every 10 years to permit regeneration of new habitat patches.	April 1 to June 15	2 weeks or more	1 inch or less on receding limb of hydrograph	10 percent chance recurrence interval
	Newly germinated cottonwood seedlings are susceptible to death from physiological stress if inundated for prolonged periods of 2 weeks or more following germination.	June 15 to October 30	2 weeks or more	Constant	10 percent chance recurrence interval
	Successful cottonwood recruitment has been documented to occur within specific elevation bands above summer base flow levels.	June 15 to October 30	Constant during time period	Constant	100 percent chance (annual recurrence)
Salmonid-Rearing Habitat	Shallow-water, seasonally inundated floodplains provide valuable rearing habitat for Chinook salmon and steelhead. Ecologically important floodplain inundation is defined as the river stage that is exceeded in at least 2 out of 3 years and sustained for at least 7 days from March 15 to May 15.	March 15 to May 15	1 week or more	Constant	66 percent chance

Source: Data summarized by AECOM in 2011b from USACE, 2002 and ESSA, 2009

An issue was identified during the RAS/EFM analysis that resulted in erroneous stages being produced by HEC-EFM. As discussed, HEC-EFM uses flow and stage hydrographs from HEC-RAS to identify whether the conditions of a given EFR are met. During this process, HEC-EFM develops a rating curve based on the flow and stage hydrograph. If the conditions of the EFR are met, HEC-EFM identifies the corresponding flow or stage and uses the rating curve to determine the complementary flow or stage. While HEC-EFM applies a robust statistical analysis in an attempt to produce a smooth, representative rating curve, for some HAAs the rating curve included erroneous stage values. In some cases, these values were several feet higher than expected, and for Cottonwood Seedling Germination resulted in significant error.

Figure A-20 shows three different rating curves for RS 11.00. The curve shown in red was produced by HEC-EFM, the curve in gray was produced by the HEC-RAS unsteady-state model, and the curve in blue was produced using HEC-RAS steady state as discussed. As shown, the HEC-EFM rating curve includes erroneous stages at several flow rates. As a result of these erroneous stages, HEC-EFM selects values that are not representative of actual conditions. Figure A-21 shows the same rating curves for flow rates up to 15,000 cfs and includes the results of the HEC-EFM analyses for HAA 11.00. This results from the significant amount of hysteresis that occurs at RS 11.00 during the continuous synthetic simulation. Hysteresis is a hydraulic condition in which multiple stages can correspond to a single flow. In general, this occurs when downstream conditions produce backwater that increases the stage during low flows, either because of tidal conditions, a hydraulic structure, or high-flow conditions on a main-steam reach. Within the pilot-study area, hysteresis occurs because (1) the water surface slope is relatively mild at RS 11.00, and (2) the downstream boundary condition is set to normal depth, which allows for a wide range of backwater conditions. The amount of hysteresis is reduced upstream where downstream conditions have minimal impact on stages and where the water surface slope is greater. To address this issue, a HEC-RAS steady-state profile was simulated for flow rates between 100 cfs and 140,000 cfs at 1,000 cfs intervals. This simulation produced the rating curves shown in blue on Figures A-20 and A-21. As demonstrated, this curve matches well with both the HEC-RAS unsteady state and HEC-EFM-derived rating curves. The steady-state rating curve was then used to override the HEC-EFM-derived rating curve.

3.2 Results and Sensitivity

The results of the HEC-EFM analyses are discussed in the following sections. HEC-EFM was initially run using the Sacramento River Ecological Flows Tool (SacEFT)-defined EFRs, which were previously developed for the Sacramento River. To determine whether changes in these EFRs would result in significant changes in the potential habitat area on the lower Feather River pilot-study area, the Cottonwood Seedling Germination and Salmonid Rearing Habitat EFRs were modified. Results for each EFR analyzed are included below.

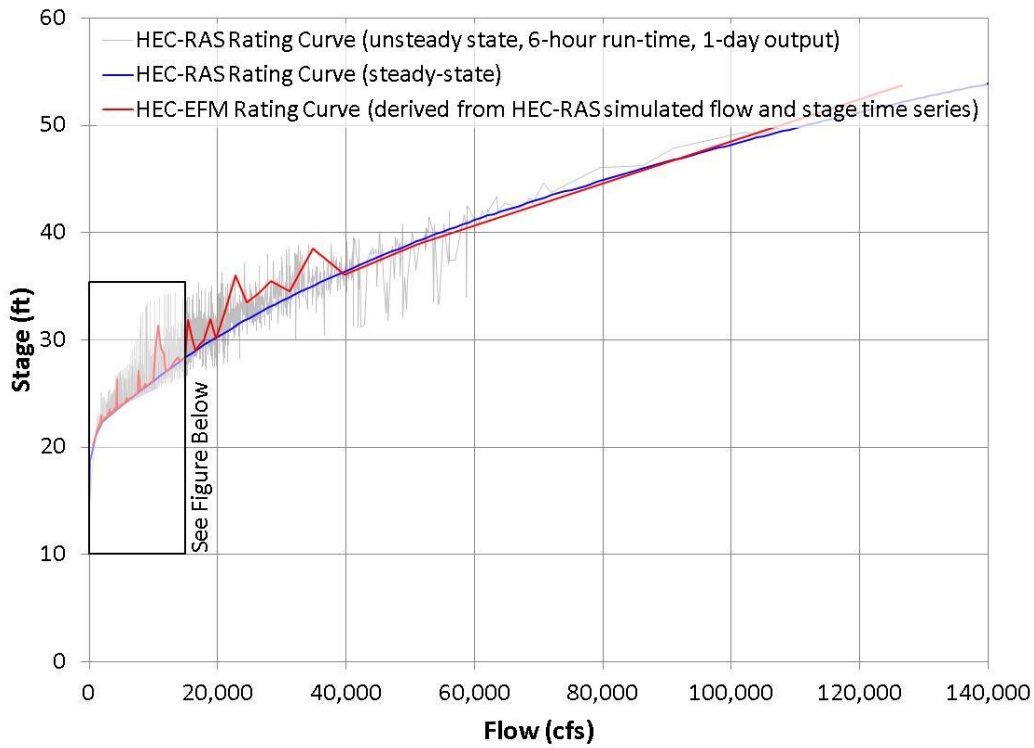

Figure A-20. Comparison of Rating Curves – RS 11.00

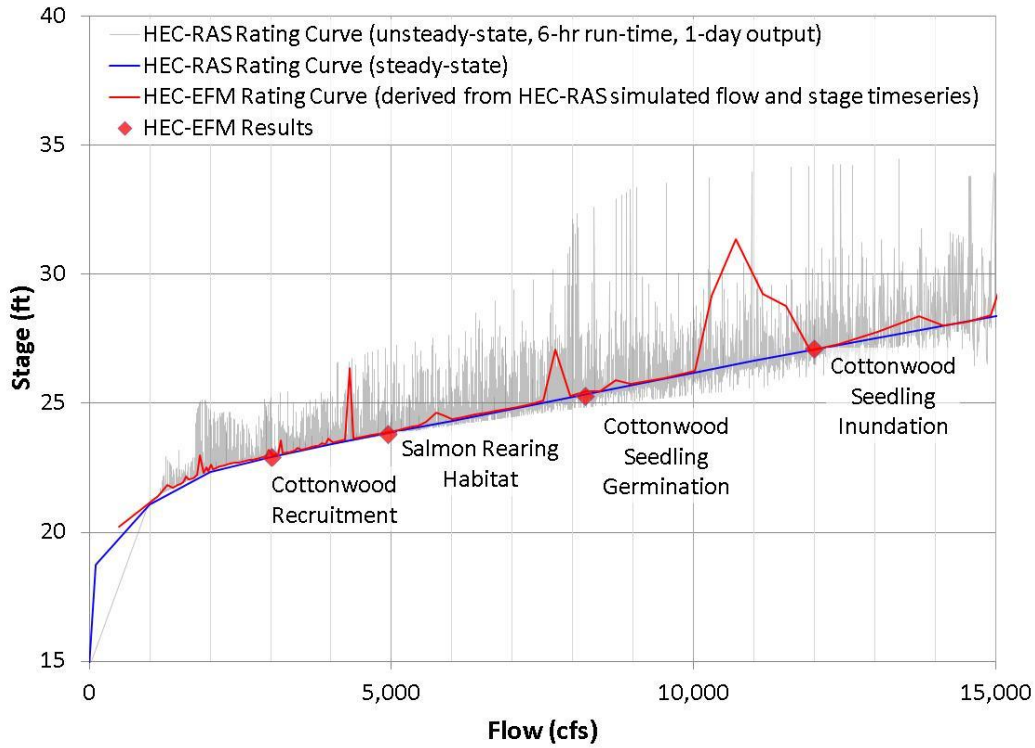

Figure A-21. Comparison of Rating Curves Showing HEC-EFM Results – RS 11.00

3.2.1 SacEFT-Defined EFRs

The results of the HEC-EFM analyses using the SacEFT-defined EFRs are shown in Tables A-5 through A-7. HEC-EFM provides a single flow and stage for each EFR and HAA, if conditions of the EFR are met. The computer processing time required to perform all 32 analyses was approximately 15 minutes.

Table A-5. HEC-EFM Results – RS 26.25–RS 22.50

Ecosystem Function Relationship	RS 26.25		RS 24.50		RS 22.50	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
Cottonwood Seedling Germination	40.6	8,802	40.1	10,710	31.3	5,774
Cottonwood Seedling Inundation	41.8	11,952	40.5	11,953	34.8	11,954
Cottonwood Recruitment	37.7	3,044	37.4	3,029	29.2	3,011
Salmonid Rearing Habitat	38.4	4,142	37.9	4,150	30.2	4,159

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

Table A-6. HEC-EFM Results—RS 19.00–RS 13.25

Ecosystem Function Relationship	RS 19.00		RS 15.75		RS 13.25	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
Cottonwood Seedling Germination	29.9	6,959	28.8	7,845	27.7	7,845
Cottonwood Seedling Inundation	32.4	11,962	30.6	11,965	29.0	11,965
Cottonwood Recruitment	27.2	3,015	26.1	3,044	24.9	3,044
Salmonid Rearing Habitat	28.1	4,181	26.9	4,187	25.6	4,181

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

Table A-7. HEC-EFM Results—RS 11.00–RS 8.50

Ecosystem Function Relationship	RS 11.00		RS 8.50	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
Cottonwood Seedling Germination	25.3	8,198	23.1	7,635
Cottonwood Seedling Inundation	27.1	11,987	25.6	12,316
Cottonwood Recruitment	22.9	3,015	19.1	2,567
Salmonid Rearing Habitat	23.8	4,942	21.8	5,684

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

3.2.2 Modified EFRs

The Cottonwood Seedling Germination and Salmonid Rearing Habitat Formation EFRs were modified to determine whether adjustments to the EFRs would result in significant changes in potential habitat area.

The Cottonwood Seedling Germination EFR Rate of Change of Stage (falling stage) statistical parameter was modified from the SacEFT-defined 1 inch per day to 2 inches per day and 3 inches per day. Also considered was a 1-inch-per-day Rate of Change of Stage from March to July, as opposed to the April to June 15 Sac-EFT-defined values. Lastly, the Rate of Change of Stage parameter was removed and instead germination was analyzed based on the 14-day minimum/maximum parameter (similar to the Cottonwood Seedling Inundation). Tables A-8 through A-10 show the results of these changes.

Table A-8. Cottonwood Seedling Germination Sensitivity – RS 26.25–RS 22.50

Ecosystem Function Relationship	RS 26.25		RS 24.50		RS 22.50	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
1 inch per day	40.6	8,802	40.1	10,710	31.3	5,774
2 inches per day	42.7	14,242	41.3	15,182	35.0	12,395
3 inches per day	42.1	12,587	40.9	13,504	34.3	10,861
March - July	40.4	8,411	40.2	10,909	31.9	6,634
14-day Minimum/Maximum (no Rate of Change)	44.5	19,757	42.4	19,759	38.1	19,760

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

Table A-9. Cottonwood Seedling Germination Sensitivity – RS 19.00–RS 13.25

Ecosystem Function Relationship	RS 19.00		RS 15.75		RS 13.25	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
1 inch per day	29.9	6,959	28.8	7,845	27.7	7,845
2 inches per day	33.1	13,680	31.6	14,361	29.9	14,394
3 inches per day	31.9	10,922	30.2	10,972	28.8	11,598
March - July	30.1	7,407	28.7	7,681	27.5	8,489
14-day Minimum/Maximum (no Rate of Change)	35.5	19,763	33.5	19,764	31.7	19,763

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

Table A-10. Cottonwood Seedling Germination Sensitivity – RS 11.00–RS 8.50

Ecosystem Function Relationship	RS 11.00		RS 8.50	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
1 inch per day	25.3	8,198	23.1	7,635
2 inches per day	28.4	15,074	27.0	15,429
3 inches per day	26.9	11,562	25.1	11,343
March - July	25.6	8,830	23.1	7,756
14-day Minimum/Maximum (no Rate of Change)	30.8	21,427	30.6	24,908

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes
cfs = cubic feet per second
RS = River Station

The following can be concluded:

1. **There appears to be an "optimum" Rate of Change of Stage value that corresponds to a maximum flow and stage and thus maximum potential habitat area.**

   If this optimum Rate of Change of Stage value is considered ecologically "acceptable" (i.e., it still provides viable habitat given the greater rate of change) then it could be used to map the maximum potential habitat area.

2. **Extending the analysis period did not significantly impact flows or stages.**

   While extending the analysis period did not impact flows or changes on the lower Feather River, results may vary depending on the operational characteristics of upstream controls (e.g., dams) and therefore may vary depending on the stream reach.

3. **Using a 14-day minimum/maximum query, as opposed to the Rate of Change of Stage, significantly increased flow and stage, resulting in greater potential habitat area.**

   Consideration should be given as to the importance of the Rate of Change of Stage query since it significantly reduces the flow and stage and thus potential habitat area.

4. **When assuming a 2-inch rate of change of stage or when removing the rate of change of stage criteria and using a 14-day minimum/maximum criteria, Cottonwood Seedling Germination produces higher flows and stages than Cottonwood Seedling Inundation.**

   This suggests that successful Cottonwood recruitment may be possible under alternative EFR criteria. It should be noted, however, that Cottonwood Seedling Germination and Inundation are not dynamically linked with HEC-EFM and that any conclusions regarding recruitment success must be considered with this in mind.

The Salmonid Rearing Habitat Formation EFR was modified from the SacEFT-defined March through May, 7-day minimum/maximum and 67 percent chance frequency criteria to analyze various frequencies, including 50, 33, 20, and 10 percent chance, a 14-day duration and no duration criteria, and a 7-day duration from March through July. Tables A-11 through A-13 show the results of these changes.

The following can be concluded:

1. **Flow and stage increase linearly with frequency.**

   As expected, lower frequency criteria resulted in greater flow and stage. Figure A-22 shows the corresponding area for each 7-day duration frequency within HAA 11.00. Although the 10 percent chance frequency produces the greatest area (note: the 10 percent chance area includes all areas mapped under the 20 percent chance area, the 20 percent chance area includes all areas mapped under the 33 percent chance area, etc.), much of the area may not correspond to ideal salmonid habitat, given that successful salmonid habitat does not rely as heavily on widespread floodplain inundation but rather habitat located within side channels and along river banks.

2. **Extending the period of the analysis to include June and July significantly increases the flow by 2 to 3 times.**

   Unlike Cottonwood Seedling Germination, increasing the period of analysis results in greater potential habitat area. If June and July were considered ecologically "acceptable" periods for salmonid rearing, the period of analysis could be extended to increase the potential habitat area.

3. **Removing the duration criteria increased the flow and stage minimally, while assuming 14-day duration versus 7-day duration minimally decreased the flow and stage.**

   Adjusting the duration of the event did not significantly impact flows, stages, or potential habitat area.

Table A-11. Salmonid Rearing Habitat Sensitivity – RS 26.25–RS 22.50

Ecosystem Function Relationship	RS 26.25		RS 24.50		RS 22.50	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
67% chance, 7-day duration	38.4	4,142	37.9	4,150	30.2	4,159
50% chance, 7-day duration	39.4	6,231	38.7	6,231	31.7	6,231
33% chance, 7-day duration	41.4	10,901	40.2	10,904	34.3	10,916
20% chance, 7-day duration	43.2	15,673	41.4	15,684	36.5	15,693
10% chance, 7-day duration	47.1	28,466	44.8	28,465	41.1	28,462
67% chance, 7-day duration March-July	41.6	11,265	40.3	11,232	34.4	11,200
67% chance; no duration	39.1	5,661	38.5	5,659	31.3	5,657
67% chance; 14-day duration	38.1	3,733	37.7	3,734	29.8	3,735

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

Table A-12. Salmonid Rearing Habitat Sensitivity – RS 19.00–RS 13.25

Ecosystem Function Relationship	RS 19.00		RS 15.75		RS 13.25	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
67% chance, 7-day duration	28.1	4,181	26.9	4,187	25.6	4,181
50% chance, 7-day duration	29.4	6,229	28.0	6,226	26.5	6,219
33% chance, 7-day duration	31.9	10,916	30.2	10,923	28.5	10,931
20% chance, 7-day duration	34.0	15,715	32.1	15,734	30.4	15,756
10% chance, 7-day duration	38.5	28,452	36.2	28,446	24.5	28,445
67% chance, 7-day duration March-July	32.0	11,121	30.2	11,060	28.5	11,031
67% chance; no duration	29.1	5,699	27.7	5,619	26.2	5,582
67% chance; 14-day duration	27.8	3,737	26.6	3,748	25.3	3,758

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

Table A-13. Salmonid Rearing Habitat Sensitivity – RS 11.00–RS 8.50

Ecosystem Function Relationship	RS 11.00		RS 8.50	
	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)
67% chance, 7-day Duration	23.8	4,942	21.8	5,684
50% chance, 7-day Duration	25.0	7,536	24.3	9,762
33% chance, 7-day Duration	27.0	11,832	27.1	15,760
20% chance, 7-day Duration	29.1	16,800	29.3	21,232
10% chance, 7-day Duration	34.4	32,453	34.7	38,506
67% chance, 7-day Duration March-July	26.7	11,175	24.7	10,592
67% chance; No Duration	24.7	6,706	23.0	7,443
67% chance; 14-day Duration	23.4	3,999	21.4	5,079

Source: Data provided by AECOM in 2011 based on modeling using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Ecosystem Functions Model and River Analysis System

Notes:
cfs = cubic feet per second
RS = River Station

3.3 Mapping

This section includes the results of the HEC-EFM analysis and the use of various mapping approaches to spatially visualize the HEC-EFM results. It also includes a discussion of how the spatial results can be further refined and reviewed to identify potential alternatives and how the final results can be presented.

3.3.1 Mapping Approaches

While HEC-EFM provides a stage and flow that meets the conditions of a given EFR, additional efforts are required to visualize the spatial area along the river that meets those conditions. Three approaches to mapping the results of HEC-EFM are presented in the following sections.

HEC-GeoRAS

The HEC-EFM results discussed above were mapped using HEC-RAS and the GIS extension to HEC's River Analysis System (HEC-GeoRAS), as recommended in the USACE-HEC *HEC-EFM Quick Start Guide* (USACE-HEC, 2009 (see Figure A-23)). This approach uses the flow rates determined by HEC-EFM but disregards the stages determined by HEC-EFM.

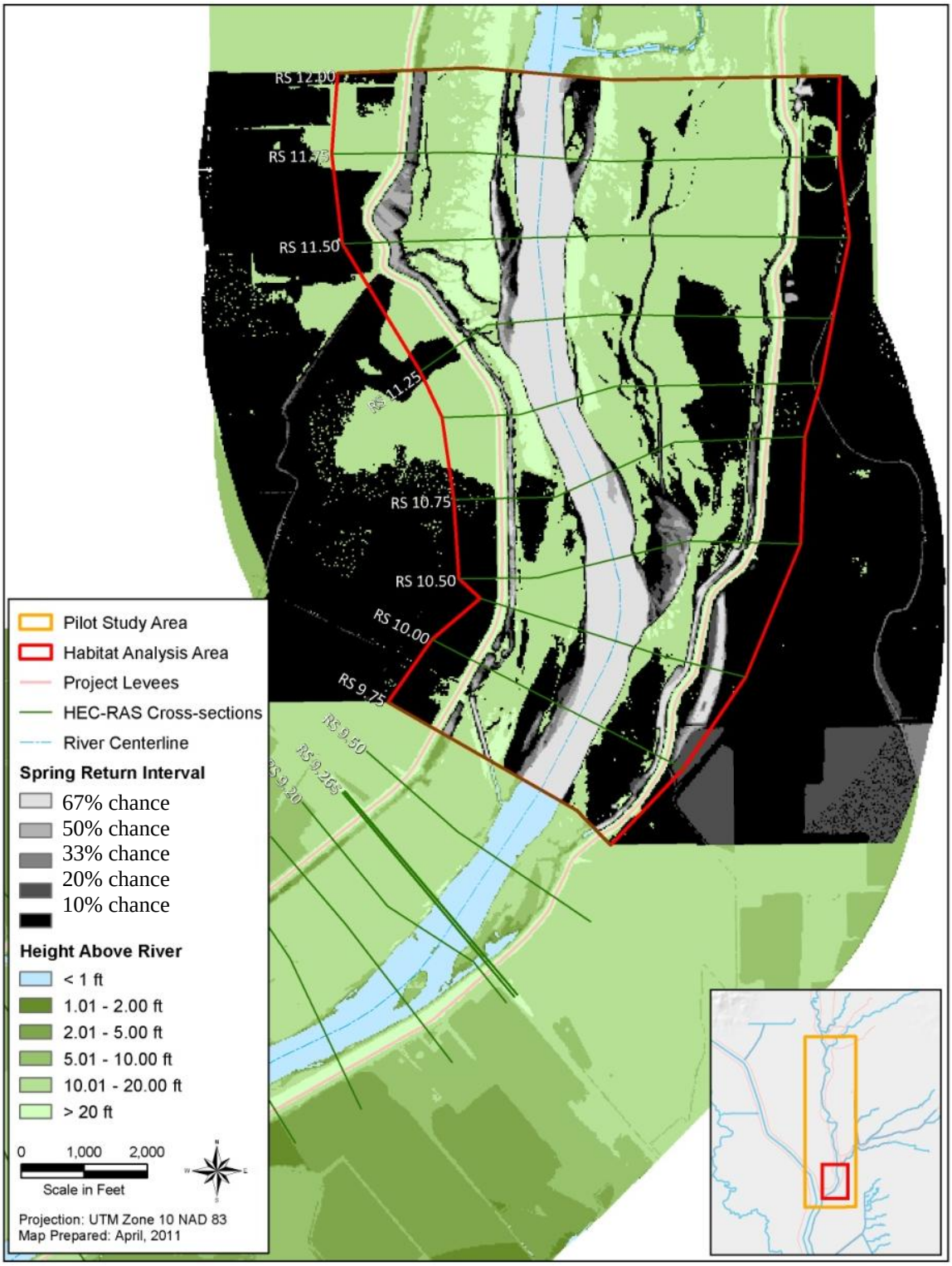

Figure A-22. Salmonid Rearing Habitat for Various Frequency Events in HAA 11.00

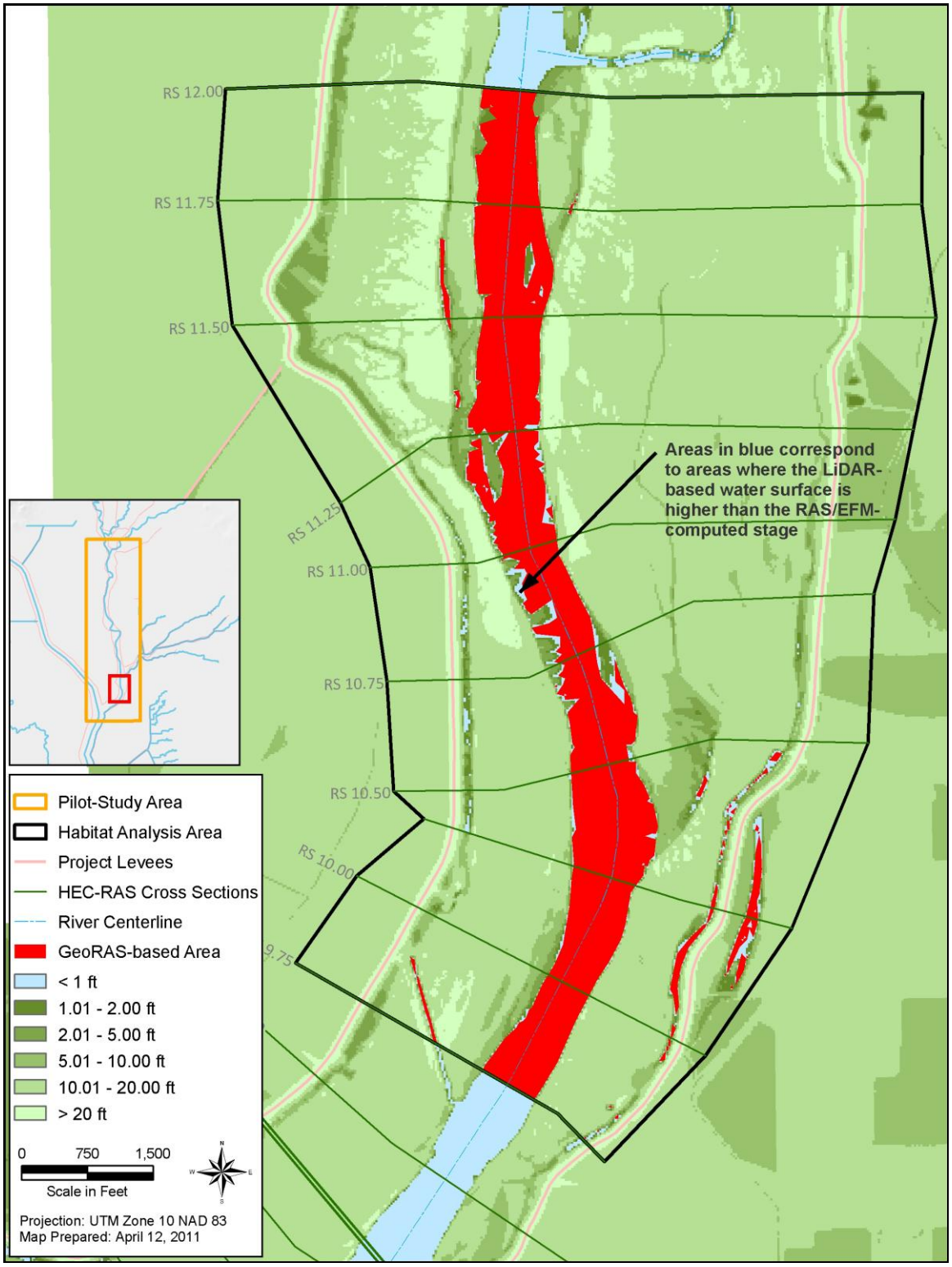

Figure A-23. Salmonid-Rearing Habitat Areas Mapped Using HEC-GeoRAS in HAA 11.00

The flow rates determined by HEC-EFM at each representative cross section were used as input for the HEC-RAS steady-state model. HEC-RAS was then used to compute the water-surface profiles for each HAA that corresponded to the flow determined by HEC-EFM. The entire pilot-study area HEC-RAS model was used to analyze each HAA (i.e., the model was not truncated to each HAA). This was done to maintain proper upstream and downstream boundary conditions and because truncating the model to each HAA would not necessarily reduce and could likely increase the level of effort.

The water-surface profile for each HAA and EFR were then mapped using the HEC-GeoRAS tool within ArcGIS. The water surface areas correspond to areas that meet the EFR conditions, as determined by HEC-EFM and HEC-RAS. It took approximately 10 minutes of processing time to run the HEC-GeoRAS tool for a single HAA and EFR. Each water surface area polygon was then clipped to its respective HAA. It should be noted that the inundation depth grid, a product of HEC-GeoRAS that is used in the HEC-EFM manual to show the extent of potential habitat, is not shown. The depth grid was not shown because the water surface area polygon is simpler for readers to identify with and is easier to work with in ArcGIS. Results are shown on Figures G-1 through G-11 in Appendix D-6G for each HAA and EFR (Cottonwood Recruitment was not mapped because potential habitat areas outside of the channel banks were not identified). The background of each map corresponds to the LiDAR-based FIP.

The following are important findings of this approach:

1. **The water surface areas mapped are the direct, raw product of the RAS/EFM analysis.**

   Areas have not been refined based on additional ecological or biological considerations, such as soil type, vegetation type, bank slope, connectivity, or land use.

2. **HEC-RAS and HEC-GeoRAS cannot map areas beyond the HEC-RAS model cross sections.**

   As a result, areas beyond existing levees are not mapped. Cross sections would need to be extended beyond the levees to map areas outside the existing levee system.

3. **EFRs that produce stages below the LiDAR observed water surface are not mapped by HEC-GeoRAS.**

   When EFR stages are below the LiDAR-observed water surface, water surface area does exist; however, the area is simply below the LiDAR-

observed water surface. To resolve this issue, bathymetry would need to be combined with the LiDAR terrain.

Height Above River

Although HEC-GeoRAS is a proven and reliable method for mapping HEC-RAS results, its limitation of mapping within cross-section extents makes it difficult to determine the potential for habitat beyond the existing levee system. Its inability to map below the LiDAR-observed water surface also reduces the value for mapping within channel banks. Thus, an alternative approach was reviewed using the FIP methodology.

After reviewing and testing the FIP approach as well as the HEC-GeoRAS and ArcGIS approaches, the FIP approach was selected as the preferred mapping approach.

Similar to the approach discussed above, HEC-RAS was used to simulate the water-surface profile for each HAA based on the flows determined by HEC-EFM. The results were exported to GIS, and HEC-GeoRAS was used to develop cross-section cut-lines with water surface elevations for each HAA and EFR. ArcGIS was then used to perform FIP analyses for each HAA and EFR. Figure A-24 shows an example of the Cottonwood Seedling Germination habitat area identified using the HEC-GeoRAS approach versus the FIP approach from RS 9.75 through RS 12.00 (HAA 11.00).

The following are important findings of this approach:

1. **The FIP analysis is capable of mapping the RAS/EFM analysis results within the entire FIP study area.**

   Mapping was not limited to the cross-section extents and provides mapping beyond the existing levee system.

2. **The FIP analysis replaces the LiDAR-observed water surface with the water-surface profiles computed by HEC-RAS, based on predefined bank breaklines.**

   As a result, the entire channel, from bank to bank, is shown as meeting the RAS/EFM analysis EFR criteria. This may overestimate the area of potential habitat within the channel. To resolve this issue, bathymetry would need to be combined with the LiDAR terrain.

3. **The water surface areas mapped are the direct, raw product of the RAS/ EFM analysis.**

   Areas have not been refined based on additional ecological or biological considerations, such as soil type, vegetation type, bank slope, connectivity, or land use.

ArcGIS

The approaches discussed above use HEC-RAS to determine the water-surface profile within each HAA that meet the conditions of each EFR. These water-surface profiles are computed by HEC-RAS using the flows determined by HEC-EFM. While these approaches provide hydraulically correct water-surface profiles through each HAA, they require a significant level of effort. An alternative was considered using ArcGIS to directly map the stage determined by HEC-EFM. This approach uses the stage determined by HEC-EFM instead of the flow rate, with the stage mapped within ArcGIS for each HAA and EFR.

This approach assumes that the stage determined by HEC-EFM for a given HAA and EFR applies uniformly across the HAA (i.e., it assumes there is no slope to the water surface throughout the HAA). This assumption may or may not be valid, depending on the hydraulic characteristics of the HAA.

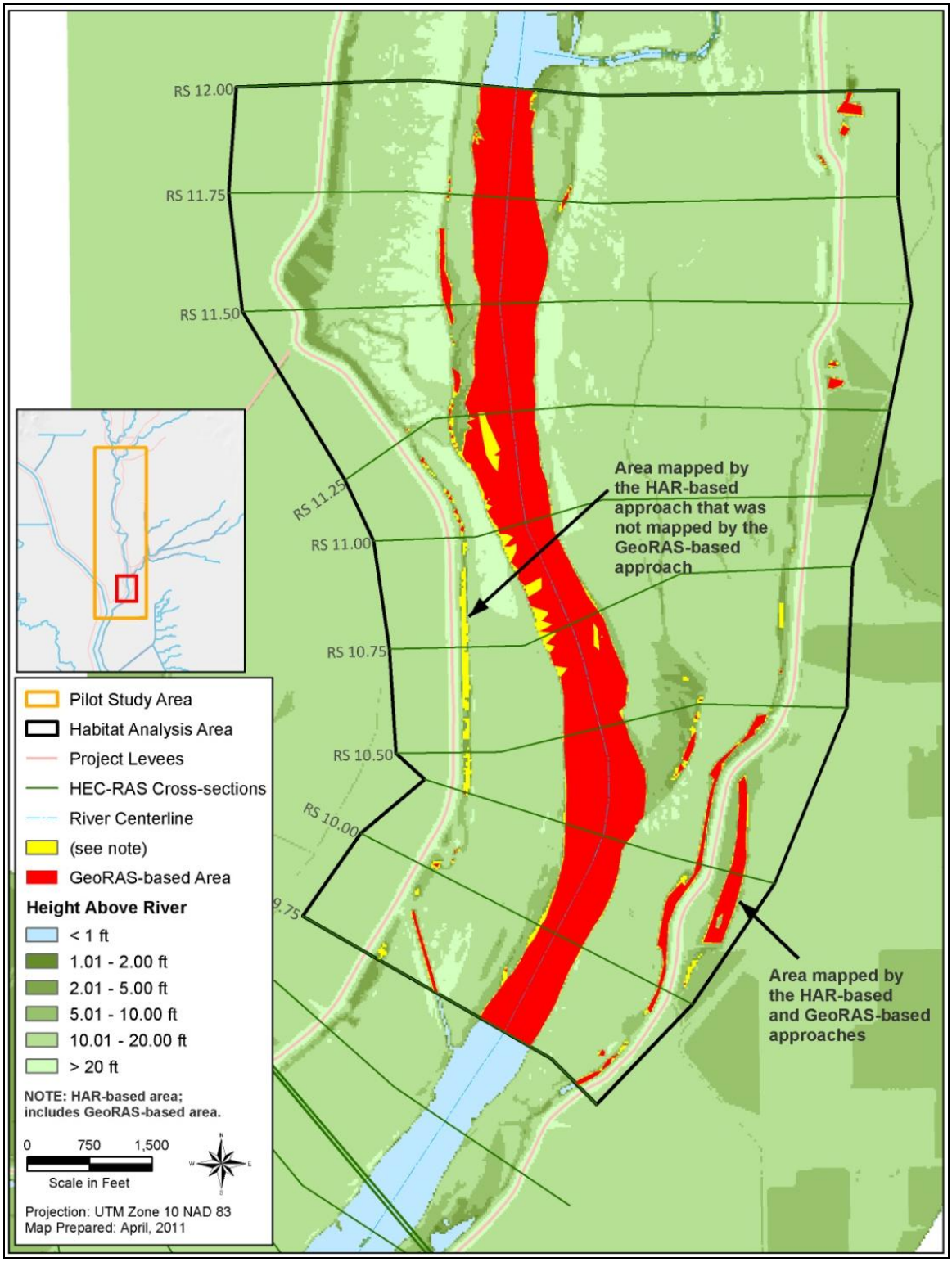

Figure A-24. Cottonwood Seedling Germination Habitat Areas Mapped Using FIP and HEC-GeoRAS in HAA 11.00

Again, this assumption *may be valid* if the HAAs were defined such that their hydraulic conditions were homogenous. Each HAA and EFR was mapped by first creating a water-surface TIN terrain model with a single elevation and then taking the difference between the TIN and the LiDAR terrain. This TIN extends beyond the cross-section extents so that mapping beyond existing levees is possible. As an example, Table A-14 shows the stages determined by HEC-RAS between RS 9.75 and RS 12.00 using the previous two mapping methods. Using this approach, the areas between these river stations would be mapped using the single stage determined by HEC-EFM for RS 11.00: 23.8 feet (see Tables A-5 through A-7).

Table A-14. HEC-RAS-Derived Stages for Salmonid-Rearing Habitat – RS 9.75–RS 11.00

River Station	Stage (feet)	River Station	Stage (feet)
9.75	22.03	11.25	24.09
10.00	22.31	11.50	24.25
10.50	23.27	11.75	24.40
10.75	23.62	12.00	24.84
11.00	23.84		

Source: Data compiled by AECOM in 2011 based on modeling using U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS)

Figure A-25 compares the mapping results using each method between RS 9.75 and RS 12.00 for Salmonid-Rearing Habitat. For this HAA, while there are differences between each approach, the results are similar, leading to the assumption that a single stage can represent an entire FIP is reasonable. This alternative approach took approximately a half day to map the entire study area for all EFRs, significantly less than the 1 to 2 days required to perform the HEC-GeoRAS- and FIP-based approaches.

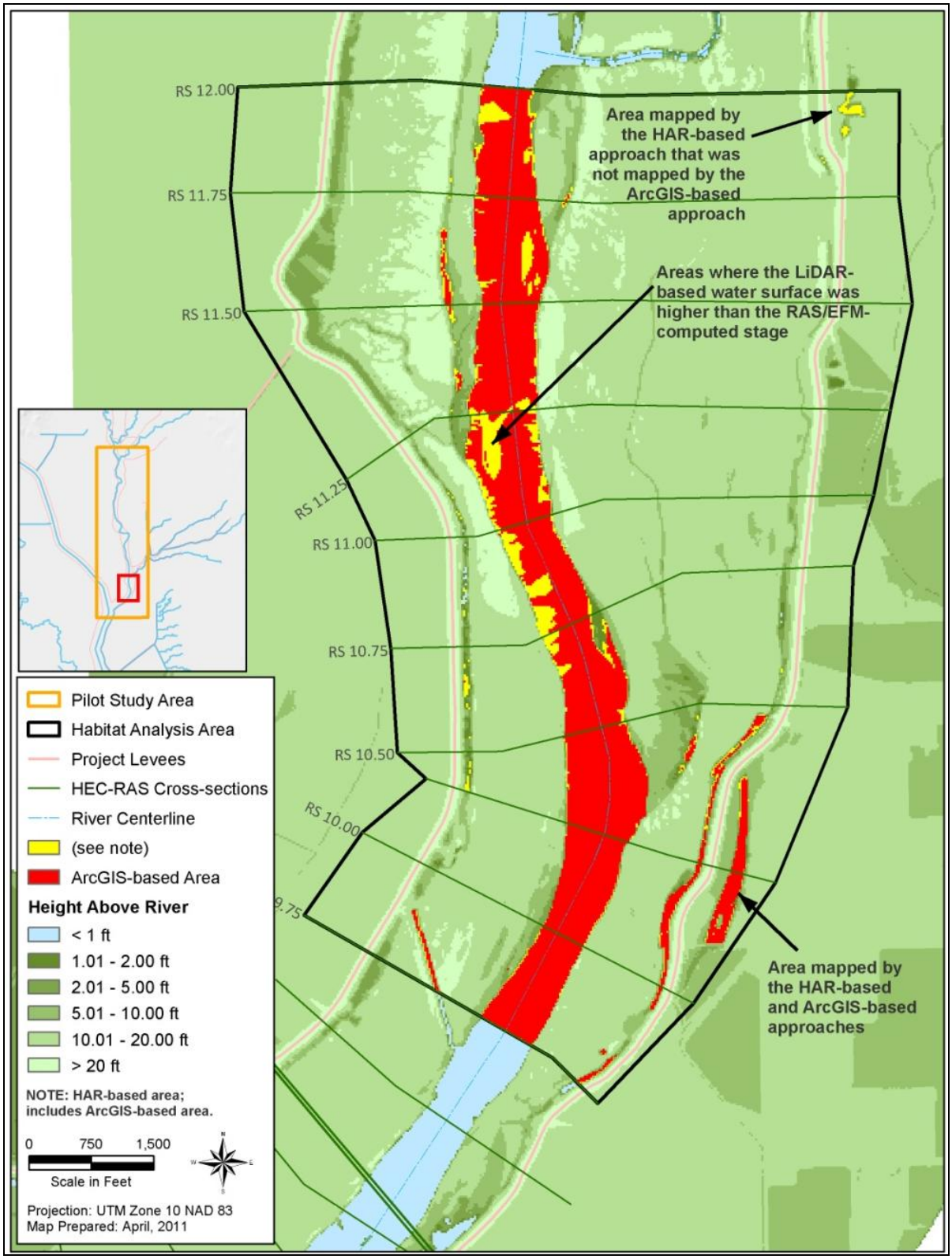

Figure A-25. Salmonid-Rearing Habitat Areas Mapped Using FIP and ArcGIS in HAA 11.00

The following are important findings of this approach:

1. **Mapping stages directly from HEC-EFM may or may not be appropriate, depending on whether the HAA is hydraulically homogenous.**

   For HAA 11.00, this approach provides a reasonable estimate of the area very similar to the FIP-based approach.

2. **The water surface areas mapped are the direct, raw product of the RAS/EFM analysis.**

   Areas have not been refined based on additional ecological or biological considerations, such as soil type, vegetation type, bank slope, connectivity, or land use.

3. **EFRs that produce stages below the LiDAR-observed water surface are not mapped by ArcGIS.**

   When EFR stages are below the LiDAR-observed water surface, water-surface area does exist; however, the area is simply below the LiDAR-observed water surface. To resolve this issue, bathymetry would need to be combined with the LiDAR terrain.

3.3.2 Refinement of Mapping Products

Results of the mapping process can be further refined, quantified, and/or visualized in ArcGIS. For example, a series of spatial analyses could be conducted to calculate the area of potential habitat based on location, connected vs. disconnected (to the main channel), and/or the specific EFR. Other GIS layers, such as soils, known habitat areas, vegetation type, bank slope, connectivity, and depth, could be used to refine the mapping products and assist in identifying areas where alternatives may be used to create additional habitat.

3.4 Conclusions

The purpose of this pilot study was to understand the methods and approaches required for the HEC-RAS and HEC-EFM analysis and to identify any issues with or alternative approaches to the analysis. The intent of this study was not to develop a final restoration opportunities analysis for the lower Feather River. This report should serve to clarify the RAS/EFM analysis and to identify topics for discussion.

The following general conclusions were reached as a result of this pilot study:

1. **While HEC-EFM is a robust tool for querying historic flow records, EFRs rely on a single set of numerical criteria (as opposed to a range) and lack dynamic (i.e., year-to-year) coupling of relationships.**

   The project team and stakeholders expressed concern that a single EFR may not adequately identify potential habitat areas because the EFR defines areas based on a single set of numerical criteria, as opposed to a range. While these criteria may reflect optimal conditions for an ecological process, the ecological process may achieve some success at sub-optimal conditions. Multiple EFRs could be developed for a single ecological process representing "optimal," "sub-optimal," and "minimal" conditions; however, this would significantly increase the level of effort required for a systemwide analysis. As an alternative, a single EFR representing a broader range of conditions could be considered.

   In addition, HEC-EFM does not dynamically couple EFRs. Since Cottonwood Seedling Recruitment relies on germination followed by minimal inundation within the same year, without dynamically coupling the two EFRs, the results are heavily skewed toward the relationship that produces the greater flow and stage.

2. **The SacEFT HEC-EFM EFRs may not be applicable systemwide.**

   The primary concern with using the SacEFT EFRs systemwide, as identified by project team members and Stakeholders, is that the existing EFRs were developed for the Sacramento River mainstem and may not be applicable to the Sacramento River tributaries and/or other rivers in the study area, such as the San Joaquin River and its tributaries.

3. **The pilot study did not identify significant amounts of potential habitat on the lower Feather River and the RAS/EFM analysis would likely produce similar results systemwide.**

   Because of the existing conditions of the lower Feather River and because of how EFRs are defined (as discussed above), limited habitat was identified on the lower Feather River. Given the conditions on other rivers within the project area (e.g., heavily leveed, restrained by dams, and/or incised), similar results may be produced systemwide.

Based on these conclusions, the project team considered developing a single EFR with a broader range of criteria, possibly with an upper- and lower-bound, to represent habitat opportunities. For example, the EFR may

represent the peak 50 percent chance flow that occurs during a 7-day duration spring and/or summer storm event. An upper and lower bound EFR may correspond to a higher or lower frequency and/or greater or smaller duration and/or time period. In combination with HEC-EFM and/or other statistical tools (e.g., the USACE HEC Statistical Software Package (HEC-SSP)), the synthetic flow record derived from the CalSim model may be queried at select locations where potential habitat is likely to exist. The EFR criteria will be based solely on flow, and since the CalSim-based flow records are developed wherever significant changes in flow occur, the development of HAAs is not critical. The flows associated with the EFR at these locations would then be mapped using HEC-RAS (steady-state) and the FIP approach. Regardless of whether HEC-EFM and/or other statistical tools, such as HEC-SSP, are used to query the flow records, it is the EFR criteria that ultimately determines the amount of potential habitat area identified. Therefore, the use of HEC-EFM versus other statistical tools should be based primarily on the ease of use, time required to set up, and output results from the software.

4.0 Acronyms and Abbreviations

cfs ..... cubic feet per second

Comprehensive Study Sacramento and San Joaquin River Basins Comprehensive Study

CVFED ..... Central Valley Floodplain Evaluation and Delineation

CVP ..... Central Valley Project

DEM ..... digital elevation model

DWR ..... California Department of Water Resources

EFR ..... Ecosystem Function Relationship

ESRI ..... Environmental Systems Research Institute, Inc.

FIP ..... floodplain inundation potential

FROA ..... Floodplain Restoration Opportunity Analysis

GIS ..... geographic information system

HAA ..... Habitat Analysis Areas

HAR ..... Height Above River

HEC-DSS ..... Hydrologic Engineering Center's Data Storage System

HEC-EFM ..... Hydrologic Engineering Center's Ecosystem Functions Model

HEC-GeoRAS ..... Hydrologic Engineering Center's River Analysis System

HEC-RAS ..... Hydrologic Engineering Center's River Analysis System

HEC-SSP ..... Hydrologic Engineering Center'S Statistical Software Package

LiDAR ..... Light Detection and Ranging

MWH ..... MWH Americas, Inc.

NAVD88 ..... North American Vertical Datum 1988

NGS ..... National Geodetic Survey

NGVD29 ..... National Geodetic Vertical Datum of 1929

RAS/EFM ..... HEC-RAS/HEC-EFM

RS ..... River Station

SacEFT.....Sacramento River Ecological Flows Tool

SWP .....State Water Project

TIN.....triangular irregular network

TM .....Technical Memorandum

USACE .....U.S. Army Corps of Engineers

USGS .....U.S. Geological Survey

WSEL .....water surface elevations

WY.....Water Year

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix B. Investigation of USGS 10-Meter DEM Accuracy

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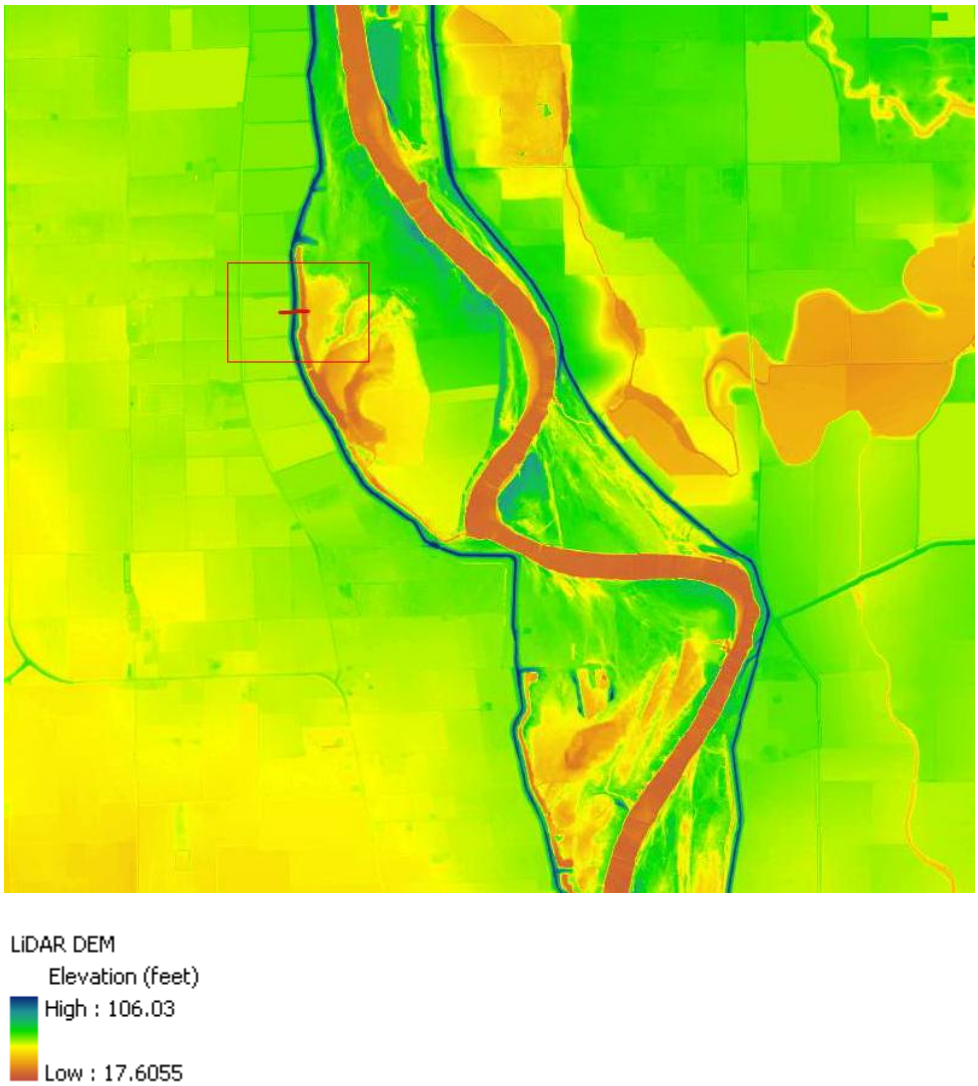
U.S. Geological Survey (USGS) 10-meter digital elevation models (DEM) were obtained (USGS, 2010) and evaluated for their appropriateness of use in the pilot study along the lower Feather River. This appendix provides the methods and results of a brief assessment of these data.

A portion of the California Department of Water Resources Central Valley Flood Evaluation and Delineation Project (CVFED) light detection and ranging (LiDAR)-derived DEM was selected (see inset box on Figure B-1) and a cross section was taken of the levee to compare the elevations from both the USGS DEM and LiDAR-derived DEM.

Elevations in the vicinity of the levee cross section are shown on Figure B-2 from the LiDAR-derived DEM, and Figure B-3 from the USGS DEM, indicating a significant difference in the two data sets with the USGS data presenting essentially "flat" topography in this location.

Figure B-4 provides a profile view of the two cross sections, demonstrating the lack of topographic relief provided in the USGS DEM data, and Figure B-5 provides tabular data indicating a USGS DEM surface is approximately 6 feet higher landward from the levee.

Given this comparison of the USGS DEM against the LiDAR DEM, it was determined that the USGS data does not pick up the crests of project levees. In many cases, the USGS data barely show any increase in elevation at the levee crest, and present a higher ground elevation landward from the levee. Based on this comparison, it was determined that the USGS DEM cannot be used as a substitute for the LiDAR-derived DEM data.



Note: Red line inside red box is a cross section used to compare the elevations of the U.S. Geological Survey digital elevation model and Light Detection and Ranging-derived digital elevation model.

Figure B-1 LiDAR-Derived DEM of the Pilot-Study Reach

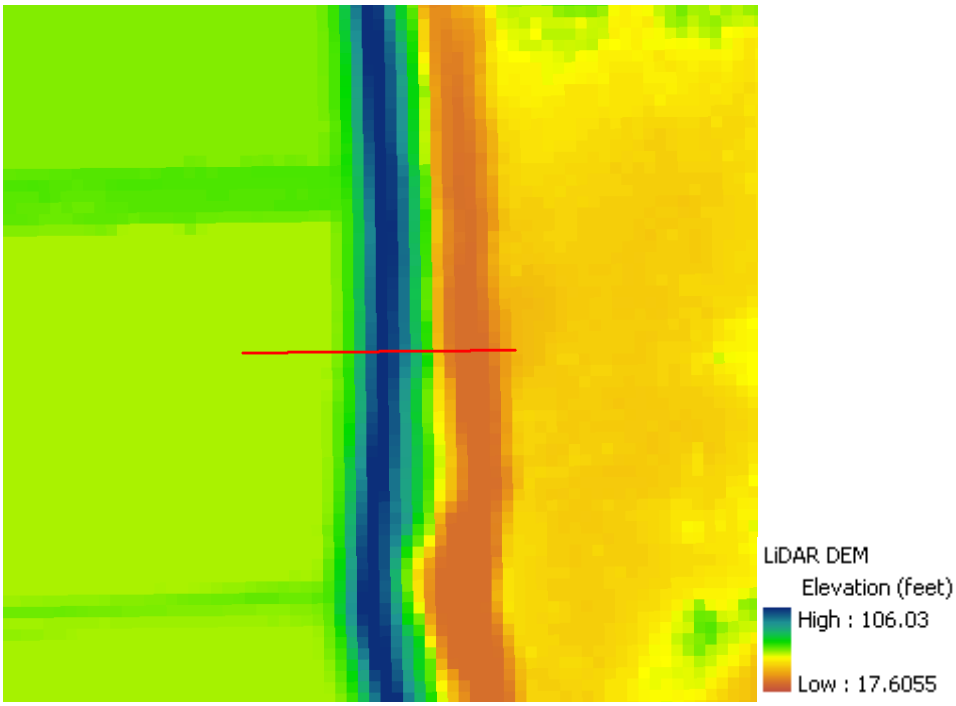


Figure B-2. Closeup of Cross Section on LiDAR DEM

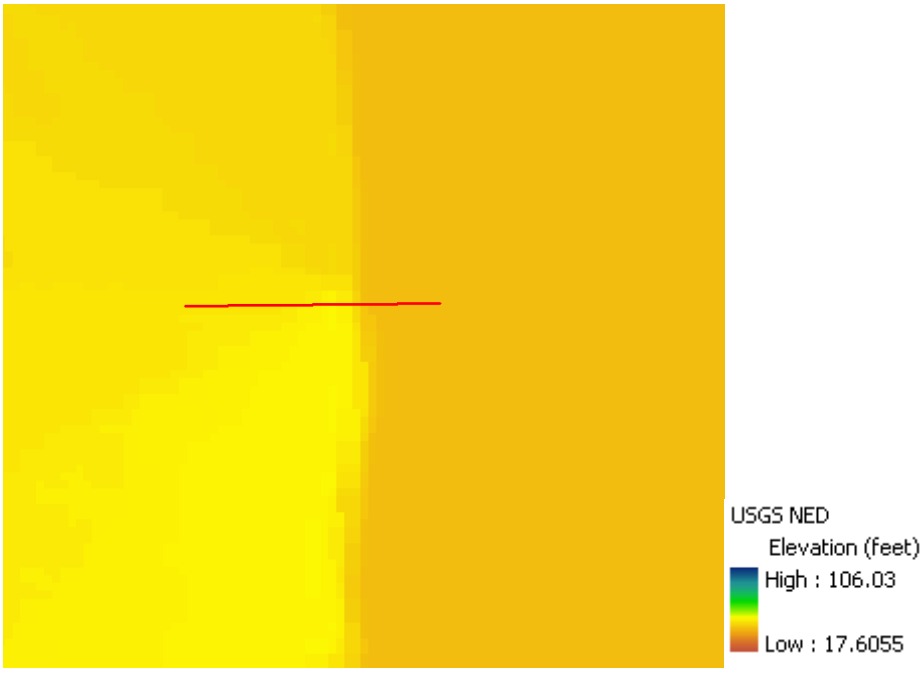


Figure B-3. Closeup of Cross Section on USGS DEM

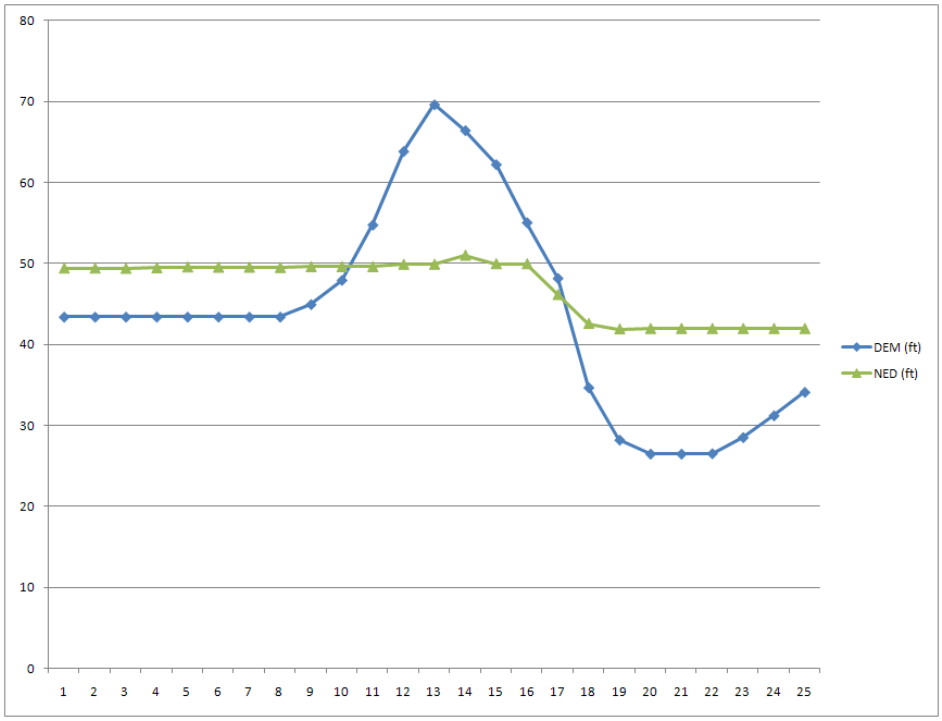


Figure B-4. Cross-Section Profiles

DEM (ft)	NED (m)	NED (ft)
43.41	15.06	49.40
43.41	15.06	49.40
43.41	15.05	49.36
43.41	15.08	49.46
43.41	15.11	49.56
43.41	15.1	49.53
43.41	15.1	49.53
43.41	15.09	49.50
44.96	15.12	49.59
47.95	15.12	49.59
54.78	15.12	49.59
63.87	15.21	49.89
69.64	15.21	49.89
66.45	15.55	51.00
62.24	15.23	49.95
55.07	15.23	49.95
48.19	14.07	46.15
34.68	12.98	42.57
28.21	12.77	41.89
26.49	12.79	41.95
26.49	12.79	41.95
26.54	12.79	41.95
28.53	12.79	41.95
31.22	12.79	41.95
34.12	12.79	41.95

Figure B-5 Tabular Comparison of Cross-Section Elevations

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix C. CVFED LiDAR Terrain Data Comparisons

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Since final digital elevation models (DEM) were not available from the California Department of Water Resources (DWR) Central Valley Flood Evaluation and Delineation Project (CVFED) program at the time of this pilot study, the DEM preparation involved the use of preliminary CVFED terrain data and incorporating/building breaklines and filling in void areas found in the data to create a triangulated irregular network (TIN) from which to derive a DEM of a specified grid cell size. An approximate 30-square-mile area was defined for the DEM preparation (Figure C-1). The light detection and ranging (LiDAR) data had data voids where there is water and dense vegetation that restricted the TIN from triangulating, essentially leaving large gaps in the TIN. Points were created in those areas to help complete the TIN.

Factors considered in the completion of the TIN and DEM included:

1. Projection – The were in a standard coordinate system; however, if they were not, then the LAS files would need to be converted to a shapefile and reprojected.

2. Data Voids – Where the data did not have interpolated points/breaklines across data void areas for the TIN to easily triangulate, "filler" points were created to provide a surface across the void areas to enable the completion of the TIN surface.

3. TIN/DEM Build – This process was iterative and required that no gaps remained in the TIN and resulting DEM. For every gap found, a search radius was applied to identify the nearest points to triangulate.

At the request of the Project Team, a comparison was made of the preparation time, resolution (usability), and file size attributes for various DEM grid size resolutions. This comparison included 5-, 25-, 50-, and 100-foot DEMs in the Feather River pilot-study area.

The time difference associated with DEM sampling from the TIN was minor. The time considerations came primarily from the initial TIN build (especially if the LiDAR has data voids) and this was estimated to take 2 to 3 days per 100 square miles. Another potentially significant impact on preparation time would be hydro-correction of the terrain surface; however, this was not done, which preserved the actual topographic condition of the floodplain surfaces.

A sample portion of the pilot-study area was prepared at the various DEM grid cell resolutions to enable a visual comparison of the resolution differences (Figures C-2 to C-5).

The file sizes resulting from the various DEM grid cell resolutions varied dramatically, with exported ASCII DEM file sizes for the same area (approximately 30 square miles) as follows: 5-foot DEM at 365.3 megabytes (MB); 25-foot DEM at 14.3MB; 50-foot DEM at 3.6MB, and 100-foot DEM at 0.9MB.

Based on the results of this comparison a decision was made by DWR to develop a 25-foot DEM using preprocessed CVFED TO20 data in the pilot-study area. The use of a 25-foot resolution DEM was determined to provide a reasonable balance among the preparation time, resolution (usability), and file sizes with the intended level of detail for the final products from this planning-level exercise.

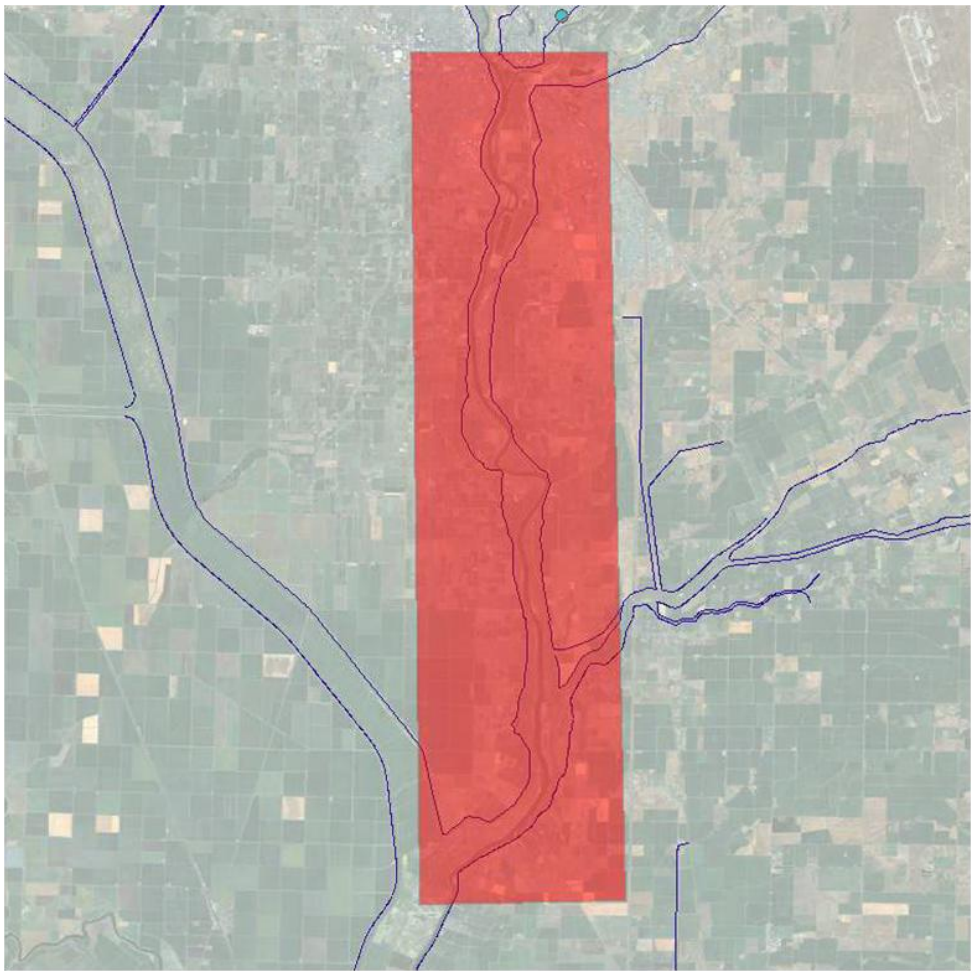

Figure C-1 Pilot-Study DEM Area

5ft DEM

25ft DEM

Figures C-2 and C-3. 5-Foot and 25-Foot DEM Grid Cell Size Resolutions, Respectively

50ft DEM

100ft DEM

Figures C-4 and C-5. 50-Foot and 100-Foot DEM Grid Cell Size Resolutions, Respectively

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix D. Levee Realignment Methodology

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Within the Feather River pilot-study reach, the Project Team noted that there were two locations where levees had been set back since the March 2008 date of the light detection and ranging (LiDAR) flight. This resulted in a need to adjust the digital elevation model (DEM) terrain surface to show actual current topographic conditions. While the Height Above River (HAR) output to date still shows the old levee position, a separate effort was made to determine a reasonable approach to adjust levee locations for subsequent HAR analyses.

The following steps were taken to adjust the location of a levee in the DEM.

1. A polygon feature was created around the area of the existing and new levee locations. The polygon was used to clip the DEM, which cut down on the processing time (Figure D-1).

2. A copy of the DEM surface limited to the polygon area was extracted by using the Extract by Mask tool located in the ArcGIS Toolbox -> Spatial Analyst Tools -> Extraction -> Extract by Mask (Figures D-2 and Figure-D3, tool input Items a through c below; and Figure D-4, output resulting from Items a through c below).

    a. Input Raster – Input the DEM.

    b. Input Raster or Feature Mask Data – Input the polygon created in Step 1.

    c. User must set file location and name.

3. The raster was converted into points using the 3D Analyst Toolbar dropdown menu under Convert -> Raster to Features (Figure D-5).

    a. Output Geometry Type – Set to Point.

    b. Input Raster – This is the extracted raster from Step 2.

    c. Field – Set to <Value>.

    d. User must set output file location and name.

4. The existing and new levees were delineated with lines that were then buffered at a distance necessary to capture the entire width of the levee cells in the DEM (Figure D-6).

5. All points within the buffered areas were selected by using Main Menu -> Selection -> Select by Location (Figures D-7 and D-8, tool input

Items a through d below; and Figures D-9 and D-10, output from Items a through d below).

a. I want to – Pull down "Select Features From."

b. The Following Layer – Click on the points file output from Step 3.

c. That – Pull down "are within."

d. The features in this layer – Pull down "New Levees Buffer" created from Step 4.

e. The DEM polygon points selected within the new levee buffer area were deleted and the DEM polygon points selected within the existing levee buffer were exported using Step 6 before being deleted.

6. The points for the existing levee were selected in Step 5 and then exported by right clicking on the file name in the Layers Catalog: File Name -> Data -> Export Data. (Figures D-11 and D-12, tool input Items a through c below).

   a. Export – Pull down "Selected features."

   b. Use the same coordinate system as – Select "this layer's source data."

   c. Output shapefile or feature class – User sets file location and name.

7. The existing levee points from Step 6 were moved into the location of the deleted new levee points (Step 5e) in the Raster to Features point output from Step 3. This was done from the upstream portion of the levee to the downstream portion, where points from the existing levee were selected in groups and manually moved into the vacant new levee location. Occasionally a group of points needed to be rotated to fit the new area and maintain a consistent levee slope and height (Figure D-13).

8. The existing and new levee point layers were appended (combined) by entering the ArcGIS Toolbox, clicking on the Index Tab at the bottom, typing "Append" into the "Type in key word to find:" box at the top, and selecting "Append (management)" (Figures D-14 and D-15, tool input Items a through c below). This combines the levee points from Step 3 (as modified in Step 5e) and the newly moved levee points from Step 7 into one file (Figure D-16).

a. Input Datasets – Enter filename for newly moved points from Step 7.

b. Target Dataset – Enter filename for points from Step 3, which were modified in Step 5e.

c. Schema Type (optional) – Pull down "NO TEST."

9. All levee points were converted into a raster grid using the Features to Raster: Spatial Analyst toolbar -> Covert -> Features to Raster. (Figures D-17 and D-18, tool input Items a through d below).

   a. Input Features – Appended points file from Step 8.

   b. Field – This was set to GRID_CODE in the dropdown box.

   c. Output Cell Size – Should be set to the cell size of the DEM.

   d. Output Raster – User sets the raster file location and name.

10. The output raster had "NoData" value cells in the location of the existing levee because those points are no longer there. The next step involved filling these NoData cells with adjacent elevations from the DEM to create a smooth surface where the existing levee used to be (Figure D-19). This was done using the Spatial Analyst toolbar -> Raster Calculator (Figure D-20). In the expression box the following expression was typed, focalmean ([output raster from Step 9], rectangle, 3, 3, data) (Figure D-21). This expression assigns the NoData cells the Mean of the 3x3 area around them. This expression did not fill in all NoData cells on the first run, so the output of this expression was run through the raster calculator a second and third time until all NoData cells were given an elevation (Figure D-22).

11. The output raster from Step 10 was converted to Points using the same Raster to Features method as in Step 3 (Figure D-23).

12. The DEM was converted to Points using the same Raster to Features method as in Steps 3 and 11 (Figure D-24).

13. Points from the DEM points file, created in Step 12, were selected within the polygon created in Step 1, using Select by Location, which was done in Step 5 (Figure D-25). Once all points within the polygon were selected, they were deleted from the DEM points file from Step 12. The points from Step 11 were fit into the vacant area (Figure D-26).

14. The Points file from Step 13 was combined with the Points file from Step 11 using the Append (management) tool, as done in Step 8.

15. The appended Points shapefile from Step 14 was converted into a raster grid, as done in Step 9 using the Features to Raster tool, and this raster output was the final result (Figure D-27). The new levee is now in the DEM. If there are any NoData cells in the area where the new levee was added in the DEM, the expression from Step 10 can be run in the Raster Calculator.

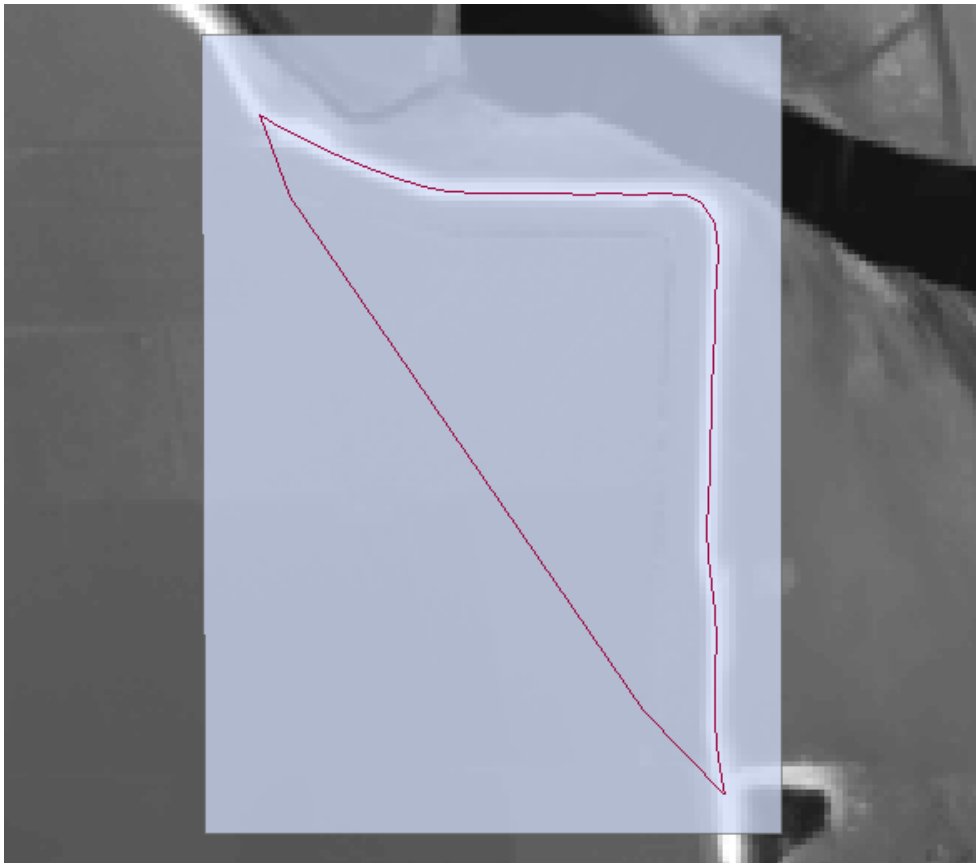

Figure D-1. Polygon Feature for DEM Extraction

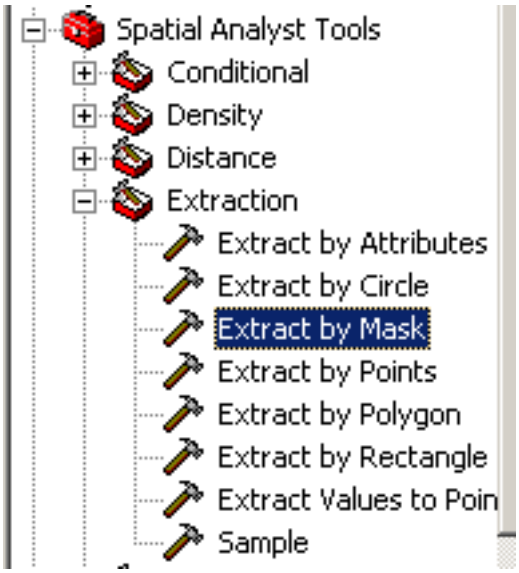

Figure D-2. Extract by Mask Tool in ArcGIS Toolbox

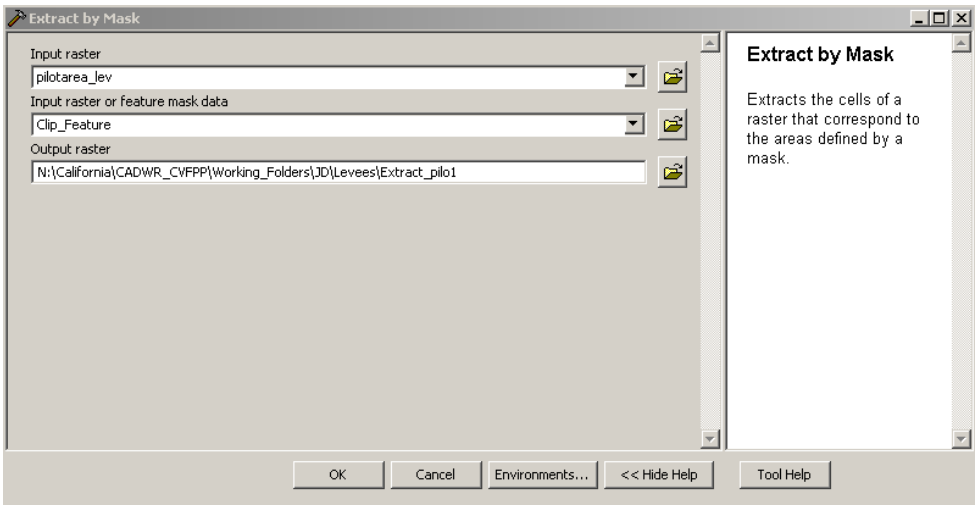

Figure D-3. Extract by Mask Menu Box

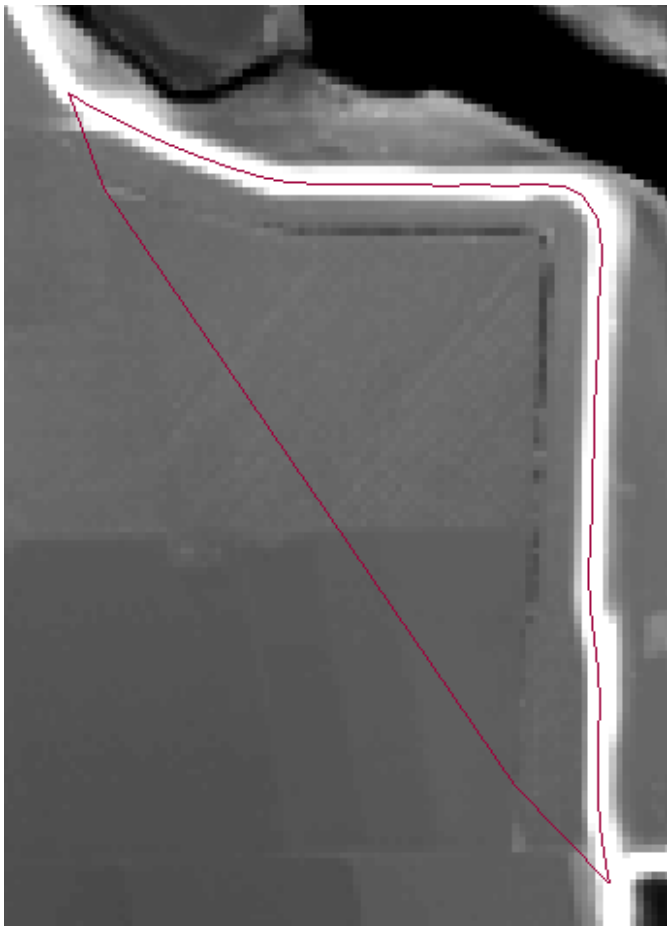

Figure D-4. Extract by Mask Output

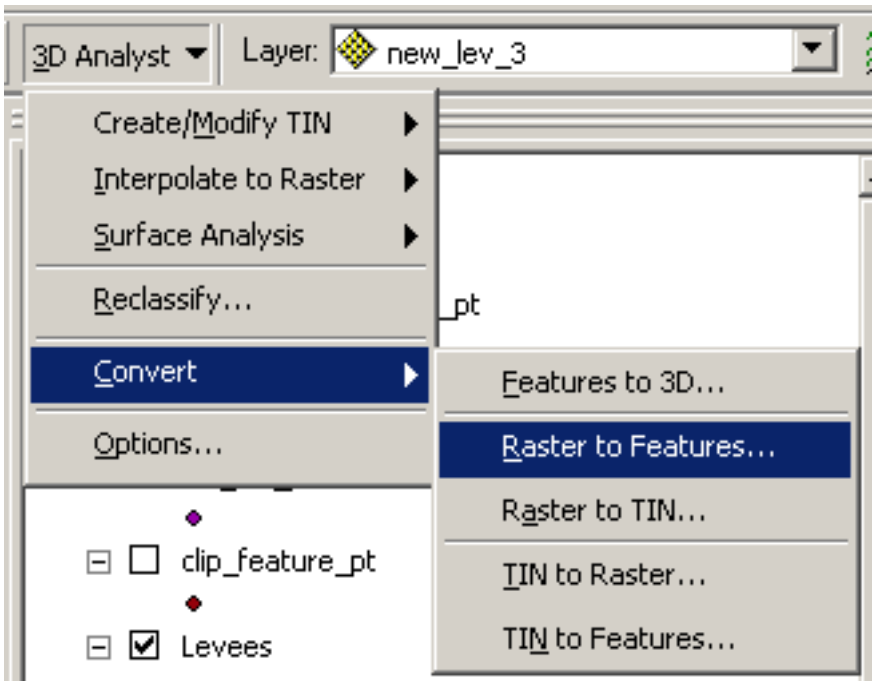

Figure D-5. Raster to Features Location in 3D Analyst Toolbar

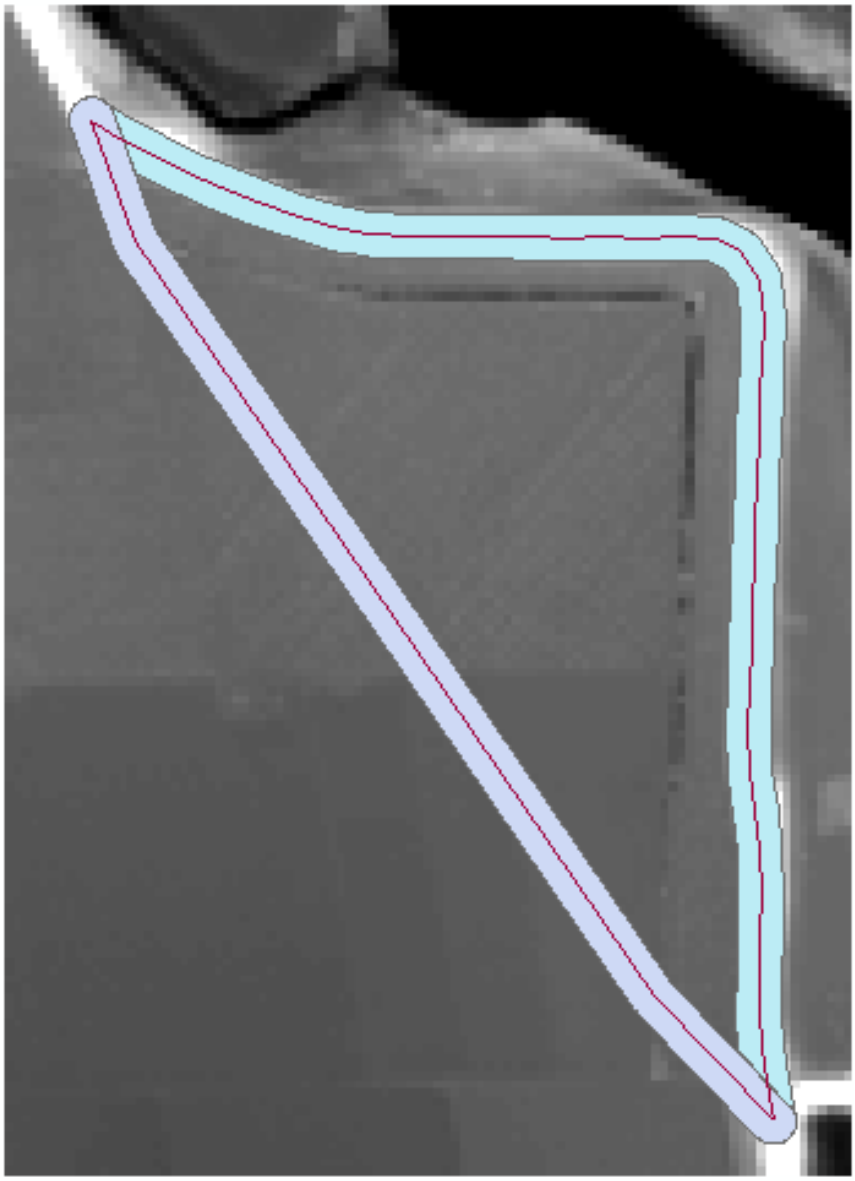

Figure D-6. Buffer of Existing and New Levee Lines

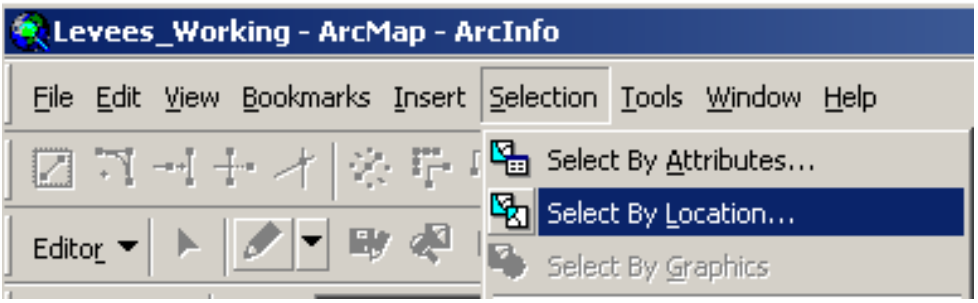

Figure D-7. Select by Location Tool

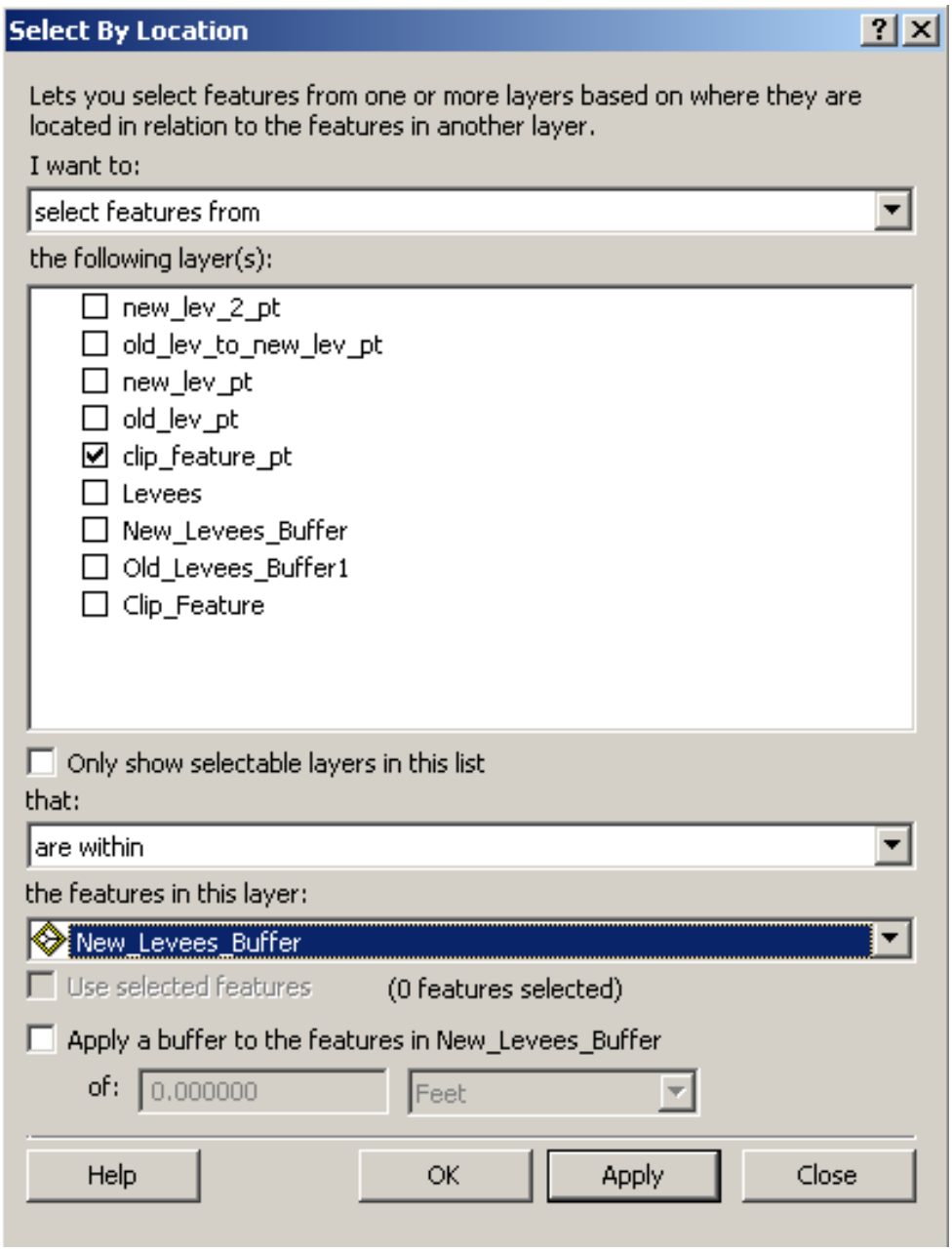

Figure D-8. Select by Location Menu Box

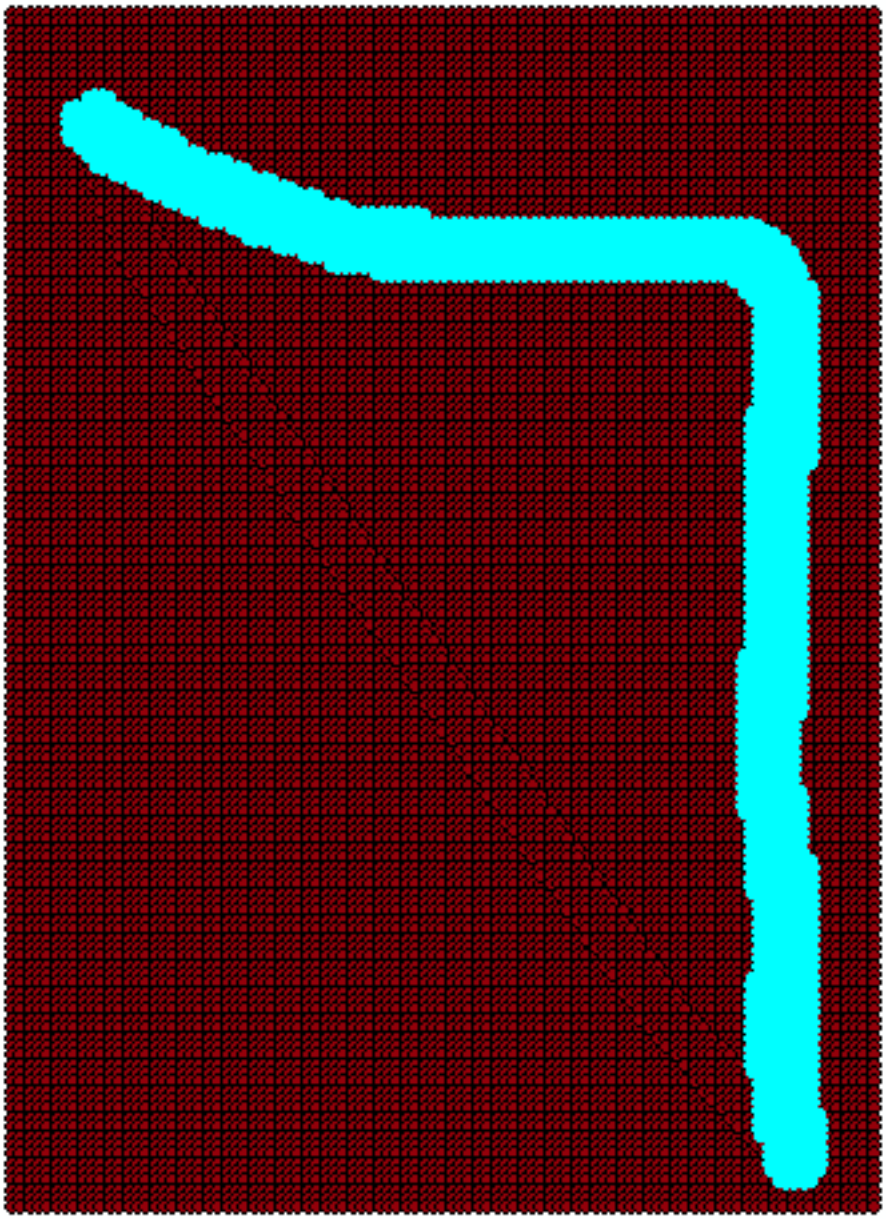

Figure D-9. Existing Levee Points

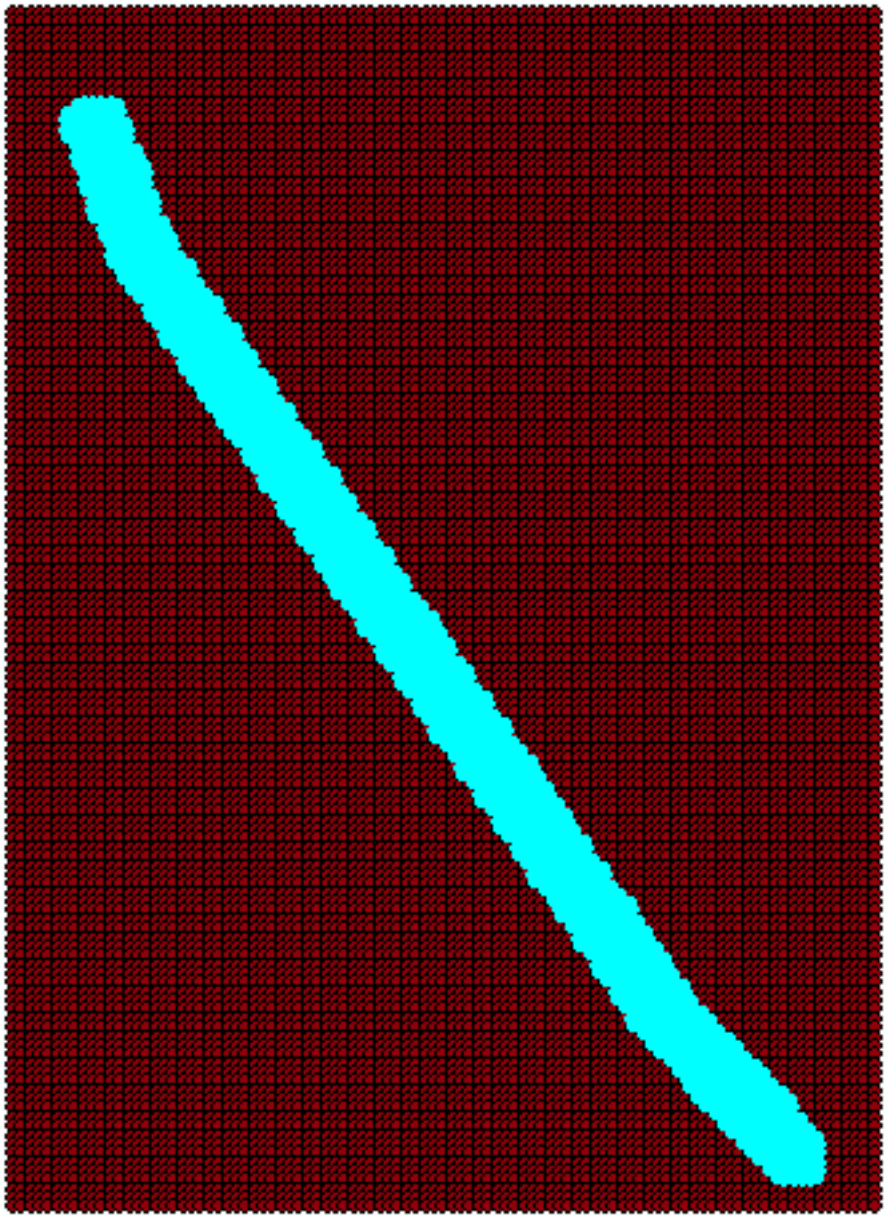

Figure D-10. New Levee Points

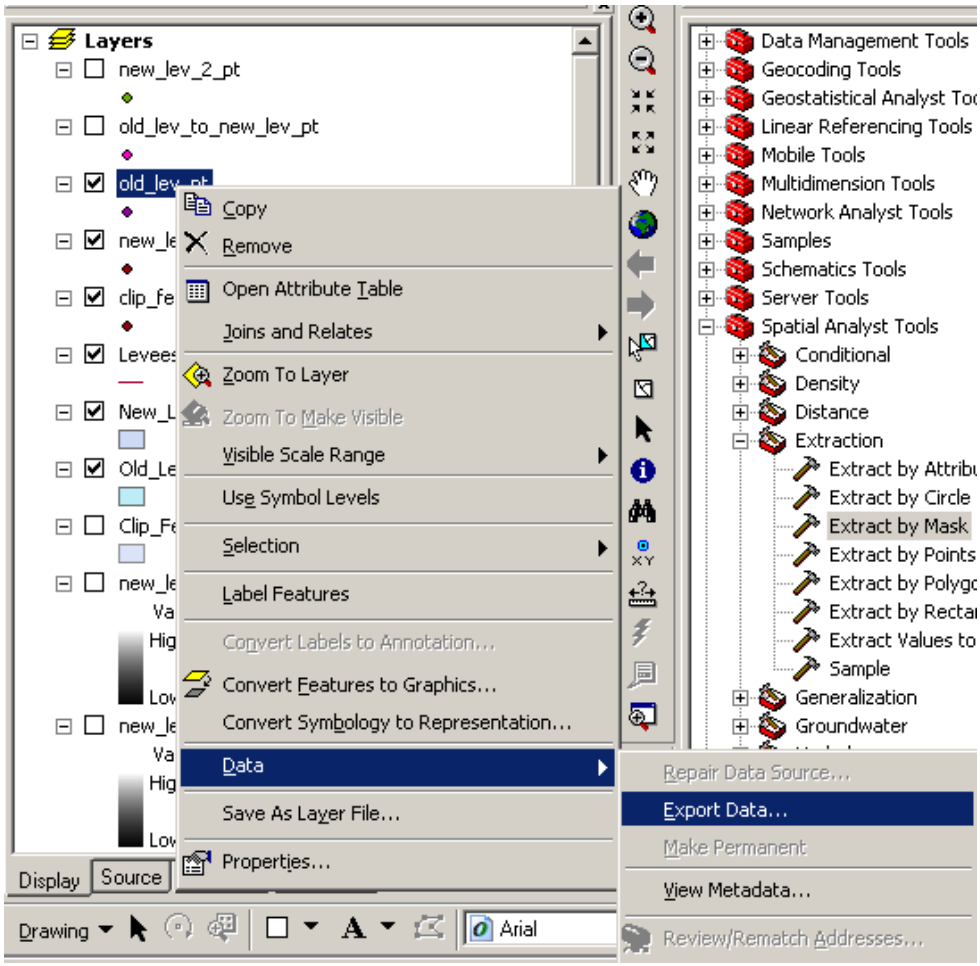

Figure D-11. Location for Export Data of the Existing Levee Points

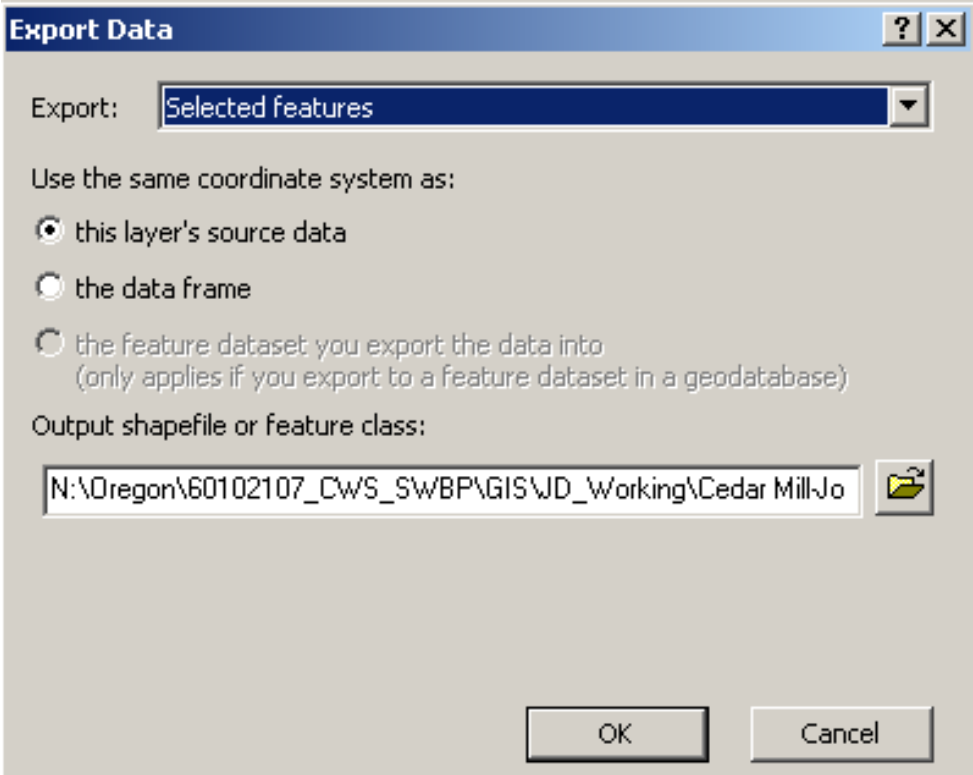

Figure D-12. Export Data Menu Box

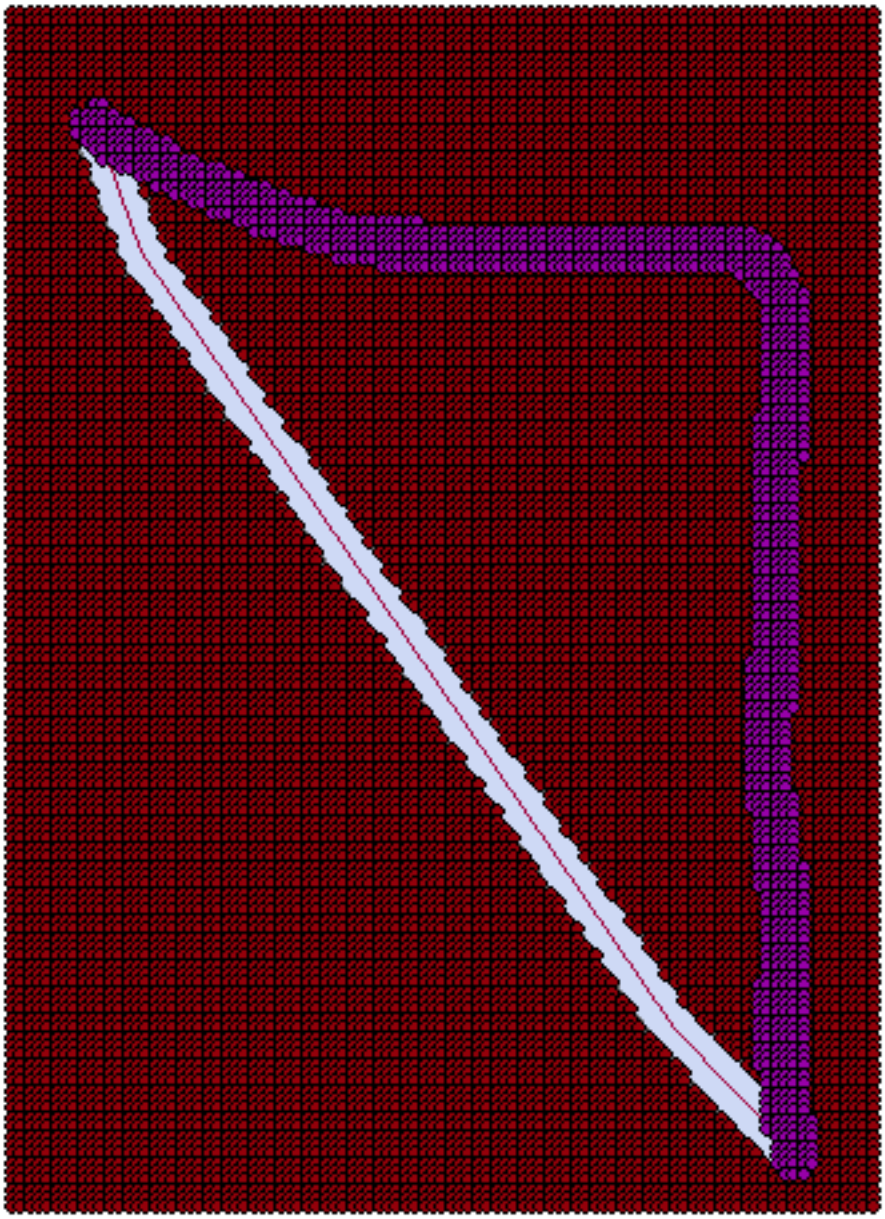

Figure D-13. Existing Levee Points (purple) Moved to New Levee Points (light grey)

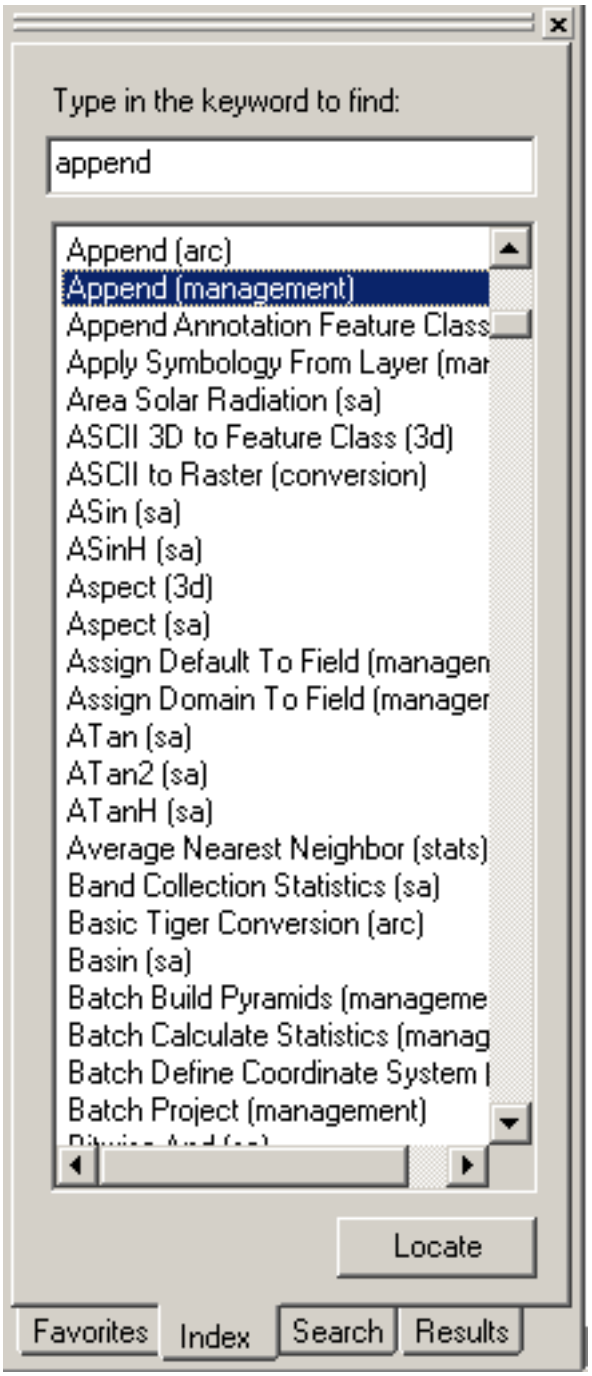

Figure D-14. Append Location in ArcGIS Toolbox

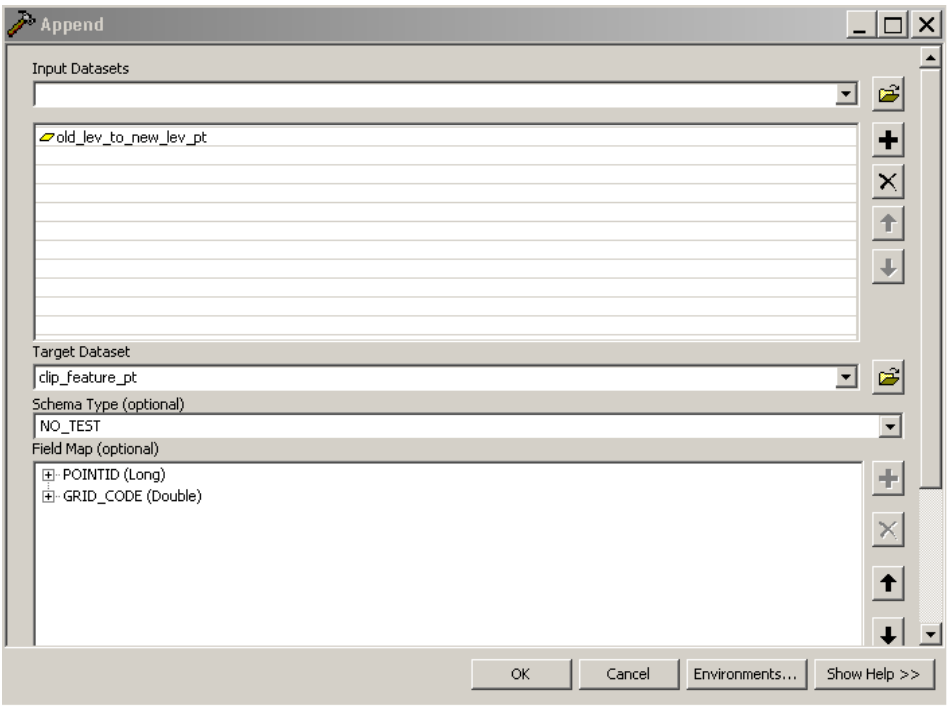

Figure D-15 – Append Menu Box

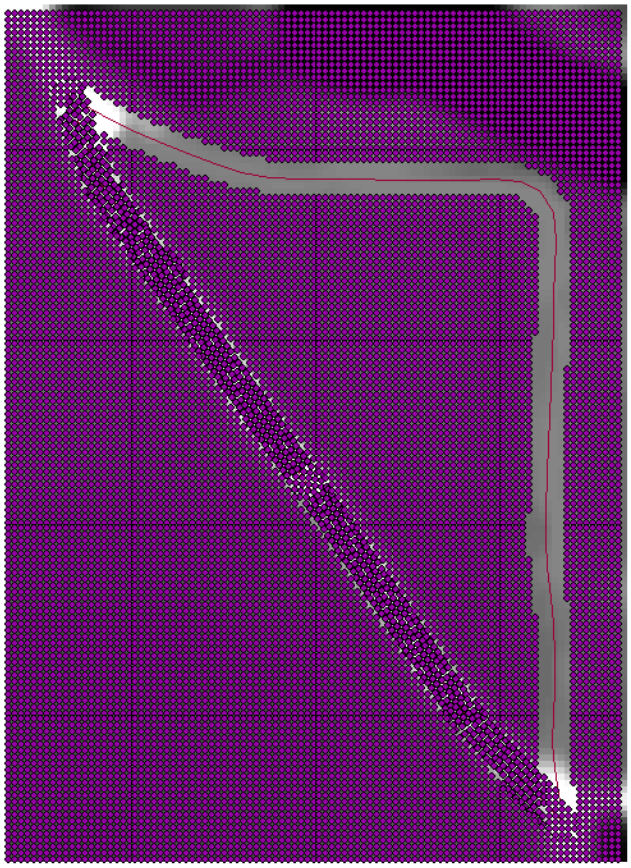

Figure D-16. Append Output

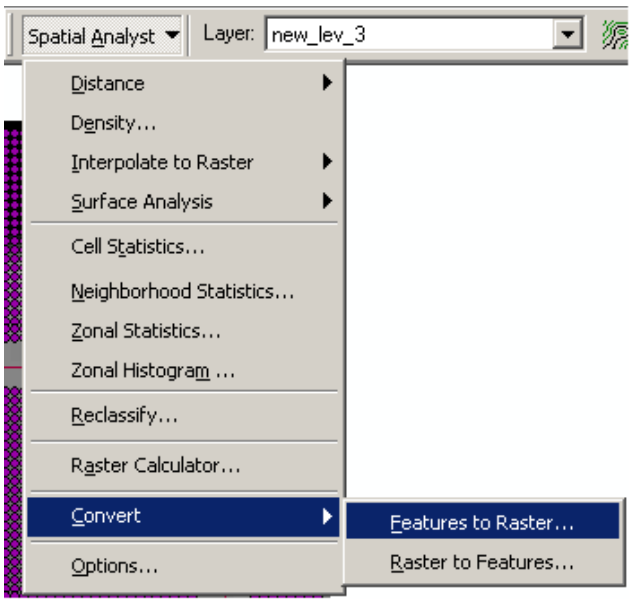

Figure D-17. Feature to Raster Location

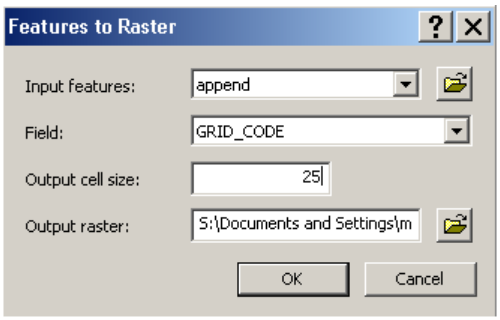

Figure D-18. Feature to Raster Menu Box

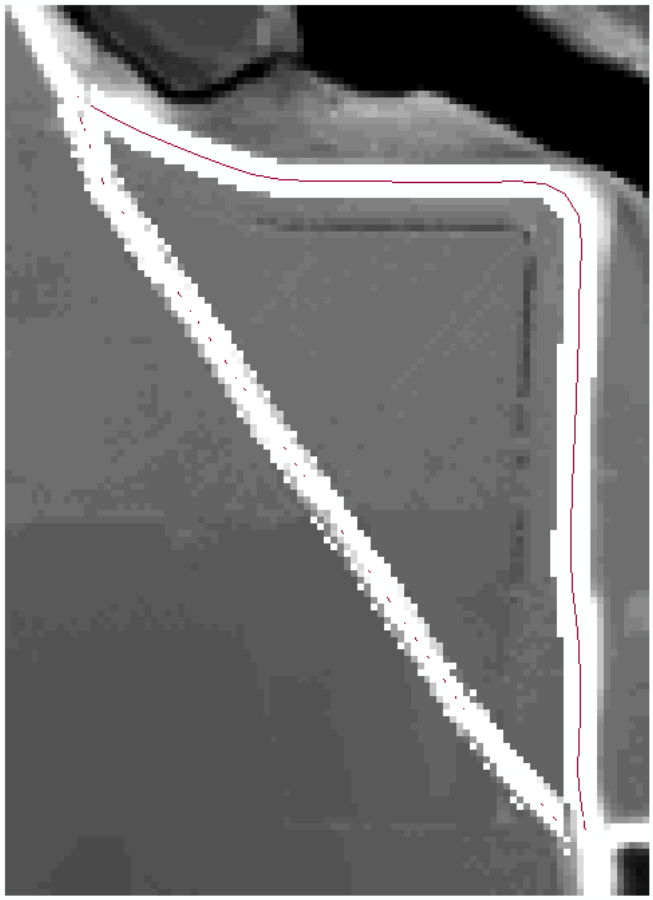

Figure D-19. Feature to Raster Output

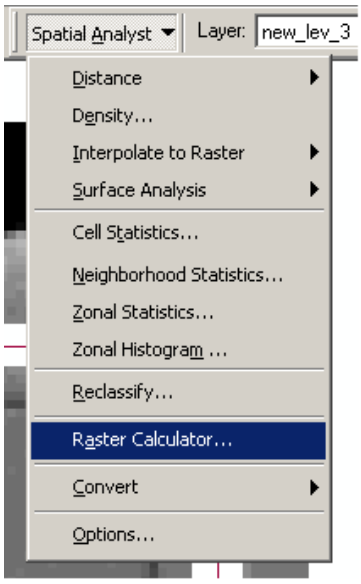

Figure D-20. Raster Calculator Location

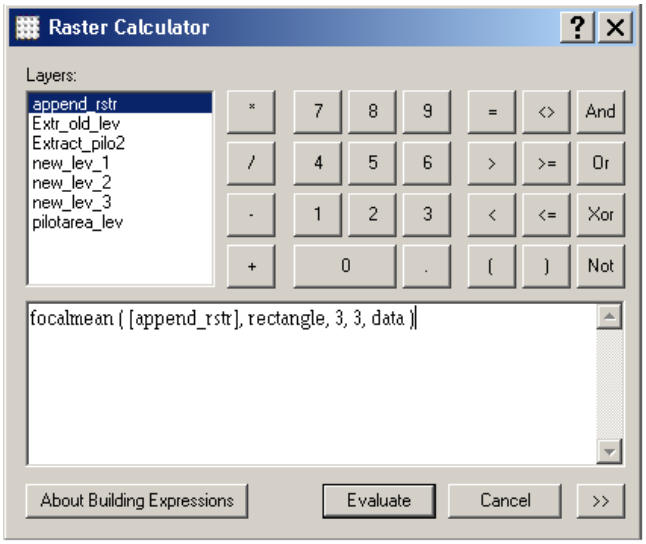

Figure D-21. Raster Calculator

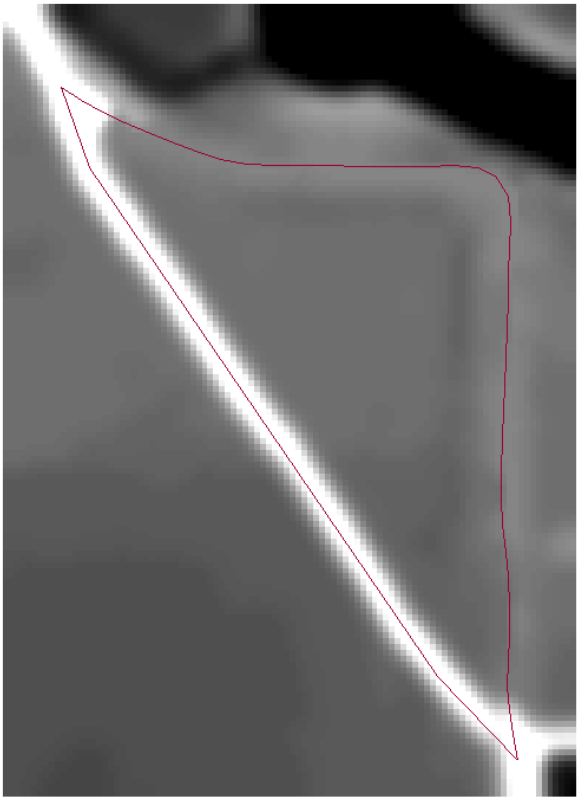

Figure D-22. Final Raster Output with New Levee

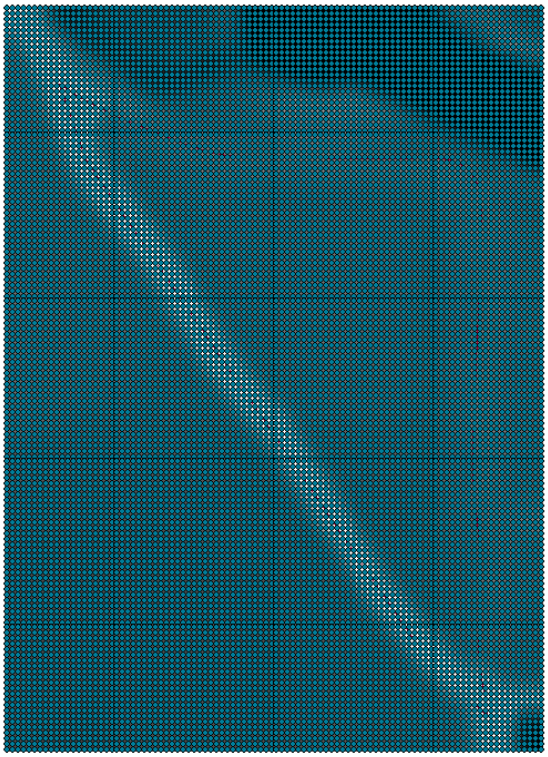

Figure D-23. Final Raster Output Converted into Points

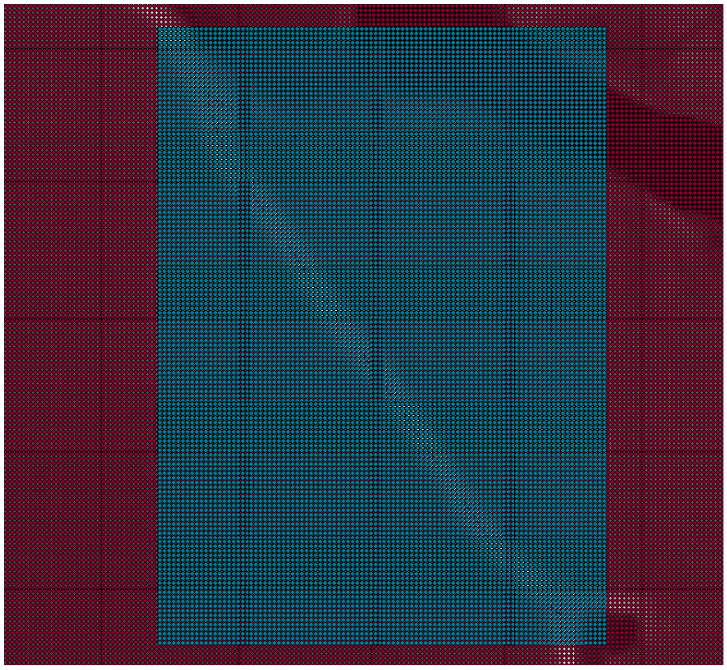

Figure D-24. DEM (outer box) and Final Raster Output (inner box)

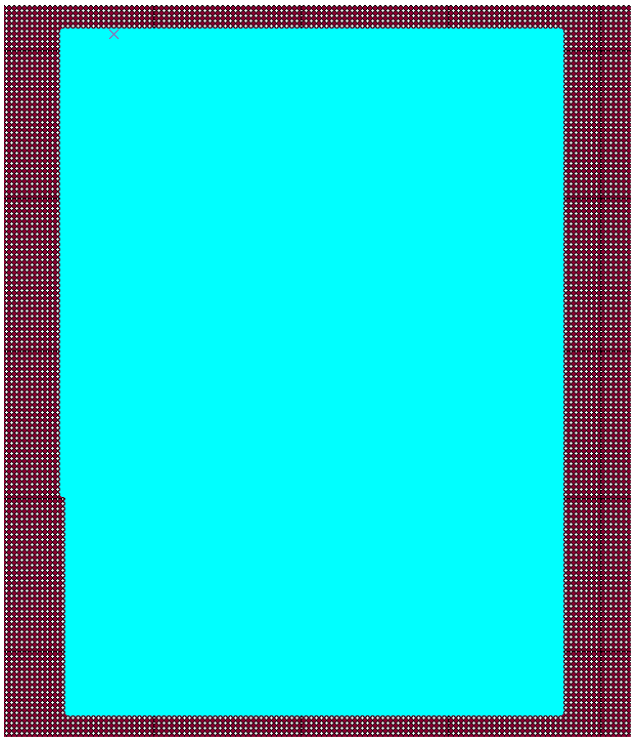

Figure D-25. DEM Points Selected with the Clip Polygon

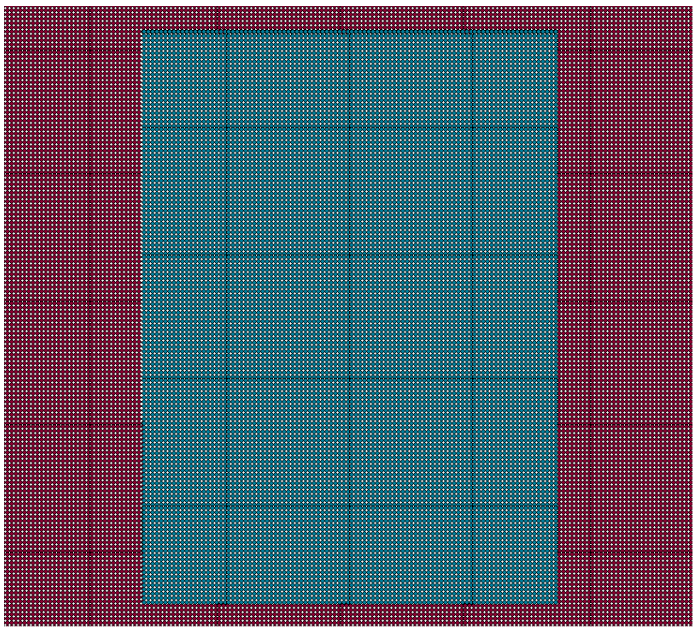

Figure D-26. Final Raster Output Points Combined in DEM

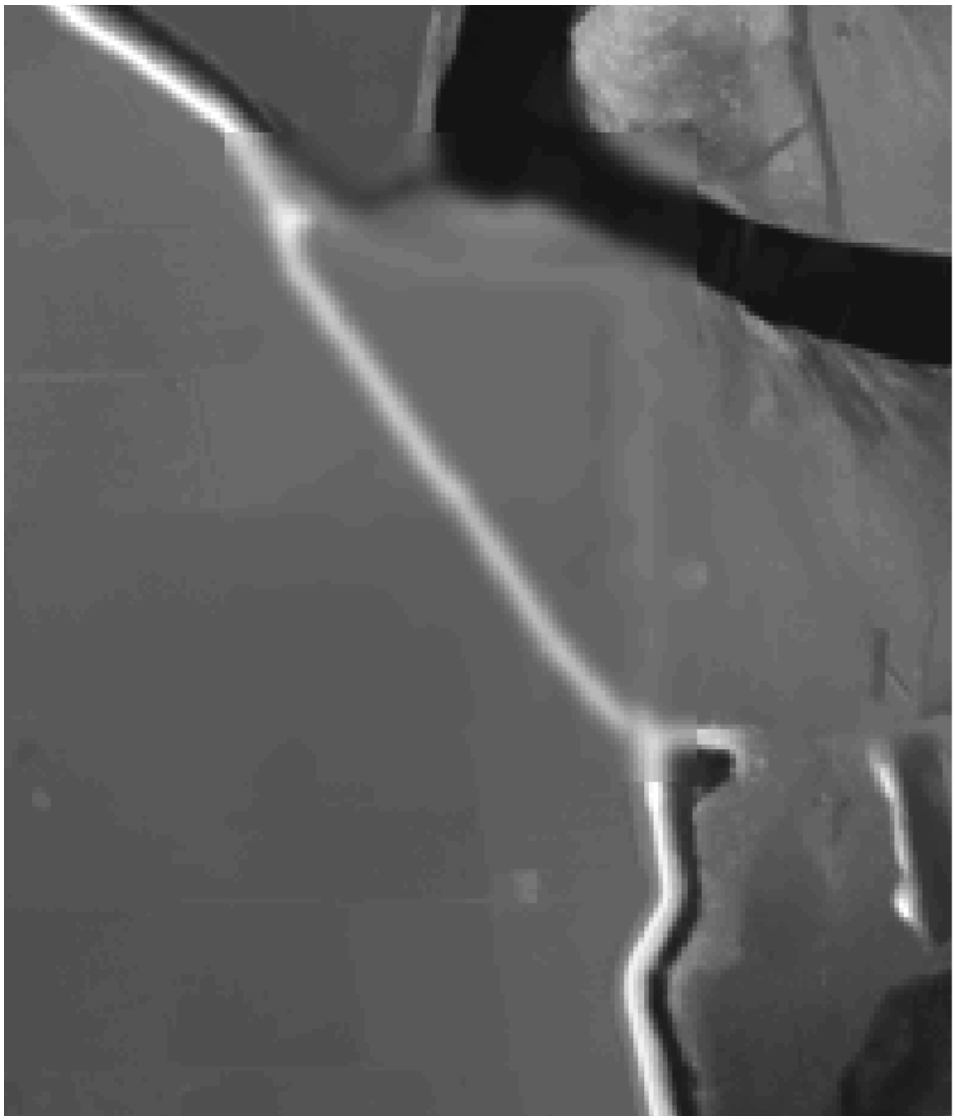

Figure D-27. DEM with New Levee Added in and Old (existing) Levee Removed

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix E. Synthetic vs. Observed Hydrographs

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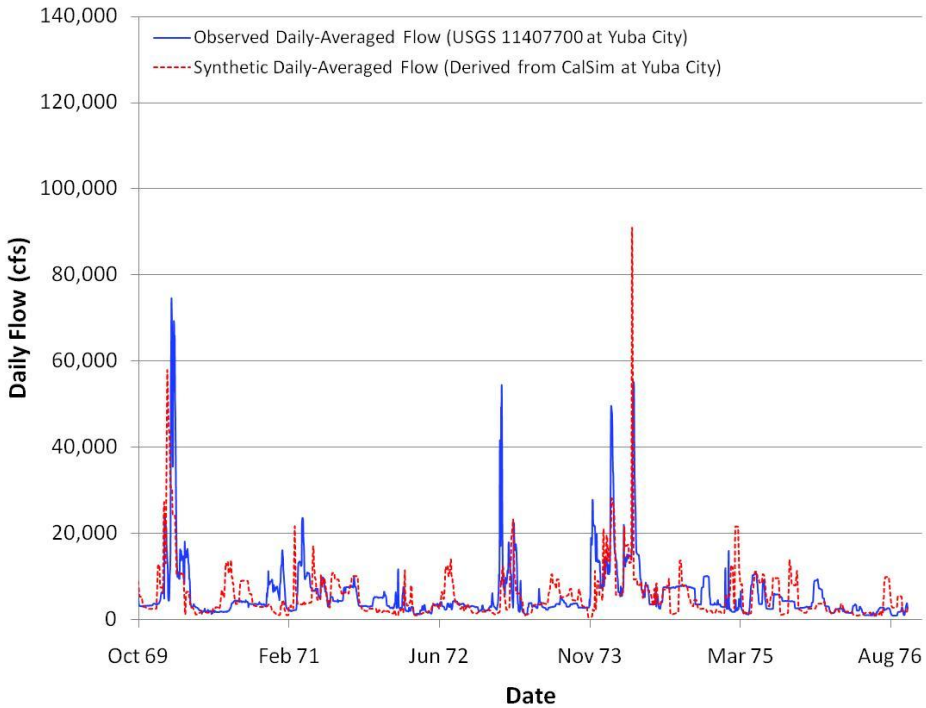

Figure E-1. Synthetic vs. Observed Flow – Yuba City

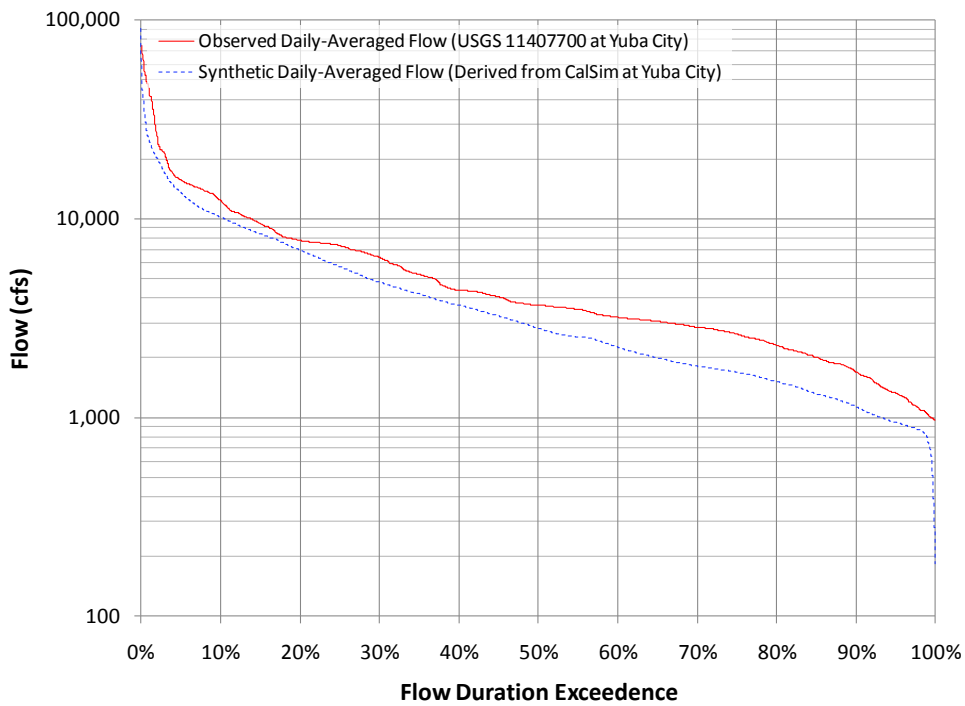

Figure E-2. Synthetic vs. Observed Flow Duration Curve – Yuba City

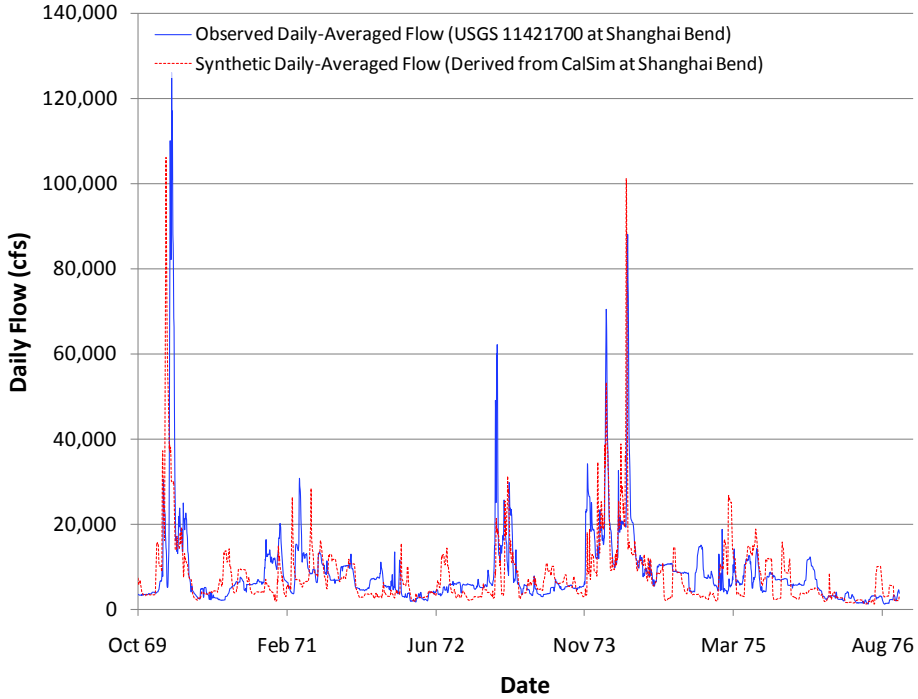

Figure E-3. Synthetic vs. Observed Flow – Shanghai Bend

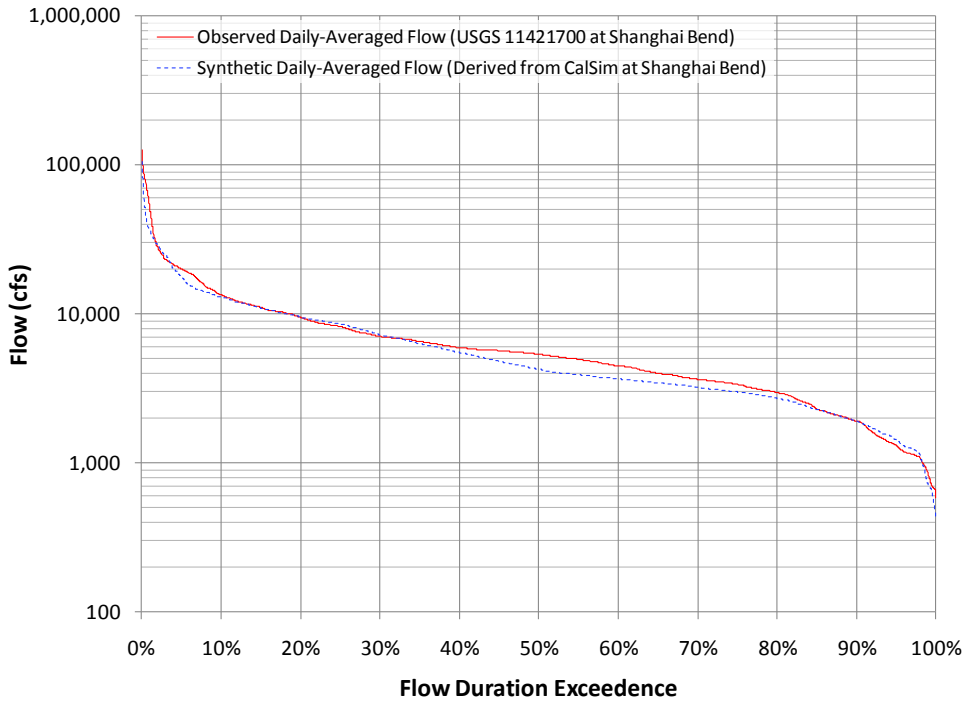

Figure E-4. Synthetic and Observed Flow Duration Curve – Shanghai Bend

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix F. HEC-EFM Ecosystem Functional Relationships

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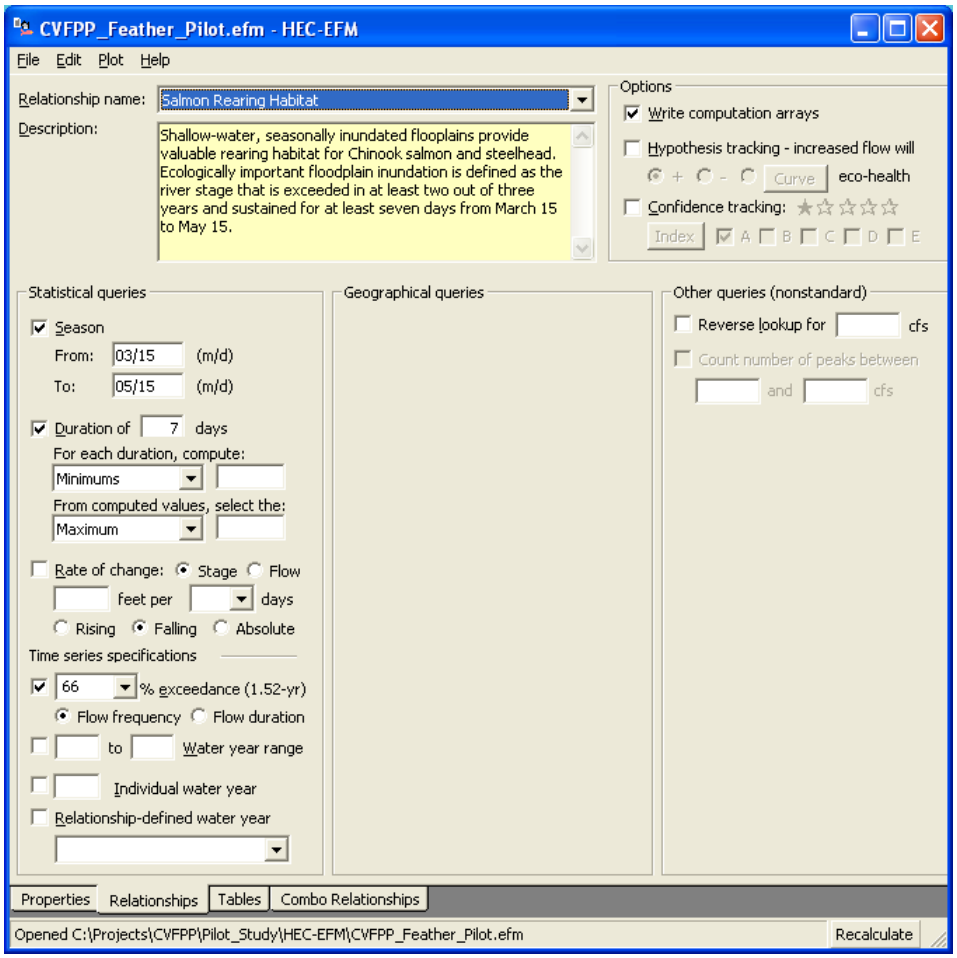

Figure F-1. Salmon Rearing Habitat Formation Ecosystem Functional Relationship (EFR)

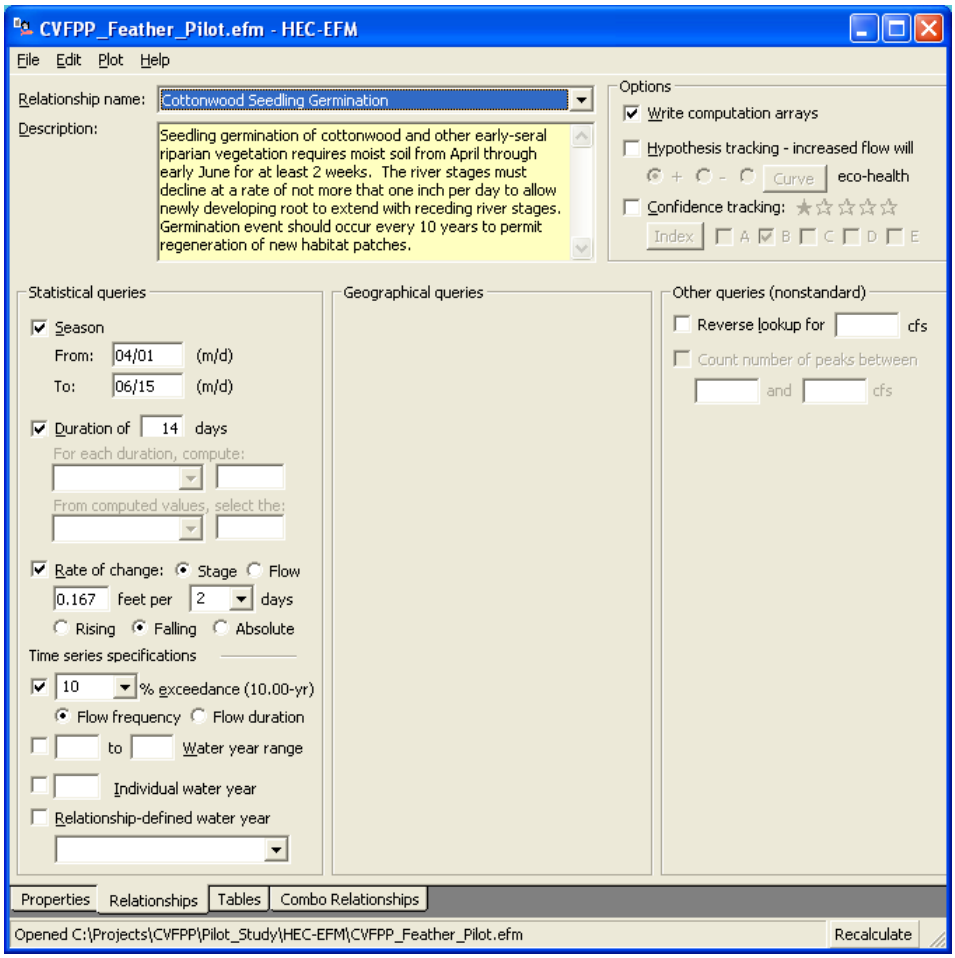

Figure F-2. Cottonwood Seedling Germination EFR

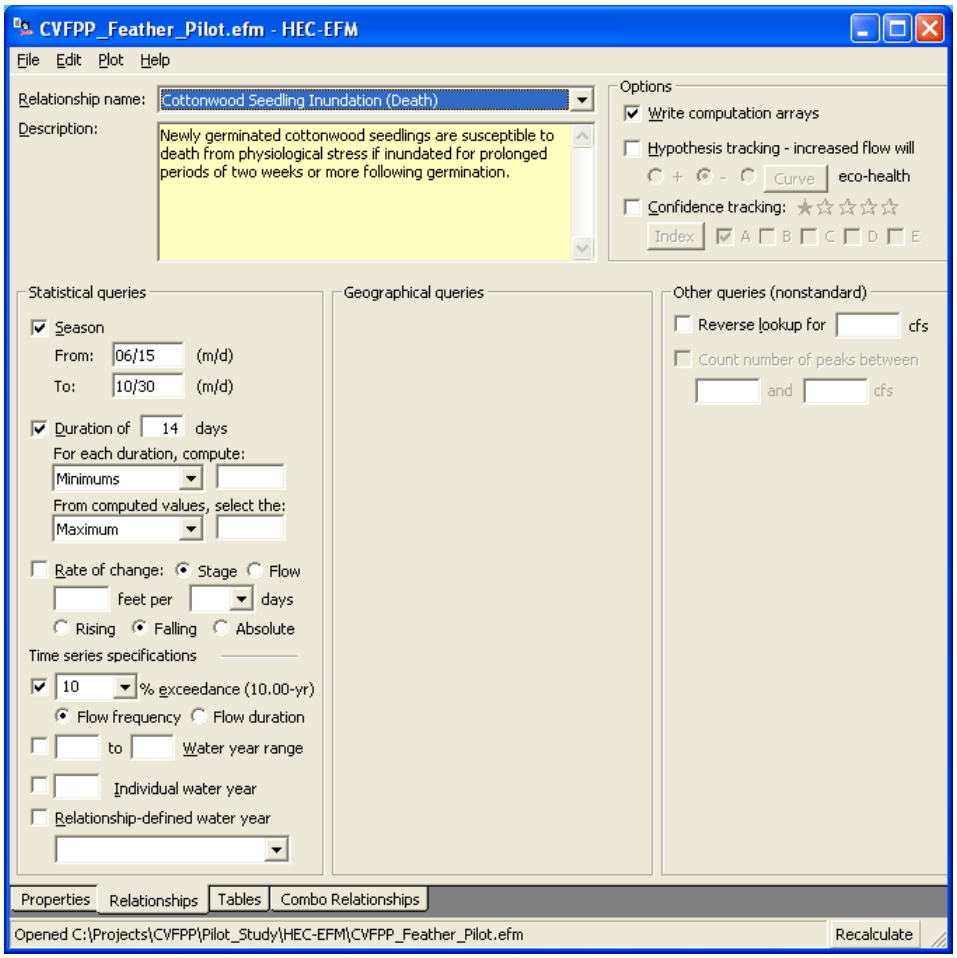

Figure F-3. Cottonwood Seedling Inundation (Death) EFR

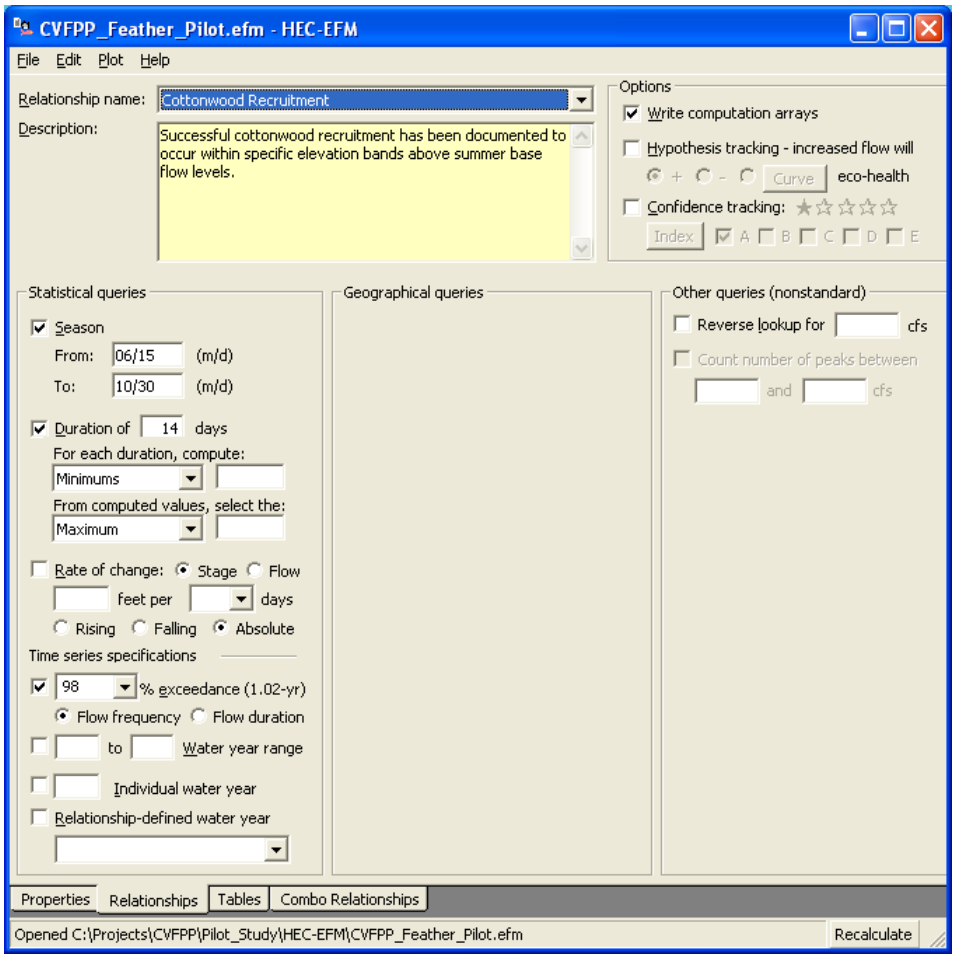

Figure F-4. Cottonwood Recruitment EFR

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Attachment 9F: Floodplain Restoration Opportunity Analysis – Appendix G. RAS/EFM Analysis FIP-Based Mapping

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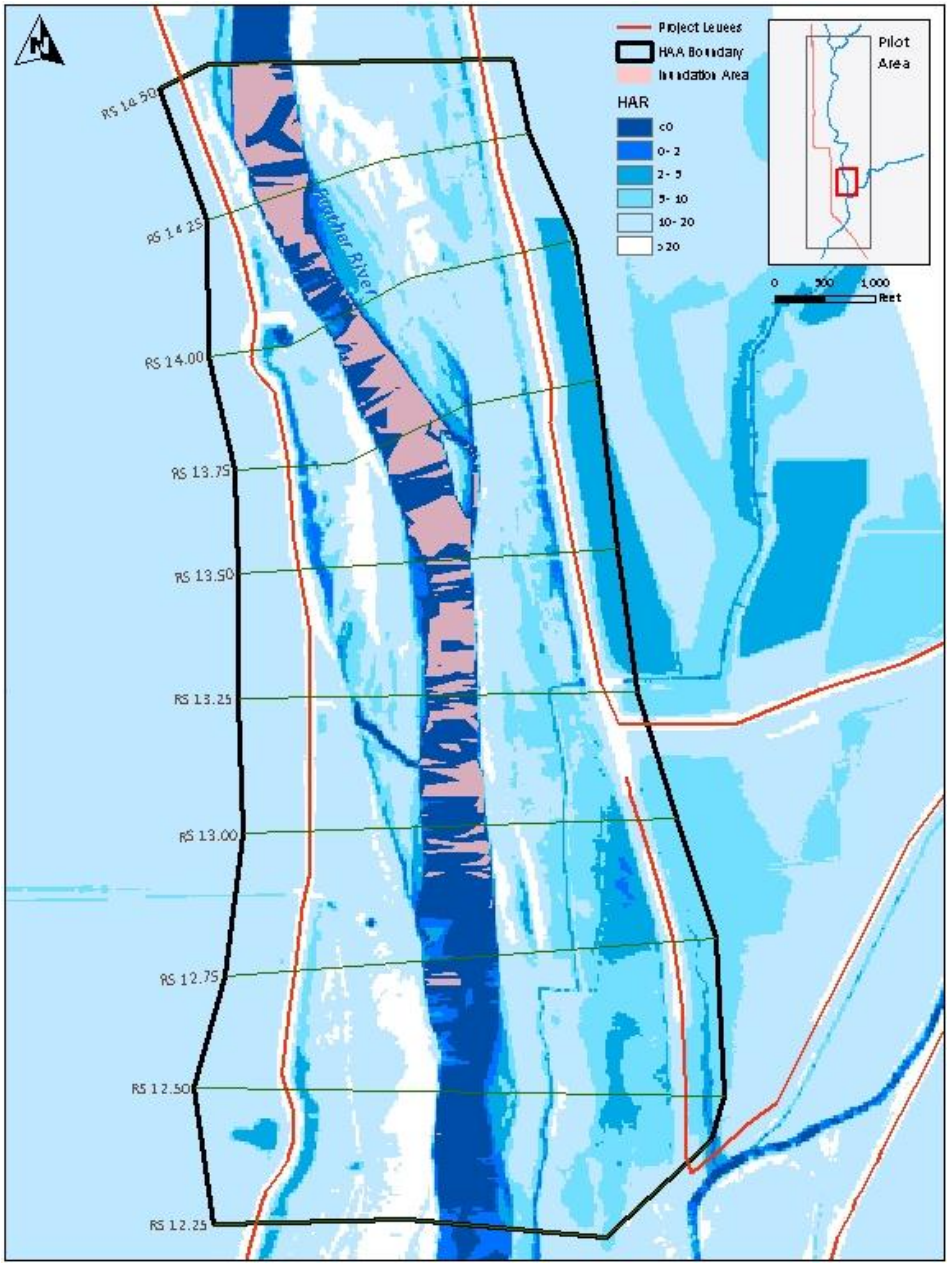

Figure G-1. Cottonwood Seedling Germination – RS 12.25 – RS 14.50

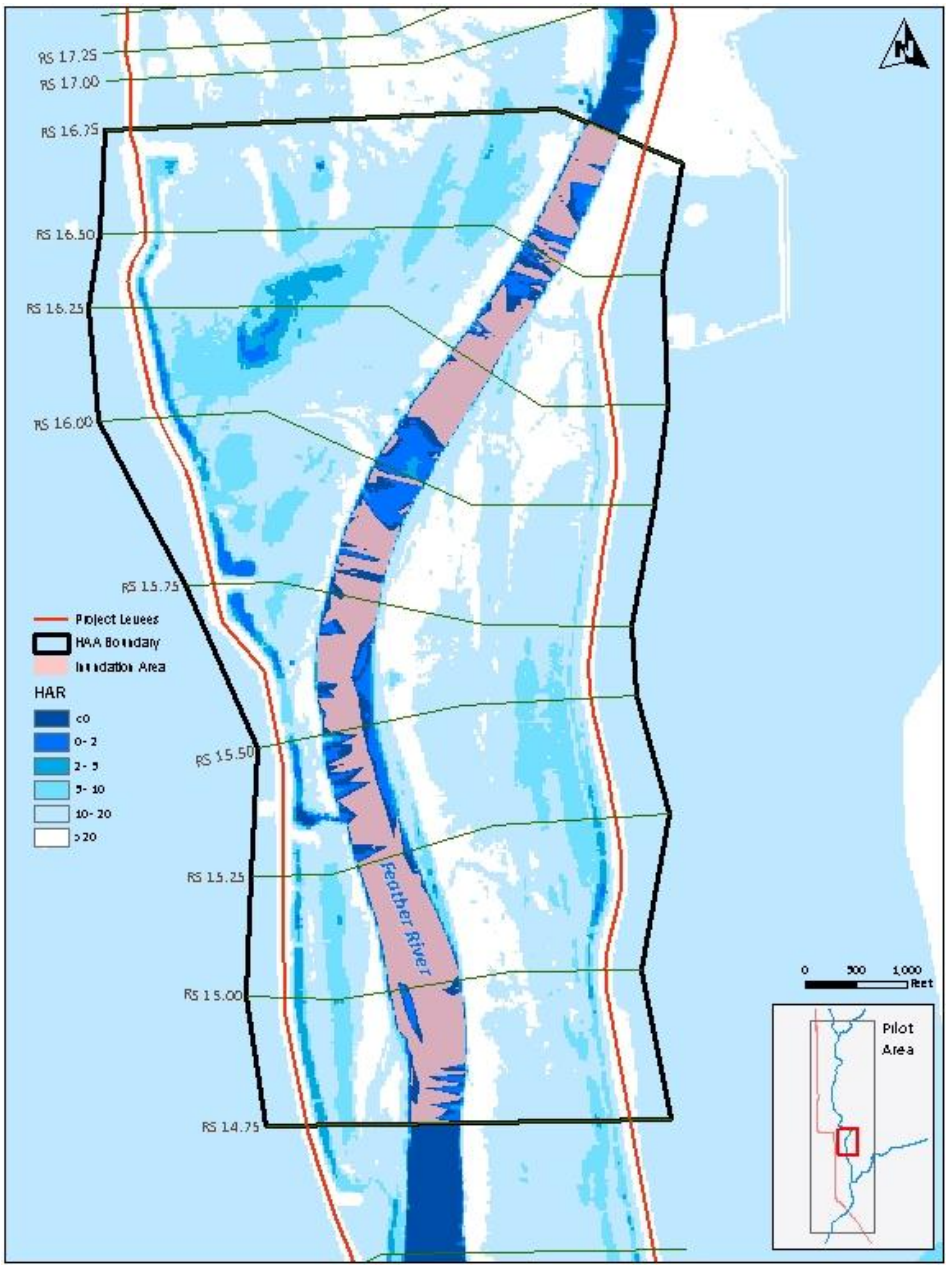

Figure G-2. Cottonwood Seedling Germination – RS 14.75 – RS 16.75

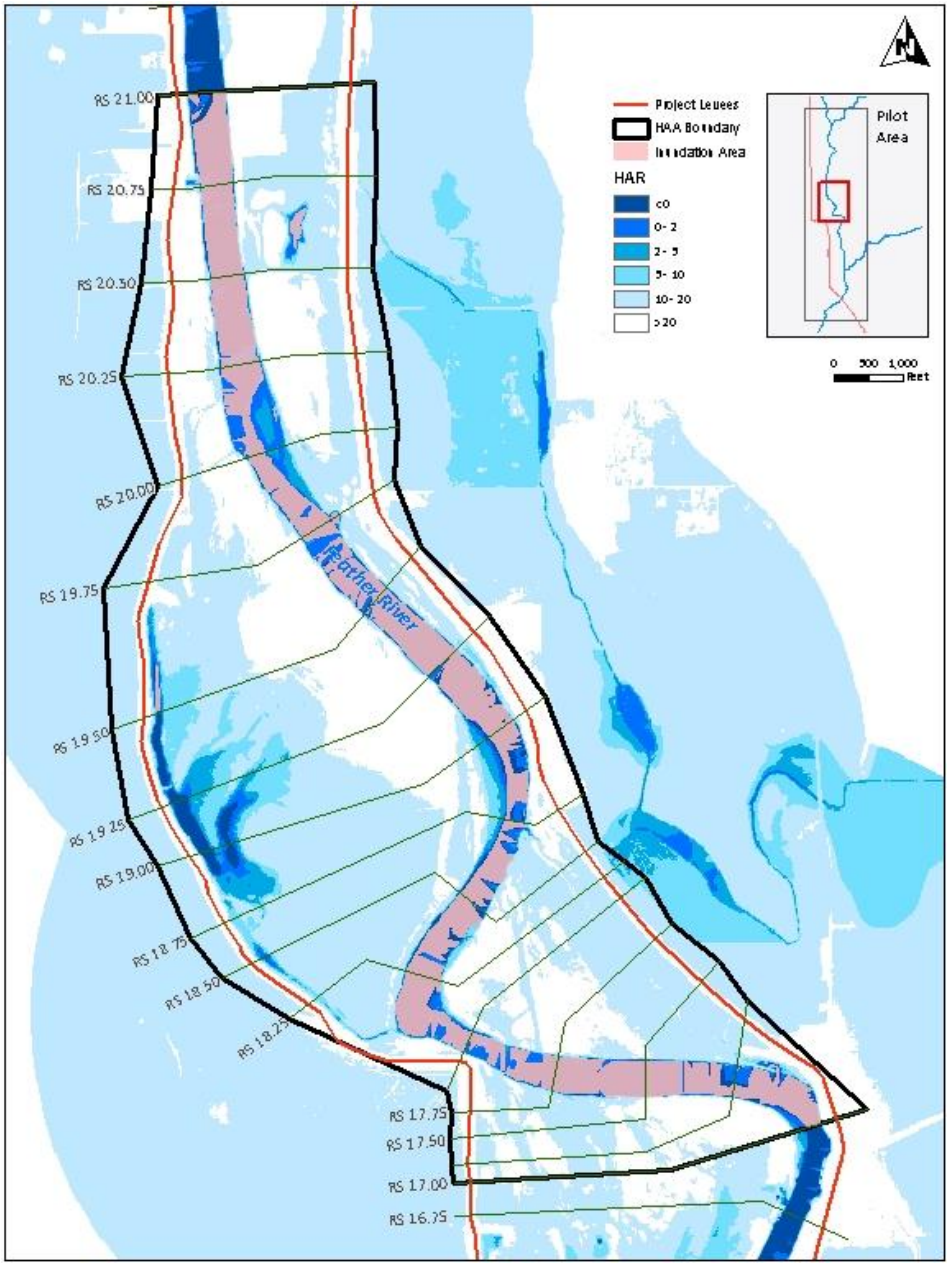

Figure G-3. Cottonwood Seedling Germination – RS 17.00 – RS 21.00

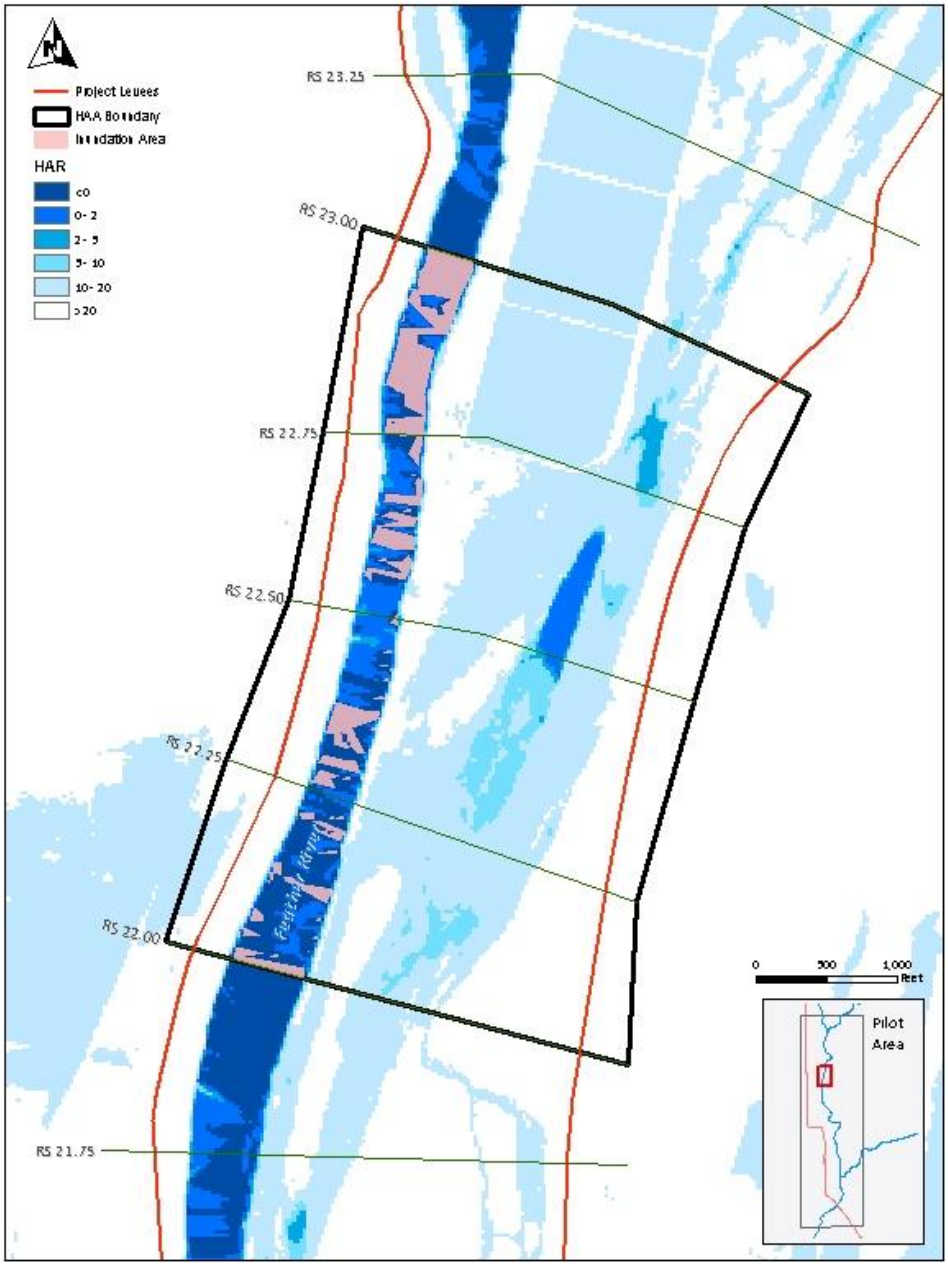

Figure G-3. Cottonwood Seedling Germination – RS 22.00 – RS 23.00

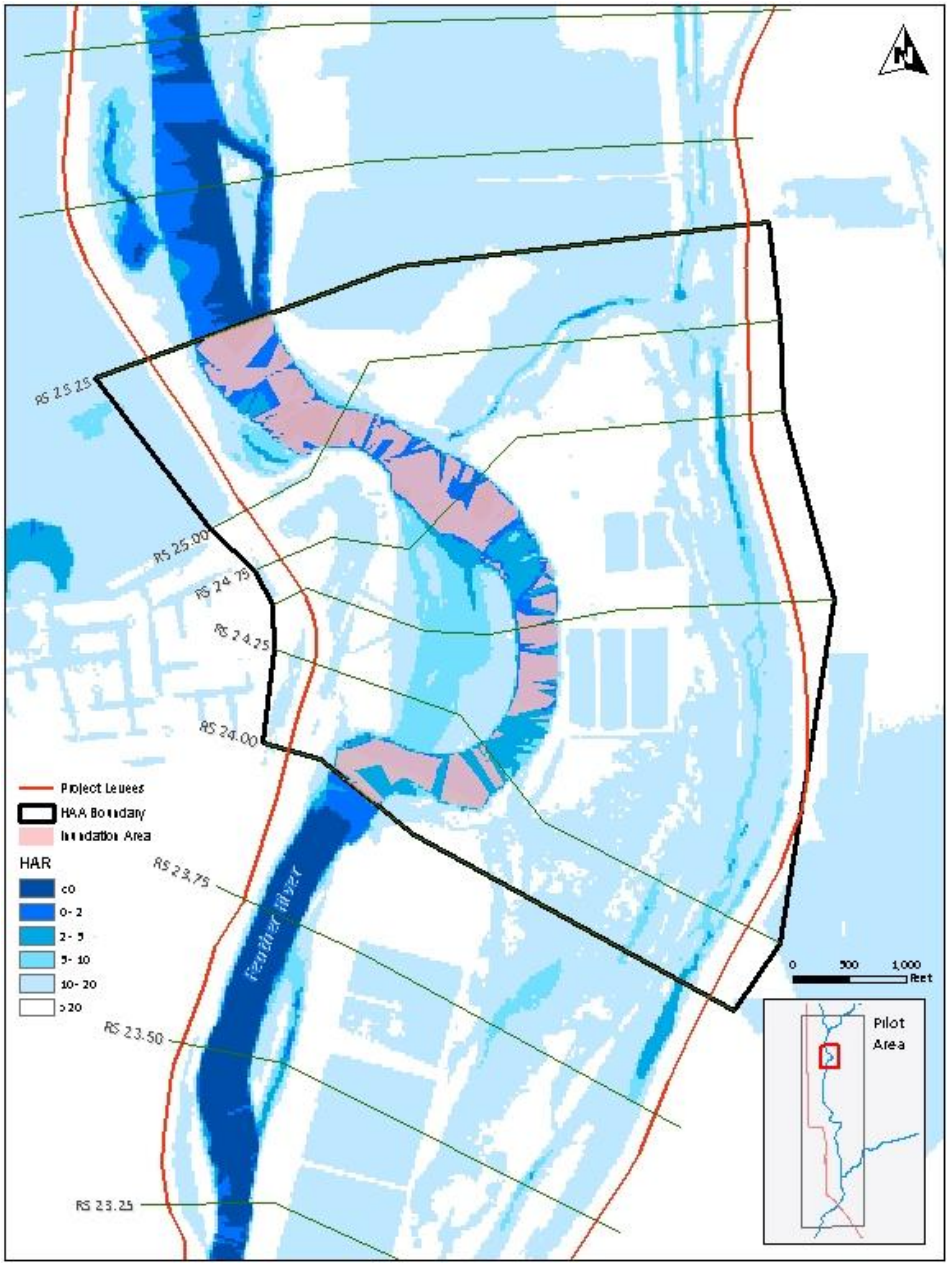

Figure G-4. Cottonwood Seedling Germination – RS 24.00 – RS 25.25

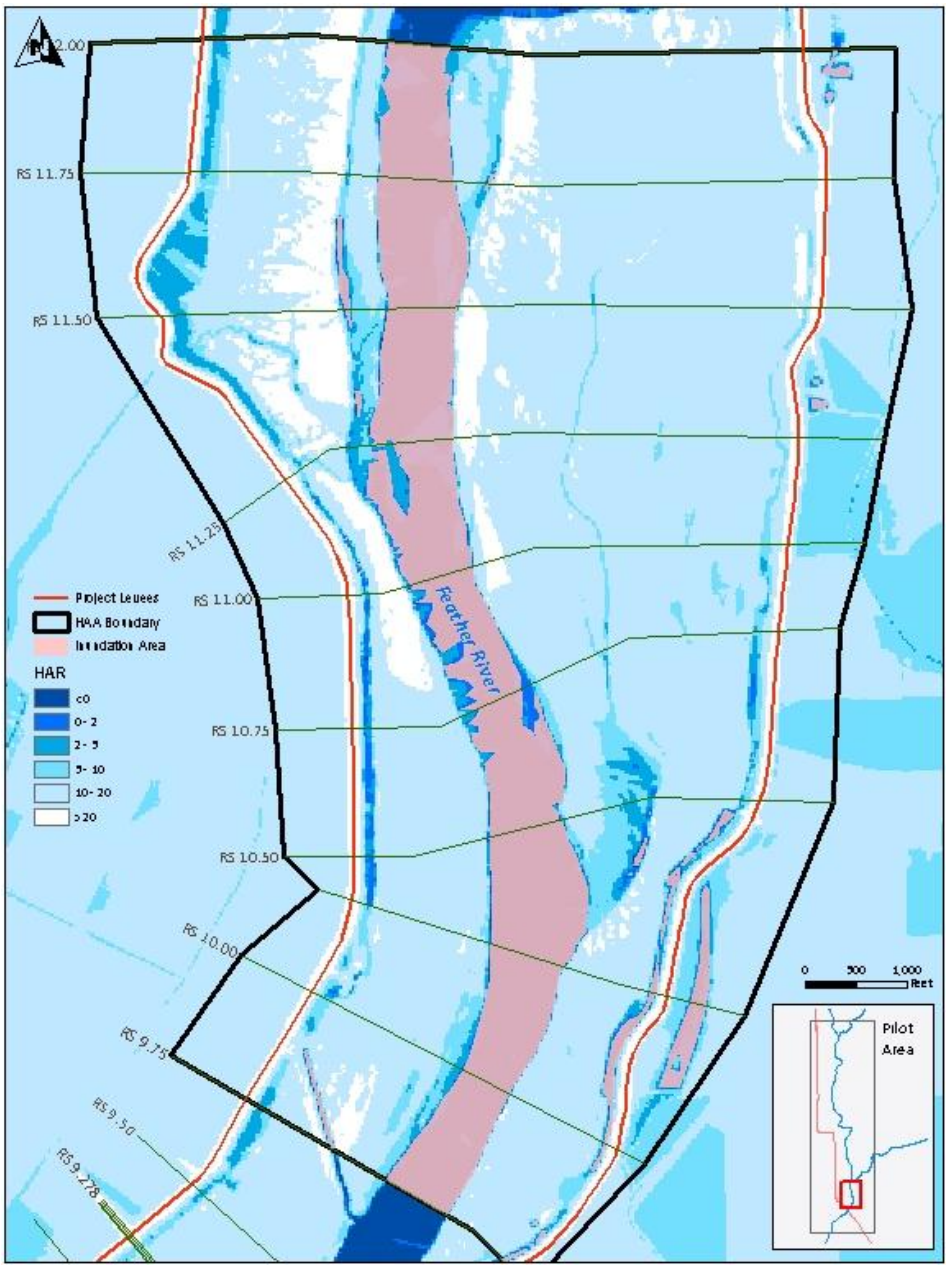

Figure G-5. Cottonwood Seedling Inundation – RS 9.75 – RS 12.00

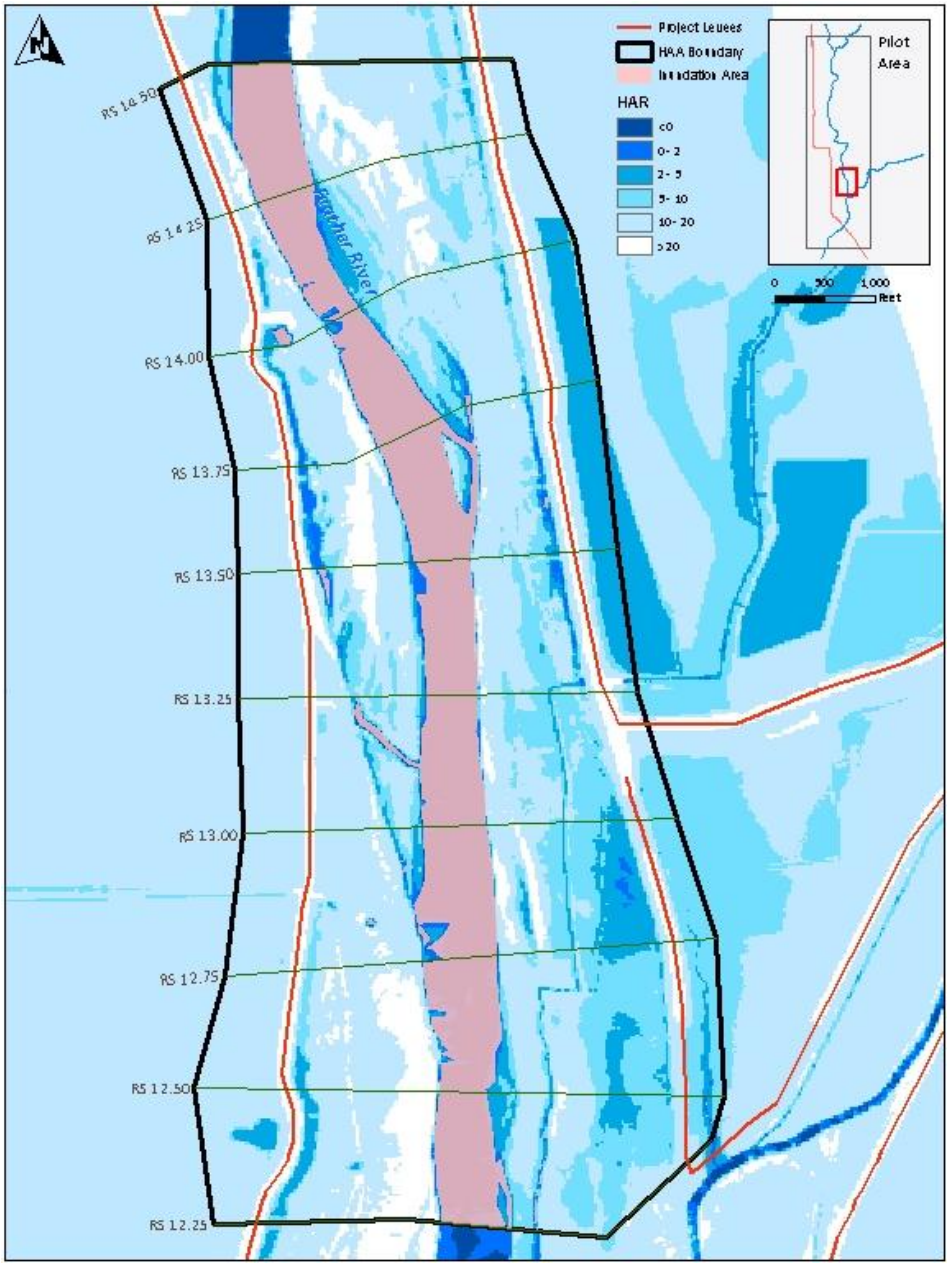

Figure G-6. Cottonwood Seedling Inundation – RS 12.25 – RS 14.50

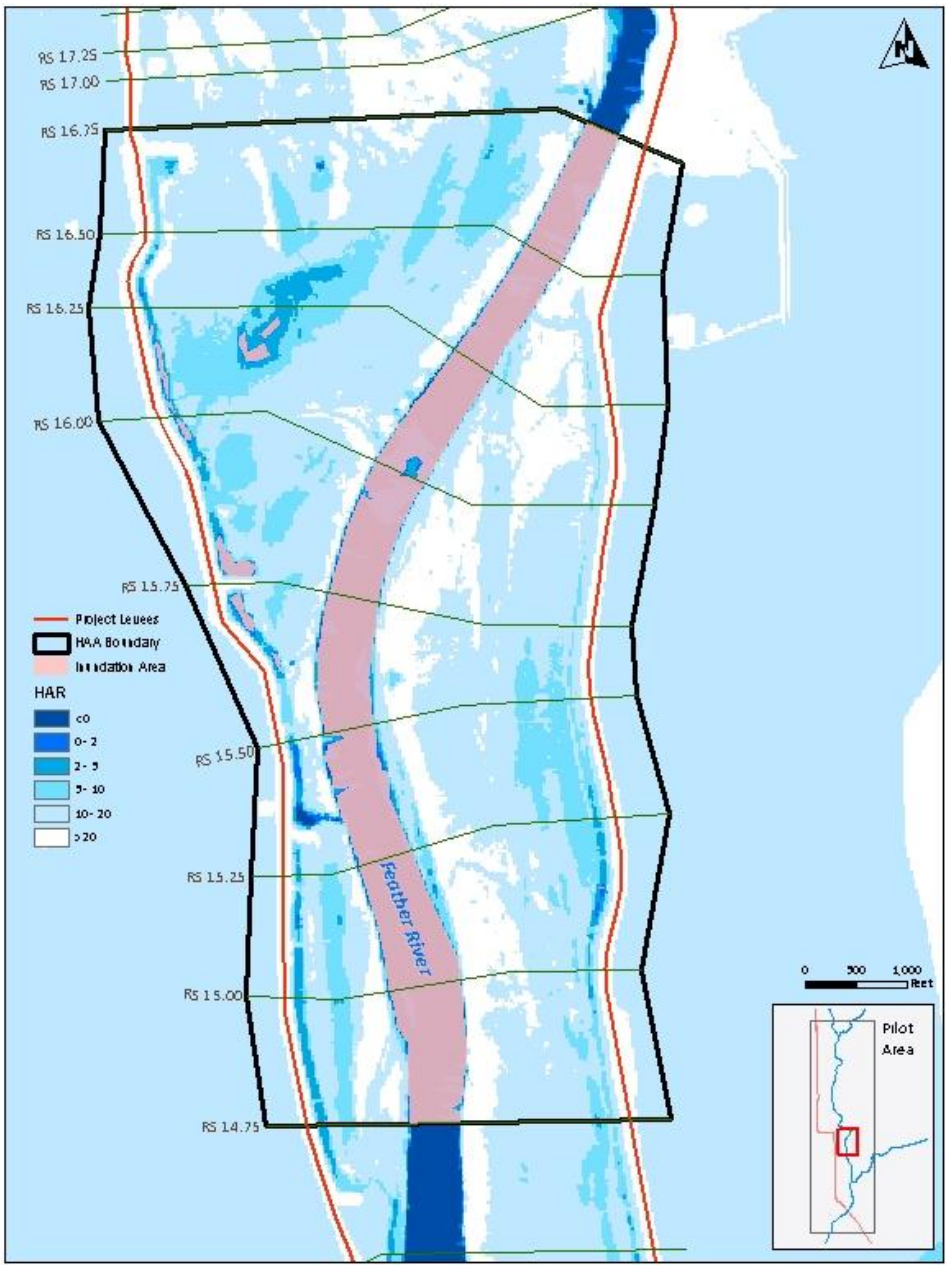

Figure G-7. Cottonwood Seedling Inundation – RS 14.75 – RS 16.75

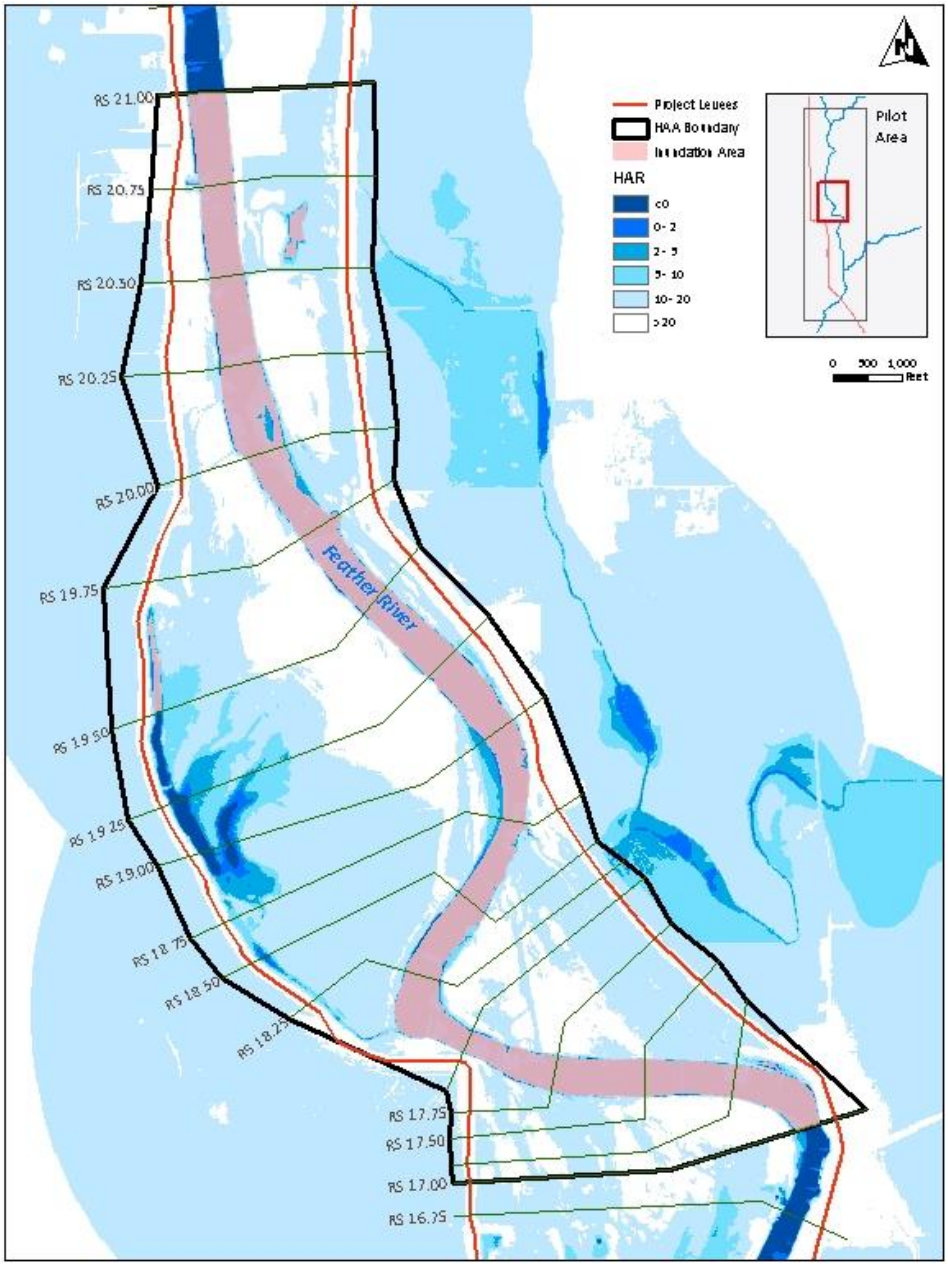

Figure G-9. Cottonwood Seedling Inundation – RS 17.00 – RS 21.00

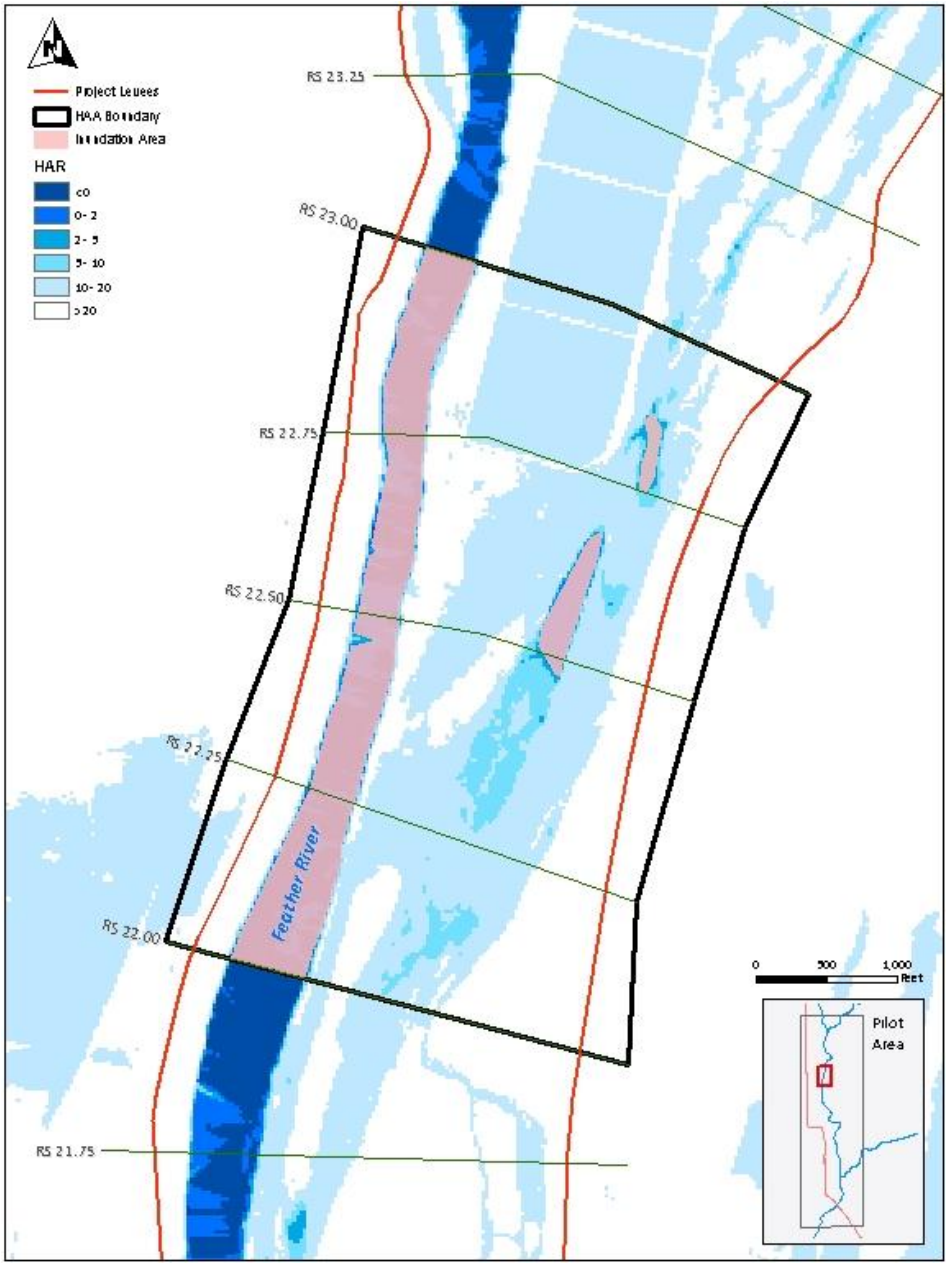

Figure G-8. Cottonwood Seedling Inundation – RS 22.00 – RS 23.00

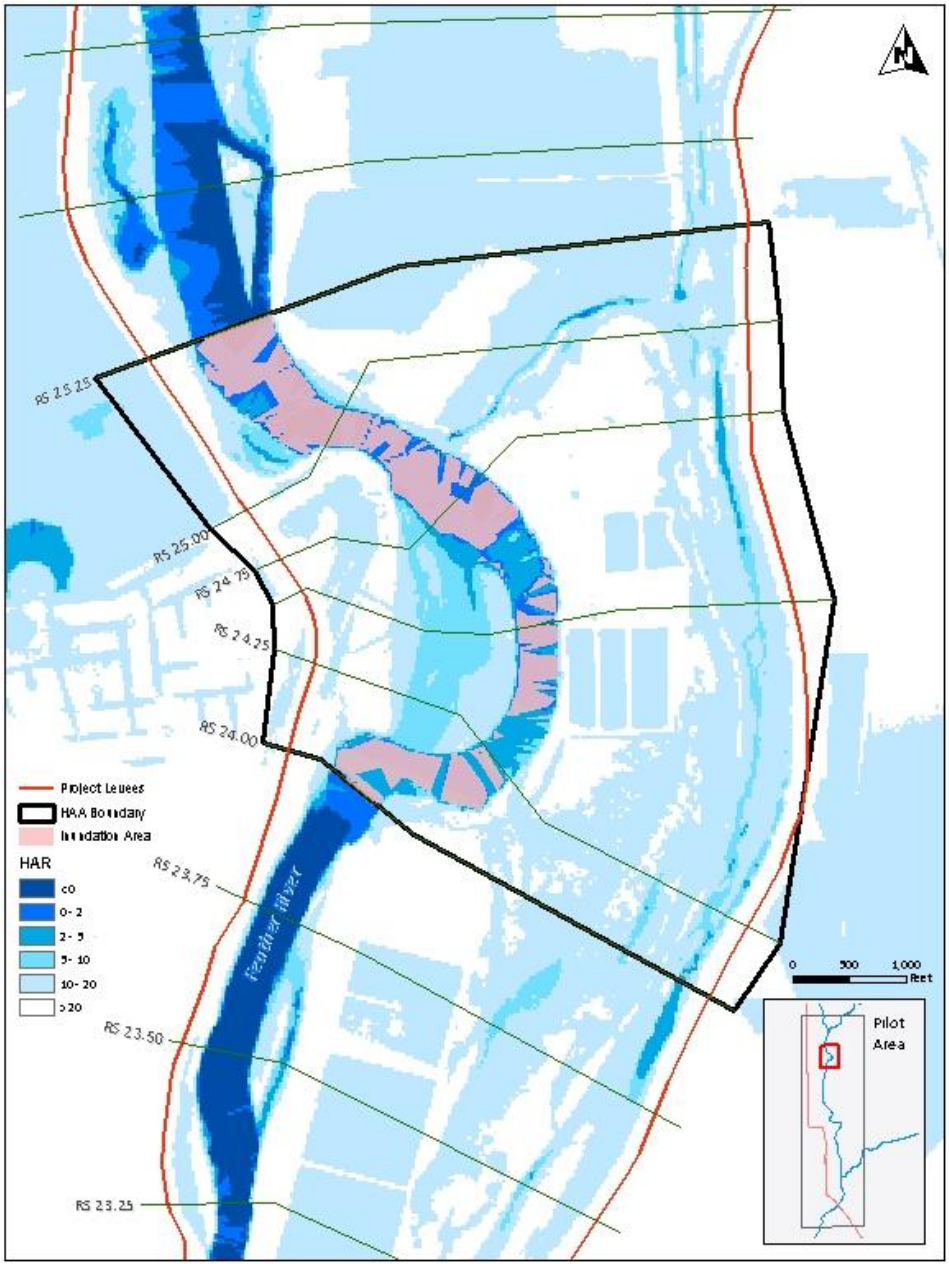

Figure G-11. Cottonwood Seedling Inundation – RS 24.00 – RS 25.25

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Attachment 9G

Regional Permitting Options

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Attachment 9G: Regional Permitting Options

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Table of Contents

1.0 Introduction 1-1

2.0 Programmatic Permitting Needs and Objectives 2-1

3.0 Potential Flood Management Activities That May Be Covered by Regional or Project Permitting 3-1
- 3.1 Activities Suitable for Programmatic Permitting 3-1
- 3.2 Activities Requiring Additional Information to Determine Suitability for Programmatic Permitting 3-2

4.0 Summary of Possible Regulatory Tools to Provide Programmatic/Regional Authorizations 4-1
- 4.1 Federal Authorities 4-1
  - 4.1.1 U.S. Army Corps of Engineers 4-2
  - 4.1.2 U.S. Fish and Wildlife Service and National Marine Fisheries Service 4-3
- 4.2 State Authorities 4-7
  - 4.2.1 California Department of Fish and Game 4-9
  - 4.2.2 Central Valley Regional Water Quality Control Board 4-13
  - 4.2.3 State Historic Preservation Officer 4-13
  - 4.2.4 Central Valley Flood Protection Board 4-15
  - 4.2.5 California State Lands Commission 4-16
- 4.3 Memoranda of Understanding and Memoranda of Agreement to Support Regulatory Compliance 4-16

5.0 Linkage with Other Regional Permitting Efforts and Current Activities 5-1

6.0 Other Potentially Applicable Regulations for Which Programmatic Authorization May or May Not Be Available 6-1
- 6.1 Federal Authorizations 6-1
- 6.2 State Authorizations 6-1
- 6.3 Local Authorizations 6-2

7.0 References 7-1

8.0 Acronyms and Abbreviations 8-1

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1.0 Introduction

Programmatic approaches to permitting and other regulatory authorizations for flood management activities (e.g., regional permitting mechanisms) are an important part of improving and integrating flood management and ecosystem conservation in the Central Valley. To support both the development of the Central Valley Flood Protection Plan (CVFPP) and the linked Central Valley Flood System Conservation Strategy, this informational document does the following:

- Describes the benefits of programmatic authorizations (as compared to project-by-project permitting).
- Identifies the types of flood management activities that potentially could be covered by such programmatic authorizations.
- Describes and evaluates several options for developing programmatic authorization mechanisms for the flood management system, and identifies important environmental regulations that apply.
- Identifies potential overlaps and gaps with existing regulatory-based regional plans (e.g., Natural Community Conservation Plans (NCCP), Habitat Conservation Plans (HCP),) and with regional or programmatic authorizations (Regional General Permits (RGP), Routine Maintenance Agreements (RMA)).

This document does not provide guidance with regard to specific projects or propose an approach to programmatic permitting for flood management activities.

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2.0 Programmatic Permitting Needs and Objectives

The California Department of Water Resources (DWR) is integrating environmental stewardship into flood management activities. Environmental stewardship has a goal of improving ecological conditions and trends, and integration of this stewardship can improve conditions relative to the existing environmental baseline and will reduce the adverse effects of flood management activities. However, it will not eliminate the need for regulatory compliance, including compensatory mitigation for unavoidable impacts to the environment. With regard to regulatory permitting for flood management activities, DWR will make every effort to employ efficient and effective permitting approaches that support the Conservation Framework goals included in the 2012 CVFPP.

Traditional project-by-project environmental permitting has several shortcomings for project proponents, regulators, and conservation interests. These shortcomings can include time-consuming negotiations to identify suitable off-site mitigation areas as compensation for projects that result in habitat loss, project delays, establishing small isolated mitigation areas that are difficult and relatively costly to manage, and temporal losses in habitat functions while habitat is being restored at compensation sites.

During the past 20 years, several regional approaches have been developed to address these permitting challenges. Local governments in the State of California (State) have been using these regional approaches to both permit land development and maintain and improve functional ecosystems. These approaches are described in Section 4.0, “Summary of Possible Regulatory Tools to Provide Programmatic Authorizations,” and include programmatic section 7 consultations, regional HCPs, NCCPs, and RGPs. Additional approaches are being developed, including Regional Advance Mitigation Planning (RAMP) and Corridor Management Plans (CMP) (see Conservation Framework, Sections 5.4.6 and 5.4.4, respectively).

These regional approaches are being used by DWR and other state and local agencies, or could be used, to meet the collective permitting needs for multiple projects on a regional scale and for longer time periods (compared to project by project permitting), while also consolidating mitigation efforts into larger, more viable conservation areas that can be more effectively managed long-term.

DWR is evaluating how existing regional approaches (e.g., regional conservation plans) may be developed to help meet its flood management permitting needs. It is also working to identify other suitable regulatory tools (e.g. programmatic permitting) that can be used where existing regional approaches are not applicable. Several conservation planning efforts that overlap with the CVFPP Statewide Planning Area are listed in Attachment 9E: Existing Conservation Objectives from Other Plans.

3.0 Potential Flood Management Activities That May Be Covered by Regional or Project Permitting

Programmatic permitting can reduce the time required for agency coordination and review for projects with minimal environmental impacts. While these permits may take longer to develop initially, permitting multiple projects together results in improved overall efficiency when compared to the timelines typically associated with project by project permitting. Programmatic permits accomplish this by incorporating specific design requirements and conservation measures up front. Because the project design, construction methods, and associated conservation measures are generally in place, agency approvals can be processed promptly. This section identifies potential actions that are suitable for programmatic compliance with State and federal regulations and those actions that may qualify for programmatic permitting.

3.1 Activities Suitable for Programmatic Permitting

DWR will be evaluating and implementing a variety of flood management activities, including some of the actions listed below. Activities that have impacts on environmental resources that are negligible or consistently below a defined threshold may qualify for programmatic permitting, as described in the following sections. It should be noted that in some situations some of the bulleted items below, when conducted on a large scale, could result in impacts that are not negligible and not necessarily below a defined threshold and therefore may require further analysis to determine suitability for programmatic permitting.

Some facilities operations, maintenance, and construction activities may be suitable for programmatic permitting. These activities include the following:

- Channel clearing and obstacle removal (e.g., snags)
- Minor (i.e., limited in size) bank stabilization and erosion repairs, including rock slope placement

- Closure structure maintenance, operation, and rehabilitation
- Structure repair
- Manual and mechanical vegetation control (terrestrial and aquatic)
- Ground surface modification by grading
- Minor vegetation or tree removal
- Penetration gap grouting or filling (e.g., rodent burrow)
- Silt, sand, or sediment removal

Some habitat enhancement and restoration activities to improve ecosystem functions also may be suitable for programmatic permitting. These activities include the following:

- Management of runoff through watershed management
- Removal of unnatural hard points within and along channels
- Control of invasive species
- Removal of barriers to fish passage
- Restoration of historical channel alignment (i.e., conduct de-channelization)
- Planting of native vegetation

3.2 Activities Requiring Additional Information to Determine Suitability for Programmatic Permitting

Some flood management activities are likely to result in more extensive changes in the landscape, such as larger, new project footprints. Major activities, such as those listed below, will need to be coordinated with other land use planning and decisions, and may require more complex programmatic permitting approaches. DWR will work with regulatory agencies to assess the level of complexity these activities might entail for regional permitting. Flood management activities requiring additional information to determine suitability for programmatic permitting include:

- **Levee Improvements or Levee Construction** – Actions involving levee improvement and construction may not be suitable for programmatic permitting because they usually cause substantial, project-specific impacts that cannot be avoided or reduced to minimal levels through predetermined design and conservation measures. However, some minor levee improvement projects with minimal impacts could be suitable. If proposed changes are limited to restoring the authorized level of protection or improving the structural integrity of the protection system and do not change the authorized structural geometry or hydraulic capacity, they may be approved in accordance with 33 Code of Federal Regulations (CFR) 208.10 through submittal of an encroachment permit application by the Central Valley Flood Protection Board (Board) to the U.S. Army Corps of Engineers (USACE). Activities that result in more than minor modification of federal levees or channel conveyance require authorization under section 14 of the Rivers and Harbors Act of 1899 (33 U.S. Code 408), referred to as "section 408." Such authorizations must be sought on an individual project basis because there is no mechanism to achieve programmatic section 408 authorization. Levee improvement and construction activities include the following:

  - Raising levees to improve flood system performance
  - Remediating erosion damage into levee prism
  - Setting back levees to connect rivers to floodplains
  - Constructing new levees or bypasses to provide flood protection to additional areas potentially affected by flooding
  - Constructing ring levees
  - Constructing training levees or levees that subdivide larger basins

- **Floodplain Management Activities** – These activities would involve the following actions:

  - Using floodproofing measures
  - Removing disconnected, redundant, and nonfunctional facilities of the State Plan of Flood Control (SPFC)

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4.0 Summary of Possible Regulatory Tools to Provide Programmatic/Regional Authorizations

Agencies with regulatory authority include USACE Regulatory Division, Central Valley Regional Water Quality Control Board (RWQCB), California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), State Historic Preservation Office (SHPO), California State Lands Commission (SLC), and the Board.

This section summarizes the regulatory mechanisms that could be used by the above agencies to provide programmatic authorizations for flood management activities. Different methods for attaining regulatory compliance are identified to facilitate discussions between DWR and regulatory agencies and determine the most appropriate permitting strategies. These permitting approaches have been developed based on review of existing permit programs and policies for comparable permitting efforts.

4.1 Federal Authorities

The National Environmental Policy Act (NEPA) requires that federal agencies review their proposed actions through a process that evaluates potential environmental effects of the proposed action and of reasonable and prudent alternatives that would avoid or minimize significant effects. Compliance with NEPA would be necessary for USACE, USFWS, NMFS, or other federal agencies providing authorization or funding for flood management activities. Requirements for compliance with NEPA are determined by NEPA and by guidelines of the Council of Environmental Quality and the federal agency undertaking the action. NEPA grants considerable discretion to federal agencies regarding the procedures for NEPA review. Consequently, timeline and requirements for NEPA compliance vary considerably among federal agencies and the various actions they undertake.

Federal agencies would conduct NEPA review for their respective federal authorizations through preparing Environmental Assessments (EA), and/or

Environmental Impact Statements (EIS) as part of the agencies' internal authorization process. If an EA concludes with a Finding of No Significant Impact (FONSI), no further NEPA documentation would be required. If the EA determines that the project may result in significant environmental effects, or if significant effects are presumed initially, preparation of an EIS would be required for NEPA compliance. In general, significance of an action's effects is determined in terms of the context and intensity of its effects, and the federal agency's NEPA guidance may provide additional direction regarding significance determinations. An EIS evaluates the potential effects of both the proposed action and reasonable alternatives; it also discusses means to mitigate adverse impacts. NEPA compliance with an EIS is completed with a Record of Decision (ROD) regarding the proposed action. NEPA compliance with an EIS generally takes more than 1 year and requires more time and expense than compliance with an EA. The duration and expense of NEPA compliance with an EA, although less than with an EIS, varies substantially among actions and agencies.

4.1.1 U.S. Army Corps of Engineers

This section summarizes the regulatory mechanisms that could be used by USACE to provide programmatic authorizations for flood management activities under section 404 of the Clean Water Act (CWA) and section 10 of the Rivers and Harbors Act of 1899 (RHA) including RGPs, and PGPs.

Clean Water Act Section 404 and Rivers and Harbors Act Section 10

Section 404 of the CWA prohibits the discharge of dredged or fill materials into waters of the United States, and section 10 of the RHA prohibits obstruction or alteration of navigable waters of the United States without prior USACE authorization. Two potential programmatic approaches are available for compliance with these statutes: an RGP and a Programmatic General Permit (PGP). USACE could develop an RGP or PGP for activities within the planning area of the CVFPP (i.e., the Systemwide Planning Area (SPA)) under the authority of section 404 (33 United States Code (USC) section 1344) and section 10 (33 USC section 403), in accordance with provisions of Regulatory Programs of the Corps of Engineers, 33 CFR section 323.2(h), for activities that are substantially similar in nature and that cause only minimal individual and cumulative environmental impacts. RGPs and PGPs are generally valid for 5 years from the date of issuance and may be renewed at USACE's discretion.

Regional General Permit

An RGP is issued by a USACE district or division and authorizes a class of activities within a geographic region that are similar in nature and have minimal individual and cumulative environmental impacts. Overall, RGPs increase the efficiency of the USACE permitting process by avoiding the

need to obtain separate permits on a project-by-project basis. To qualify for authorization under an RGP permit, applicants must meet general and special conditions established for that RGP. Once an RGP is issued, applicants can use the permit if the stated conditions are met. RGPs typically require project-by-project notification to USACE, and USACE issues a Notice to Proceed if the terms of the RGP are met. RGP processing timelines are difficult to anticipate and are based on agency coordination and workloads; however, a 1- to 2-year time frame from preapplication coordination to RGP issuance is a reasonable expectation.

Programmatic General Permit

A PGP may be issued by a USACE division where a local, state, or other federal program provides protections for the aquatic environment that are at least equivalent to the protections provided by USACE's Regulatory Program. The PGP is a mechanism available to local, tribal State, and federal regulatory authorities (other regulatory authorities (ORA)). A PGP provides the written vehicle that identifies the terms, limitations, and conditions under which specific projects regulated by an ORA program may be authorized by a regulator under USACE's Regulatory Program with a more efficient and abbreviated review by USACE. Under a PGP, USACE may delegate parts of its administrative authority to allow the ORA, in this case DWR, to review project-specific PGP notifications and issue Notices to Proceed. PGPs may thus simplify the evaluation process and facilitate a "one-stop-shopping" permitting approach. RGP processing timelines are difficult to anticipate and are based on agency coordination and workloads; it would be reasonable to anticipate a 2- to 5-year time frame from preapplication coordination to PGP issuance.

4.1.2 U.S. Fish and Wildlife Service and National Marine Fisheries Service

This section summarizes the regulatory mechanisms that could be used by USFWS to provide programmatic authorizations for flood management activities under the Endangered Species Act of 1973, as amended (16 USC 1531 et. seq.) (ESA) including Biological Opinions (BOs) and Programmatic Biological Opinions (PBOs) under section 7; HCPs under section 10; and Safe Harbor Agreements (SHAs) under the authority of section 10(a)(1)(A).

Endangered Species Act Section 7

Once a fish or wildlife species is listed as endangered or threatened under ESA, the act prohibits "take" of the species. To "take" a species means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Also, habitat modification or degradation that results in death or injury to listed species by impairing

behavioral patterns constitutes take. In addition, the ESA prohibits the destruction or adverse modification of designated critical habitat. Designated critical habitat encompasses areas that are essential to the conservation of threatened and endangered species, and includes geographic areas "on which are found those physical or biological features essential to the conservation of the species and which may require special management considerations or protection." Generally, USFWS (under the Department of the Interior) administers the ESA for terrestrial and freshwater species, and NMFS (under the Department of Commerce) administers the ESA for marine and anadromous species.

Section 7(a)(2) of the ESA requires federal agencies that are undertaking funding, permitting, or authorizing actions to consult with USFWS and/or NMFS to evaluate whether these actions would affect listed species or designated critical habitat. The issuance of a permit by a federal agency (federal action agency) provides a federal nexus for a State agency action or project for ESA compliance through section 7 consultation. For example, as part of issuing a 404 permit, which may provide a federal nexus for at least a portion of a project, USACE would initiate section 7 consultation with both USFWS and NMFS.

Based on this consultation, USFWS and NMFS may issue a BO, which states whether or not the federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat. Non-jeopardy BOs include an incidental take statement, describing the amount of "take" that is allowed to occur for otherwise lawful activities. BOs also include "reasonable and prudent measures" that USFWS and NMFS believe are necessary and appropriate to minimize the effects of a project, as well as terms and conditions to minimize incidental take or avoid take altogether. The formal section 7 consultation period is 135 days (beginning only after the USFWS has determined the application is complete); however, this time frame may vary based on agency workload.

A State agency may engage directly with the USFWS and/or NMFS through a technical assistance request, however, under section 7, a BO cannot be issued to a State agency directly. A BO can only be issued to the federal action agency.

Federal action agencies may request multiaction, or "ecosystem-based," programmatic consultations. Programmatic consultations evaluate the potential for related agency actions to affect listed and proposed species and designated and proposed critical habitat. Programmatic consultations are often based on a federal agency's proposal to apply specified standards or design criteria to future proposed actions. Programmatic consultations

can increase the efficiency of the section 7 consultation process because much of the effects analysis is completed one time, up front, rather than repeatedly for each separate action. Further, because programmatic analysis incorporates anticipated effects of a federal agency's future projects, the process for completing consultation for future actions proposed under the programmatic consultation can be shortened. Based on similar program-level authorizations throughout the state of California for efforts comparable in scale and complexity to the flood management activities considered by the CVFPP, it is anticipated that some future flood management projects would be addressed by the USFWS and NMFS in PBOs, or a combined PBO/a not-likely-to-adversely-affect letters from each of these agencies.

ESA Section 10 Habitat Conservation Plans

Any CVFPP activities that do not have a federal nexus (USACE or other federal agency) cannot consult under section 7 of the ESA. Instead, ESA compliance needs to be achieved under section 10 of ESA, through preparation of an HCP. HCPs are planning documents prepared by nonfederal parties as part of an application for an incidental take permit. An HCP assesses the impacts of a proposed action on species (which may include federally listed and state-listed species and candidate species), proposes measures to monitor, minimize, and mitigate these impacts, and analyzes action alternatives. On approval of an HCP, USFWS and NMFS issue incidental take permits, which allow the nonfederal party to legally proceed with an activity that otherwise would result in unlawful take of a protected species. In addition to the incidental take permit, USFWS and NMFS complete a BO under section 7 of the ESA and finalize the NEPA analysis documents.

Although HCPs vary in scale and scope, they provide an approach to addressing a set of actions across a broad geographic region that evaluates impacts on a range of ecosystems, habitats, and species. Just as the size, configuration, and location of HCPs varies, so does the permit duration. Permit duration takes into account both the biological impacts resulting from the proposed land use and economic developmental differences. HCP development and permit processing phases do not have statutory time frames but can be roughly estimated as taking 1 year to 5 years to complete in the Sacramento region.

Some flood management activities may qualify for a low-effect HCP. To enable the formal screening process for a low-effect HCP, DWR would need to provide to USFWS and NMFS a list of flood management activities proposed for coverage. Determination of whether an HCP qualifies for the low-effect category is based on anticipated impacts by activities covered in the HCP before implementation of mitigation. Low-effect HCPs are those

involving (1) minor or negligible effects on federally listed, proposed, or candidate species and their habitats covered under the HCP, and (2) minor or negligible effects on other environmental values or resources. "Low-effect HCP" incidental take permits are permits that, despite their authorization of some small level of incidental take, individually and cumulatively have a minor or negligible effect on the species covered in the HCP. A timeline for low-effect HCPs is difficult to estimate but is expected to require less time for HCP development and permit processing relative to a standard HCP.

DFG works with applicants to develop NCCPs (see below) jointly with USFWS HCPs to provide one planning process and document. However, in some cases, a local government may decide not to pursue an NCCP to accompany the federal HCP. Thus, not all HCPs comply with NCCP standards.

Whenever practical, USFWS and NMFS give consideration to programmatic or ecoregion consultation with federal agencies having major programs in HCP areas to facilitate overall consultation and recovery actions for the species involved. This type of consultation would involve programmatic review of the agencies' activities and would be most effective if conducted simultaneously with development of the HCP. Such simultaneous consideration of both federal and nonfederal programs could (1) assist in assessing overall effects on a species/group of species/ecosystem from multiple actions, (2) result in a better determination of the respective roles of all parties in conserving the species/ecosystem, (3) assist in determining the priority of all proposed actions for use of any "resource cushion" that may exist, and (4) demonstrate that all parties are being provided equal consideration at equal speed (programmatic consultations do not have applicants and are subject to mutually agreed-on time frames).

Safe Harbor Agreement

An SHA is a voluntary agreement between private or nonfederal landowners and USFWS. NMFS does not issue SHAs. Under an SHA, a landowner enhances their property in ways that benefit listed species, and is issued an Enhancement of Survival Permit under the authority of section 10(a)(1)(A) of the ESA. This permit authorizes incidental take of species that may result from actions undertaken by a landowner under the SHA, which could include returning the property to baseline conditions at the end of the agreement. Obtaining permits using an SHA is of limited applicability for DWR. Because an SHA can be entered into only by the landowner, a maintaining agency with an easement for maintenance (typical for DWR) cannot obtain an SHA. The agreement has to be initiated

by the landowner. An SHA typically takes 6 months to 9 months to develop, although complex agreements may take longer.

4.2 State Authorities

Projects by public agencies and private entities subject to discretionary approvals by government agencies must go through the environmental review process required by the California Environmental Quality Act (CEQA). CEQA defines a project as any activity that "may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment" (Public Resources Code section 21065). Projects potentially entailing discretionary approvals include activities directly undertaken by a public agency; activities supported, in whole or part, through financial assistance from public agencies; and activities that involve the issuance of a lease, permit, license, certificate, or other entitlement.

Consequently, a certified CEQA document is required for issuance of a section 401 water quality certification by RWQCB or the State Water Resources Control Board (SWRCB), a Lake and Streambed Alteration Agreement (LSAA) by DFG, a Master Lease from the SLC, and a National Pollutant Discharge Elimination System (NPDES) permit or waiver from the RWQCB. A CEQA document is also required prior to DFG approval of an NCCP. Therefore, regional/programmatic permitting is greatly facilitated by related CEQA documents providing well-substantiated impact analyses and clearly defined and implementable avoidance, minimization, and mitigation measures. Flood management projects may quality for CEQA exemptions under two categories: statutory exemptions (Title 14 of the California Code of Regulations (CCR), Article 18, sections 15260 to 15285), or categorical exemptions (Title 14 of the CCR, Article 19, sections 15300 to 15332). A full description of all exemptions and the requirements to qualify for the exemptions is listed in the CCR. Types of projects that may be exempt include, but are not limited to:

- emergency repairs necessary to maintain service essential to the public health, safety, or welfare (section 15269(b))
- maintenance dredging where the spoil is deposited in a spoil area authorized by all applicable state and federal regulatory agencies (section 15304 (g))
- repair, maintenance or minor alteration of existing public structures that involve negligible or no expansion of an existing use (section 15301)

Several specific types of CEQA documents can be adopted or certified, but the primary general types are the Negative Declaration (ND) or Mitigated Negative Declaration (MND) and the Environmental Impact Report (EIR). An ND or MND is prepared when there is no substantial evidence that a significant impact may occur, which, in the case of an MND, is determined after revisions to a project (e.g., mitigation measures). An EIR is prepared when it may be fairly argued that, based on substantial evidence, a project may have a significant environmental effect.

An EIR may be prepared for a plan, policy, or program (e.g., a Program EIR (PEIR)) or for a specific project. When prepared for a plan, policy, or program, the level of detail in the EIR can correspond to the degree of specificity involved in the underlying activity. An EIR on a construction project will necessarily be more detailed about the specific effects of the project than will an EIR on the adoption of a plan or policy. An EIR on the adoption or amendment of a plan, policy, or program should focus on the secondary effects that can be expected to follow from the adoption or amendment, but need not be as detailed as an EIR on specific construction projects that might follow. A subsequent ND/MND or EIR would address environmental impacts specific to the individual projects implemented as part of the plan, policy, or program. In some cases, if the project specific impacts and effects are adequately described and are entirely within the scope of and addressed by an EIR for a plan, policy, or program, no additional ND/MND or EIR is required. This multilayered approach to CEQA compliance is referred to as tiering, and results in a more efficient CEQA process because CEQA review for projects tiering from a certified EIR can be limited to issues not sufficiently evaluated in the “first-tier” document.

A PEIR or Master EIR could be an appropriate CEQA document for some flood management actions. The PEIR or Master EIR would guide and inform preparation of the appropriate subsequent CEQA documents that would identify the scope of projects and probable environmental impacts associated with proposed maintenance and habitat restoration activities, as well as the aggregate and cumulative impact of the project to the extent that these impacts can be defined and are not speculative. In addition to providing CEQA coverage for 401 certification, LSAA, ITP, Master Lease, and NPDES permits, issuing such a CEQA document would provide an avenue for integrating management of cultural resources required for section 106 of the National Historic Preservation Act (NHPA) and would address potential program-level impacts to State-listed species, water quality, and lands within the extended Systemwide Planning Area.

4.2.1 California Department of Fish and Game

This section summarizes the regulatory mechanisms that could be used by DFG to provide programmatic authorizations for flood management activities. Under section 1600 of the California Fish and Game Code, these mechanisms include a Master LSAA, a Long-Term LSAA, or an RMA. Though not discussed in the 1600 code, a Memorandum of Understanding (MOU) or a Memorandum of Agreement (MOA) between DFG and DWR can also be used to increase the efficiency for compliance under section 1600. Thus, this approach is also described below. Other regulatory mechanisms described include an ITP, consistency determination (only applicable where state-listed species are not present, or covered by the USFWS BO) or NCCP pursuant to California Fish and Game Code section 2081(b) and 2081(c) and CCR 14(6)(1); and Safe Harbor Agreements (SHA) pursuant to section 2089.2 of the California Fish and Game Code.

Lake and Streambed Alteration Agreement

Section 1600 of the California Fish and Game Code requires notification to DFG before conducting activities that will substantially obstruct or divert the natural flow of State waters; substantially change or use materials from a bed, bank, or channel; or deposit materials into a river, stream, or lake. Potential mechanisms for authorizing DWR's flood management activities under section 1600 include development of a Master LSAA, a Long-Term LSAA, an MOU or MOA between DFG and DWR.

Yard efforts for the limited levees of the State-maintained areas in the Sacramento Basin, include a 2006 MOU between DFG and the Division of Flood Management of DWR for maintenance of State-maintained flood control projects in the Sacramento River and Feather River Wildlife Areas (DFG and DWR 2006) and a Streambed Alteration Agreement for routine maintenance of flood control projects by the DWR Sacramento and Sutter Maintenance Yards (RMA) that became effective on January 6, 2011 (DFG 2011). There are no State-maintained areas in the San Joaquin Basin. The 2011 RMA (the RMA is a type of MOA) requires that DWR provide detailed notification to DFG prior to conducting routing maintenance so that DFG can confirm that the work does not adversely affect fish and wildlife resources, and is covered under the RMA. Additionally, an annual report is submitted to DFG summarizing the work completed that year. An MOU or MOA could be used to increase the efficiency of the process for CVFPP compliance with section 1602 of the California Fish and Game Code using the current routine maintenance LSAA as a reference.

Another vehicle for flood management activities to comply with section 1602 would be a Master LSAA. Under this type of agreement, DFG would maintain authority over the LSAA process and be notified prior to the

beginning of a new project under the agreement. A Master LSAA allows DFG to assess the potential impacts of a project on a case-by-case basis and determine the specific avoidance and minimization measures for the species that may be present in the location of the project. In addition, conditions may change on an annual basis, such as occupation by nesting raptors that were previously absent from a project area. It also allows DFG to regularly ensure that conditions of the Master LSAA are being implemented.

DFG jurisdiction is divided into seven regions that cover portion of the State. The SPA covers four of these regions and, therefore, will have varying avoidance and minimization measures depending on the region. With DFG maintaining authority over issuing project specific LSAA's under a Master LSAA, each region affected by a particular project, will be able to include avoidance and minimization measures that are applicable for their specific area.

The timeline for executing a Master LSAA, a Long-Term LSAA, an RMA, or an MOU or MOA between DFG and DWR is difficult to anticipate, but can be roughly estimated to take approximately 12 months to 18 months, depending on DFG and DWR workloads.

Executing a California Fish and Game Code section 1602 authorization mechanism would require certification of CEQA compliance; DFG would be a responsible agency for CEQA compliance. In acting on issuing a section 1600 authorization, DFG would rely on the CEQA document to prepare and issue its own findings regarding the project, and to decide whether or not to grant section 1600 authorization.

California Endangered Species Act

The California Endangered Species Act (CESA) prohibits activities that will result in “take” of State-listed and candidate species without prior DFG authorization through an ITP. Section 86 of the California Fish and Game Code defines “take” as the act or attempt to “hunt, pursue, catch, capture, or kill or attempt to hunt, pursue, catch, capture, or kill.” DFG may authorize take of State-listed and candidate species through the issuance of an ITP, pursuant to California Fish and Game Code section 2081(b) and 2081(c) and CCR 14(6)(1).

A 2081(b) permit will authorize take that is incidental to an otherwise lawful activity as long as the impacts of the authorized take are minimized and fully mitigated. Measures to minimize and fully mitigate impacts must (1) be roughly proportional in extent when compared to the impact of the take on the species, (2) maintain the applicant’s objectives to the greatest

extent possible, (3) be capable of successful implementation, and (4) have adequate funding to implement and monitor compliance.

DFG has 30 days to determine whether a 2081(b) permit application is complete. DFG then has another 90 to 120 days (depending on whether DFG is a responsible or lead agency under CEQA) to complete a substantive review of the permit application; these time frames are extendable for 150 days (if DFG is responsible agency) to 180 days (if DFG is a lead agency) with written notice. However, these times frames are discretionary. If DFG does not act within this time frame, CESA's take prohibition is not suspended, and proposed permits do not become effective by operation of law.

CESA compliance may also be obtained through the use of Consistency Determinations. Consistency Determinations can only be used for species that are listed under the ESA and CESA, and cannot be extended to species that are listed by the State but are not afforded protection under the federal ESA. California Fish and Game Code section 2080.1 states the requirements and procedures for a 2080.1 Consistency Determination. A Consistency Determination may be obtained from DFG when a BO has been issued by USFWS and/or NMFS pursuant to an ESA section 7 consultation (incidental take statement) or ESA section 10(a) incidental take permit. DFG must determine that the conditions specified in the federal incidental take statement or permit are consistent with CESA for species that are listed under both the ESA and CESA. If it is determined that the federal incidental take statement or permit is not sufficient for compliance with CESA, then a State ITP under section 2081(b) of the California Fish and Game Code may be required. An ITP may also be obtained through an NCCP provided that both the species and the activity are covered by the NCCP (see Natural Community Conservation Planning below).

Because BOs issued by USFWS and/or NMFS do not allow DFG to add conditions to a federal incidental take statement/permit and BO, 2081(b) permits are often preferable to 2080.1 Consistency Determinations. However, if interagency coordination is effective and DFG can work with USFWS to provide input to the content of the BO, a consistency determination is both effective and efficient for DFG.

DFG must make determination as to consistency within 30 days of receipt of written request and copy of federal authorization or "no further authorization of approval is necessary" under CESA (California Fish and Game Code 2080.1(c)). A consistency determination is automatically repealed if there is an amendment to the federal permit that "alters the

requirement for issuing an incidental take statement or incidental take permit, as applicable" (section 2080.1(e)).

Protection of Bird Nests, Eggs, and Birds of Prey

Under California Department of Fish and Game Code sections 3503 and 3503.5, it is unlawful to take, possess, or needlessly destroy the nest or eggs of any bird, or take possess or destroy any birds in the orders Falconiformes or Strigiformes (birds of prey) or to take, possess, or destroy the nest or eggs of any such bird. DFG frequently includes conditions in an LSAA or suggests specific language for a CEQA document to protect bird nests, eggs, and birds of prey. This usually includes avoidance and minimization measures, including work windows for tree and shrub removal and maintaining disturbance buffers to protect all nesting raptors and birds, including western burrowing owl.

Natural Community Conservation Planning

DFG administrates the NCCP program, pursuant to sections 2800-2835 of the California Fish and Game Code, with the primary objective of conserving natural communities at the ecosystem level while accommodating compatible land use. DFG may issue an ITP authorizing the take of species covered in an NCCP, pursuant to section 2835 of the NCCP Act of 2003.

As mentioned previously, DFG works with local governments and other applicants to develop NCCPs jointly with USFWS HCPs (see above) to provide one planning process and document. In some cases, local government decides not to pursue the higher conservation standard of NCCP and works with DFG to provide a State regional ITP to accompany the federal HCP. Thus, not all HCPs comply with NCCP standards. The NCCP development and permit processing phases do not have statutory time frames but can be roughly estimated as taking 1 year to 5 years in the Sacramento region to complete.

Safe Harbor Agreements

DFG operates the Safe Harbor Agreement Program pursuant to section 2089.2 of the California Fish and Game Code. The program is similar to the federal SHA program and encourages landowners to enhance habitat for threatened and endangered wildlife while providing incidental take coverage. Because DFG has issued few SHAs, it is difficult to provide a timeline for approval. The State SHA program has the same limitations for use by DWR as described above under the Federal SHA in Section 4.1.2 "U.S. Fish and Wildlife Service and National Marine Fisheries Service." Only the landowner, not an easement holder, can initiate an SHA.

4.2.2 Central Valley Regional Water Quality Control Board

This section summarizes the regulatory mechanisms that could be used by the RWQCB to provide programmatic authorizations for flood management activities that entail a federal action, such as issuance of a federal permit under section 404 of the CWA, and provides details regarding issuance of water quality certifications under section 401 of the Clean Water Act (CWA).

Clean Water Act Section 401

Applicants seeking a federal permit under section 404 of the CWA must also obtain a Water Quality Certification from RWQCB in accordance with section 401 of the Clean Water Act. In California, the U.S. Environmental Protection Agency (EPA) has delegated authority to the RWQCBs to issue 401 Water Quality Certifications. A section 401 Water Quality Certification of the 404 programmatic permit would provide another level of streamlining for flood management activities. However, if the 404 permit is not certified under section 401, each maintenance and restoration project carried out under the 404 permit would require separate section 401 certification before initiation of project activities.

The RWQCB could develop a 401 Water Quality Certification to authorize flood management activities under section 401 of the CWA concurrently with USACE's programmatic 404 permit. Issuance of the 401 Water Quality Certification would require adoption of a final CEQA document. The RWQCB or SWRCB would be a responsible agency under CEQA. In acting on issuance of the 401 certification, the RWQCB or SWRCB would rely on the CEQA document to prepare and issue its own findings regarding the project, and to then decide whether or not to issue a Water Quality Certification. A draft 401 certification would be circulated for 30 days to 60 days for public review and comment. An additional 60 days may be required to schedule an RWQCB meeting, if necessary. The 401 Certification would likely be effective for 5 years and may be renewed at the RWQCB or SWRCB's discretion concurrent with renewal of the 404 permit.

Time frames for 401Water Quality Certification vary but would be anticipated to coincide with the associated USACE 404 permit processing timelines.

4.2.3 State Historic Preservation Officer

This section summarizes the regulatory mechanisms that could be used by SHPO to provide programmatic authorizations for flood management

activities under section 106 of the NHPA. Programmatic authorization can be accomplished through a Programmatic Agreement (PA) using the process defined in 36 CFR Part 800.14 in consultation with USACE and is described in more detail below.

National Historic Preservation Act Section 106

For compliance with this federal act, the identification of historic resources and effects on historic resources by federal lead agencies is reviewed by the SHPO. Section 106 of the NHPA requires federal agencies to take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. USACE must comply with section 106 of the NHPA to issue a 404 permit, because this federal action constitutes an undertaking within the meaning of the implementing regulations for section 106 (Title 36, CFR Part 800.16(y)).

For the some flood management activities, USACE and the SHPO could execute a PA using the process defined in 36 CFR Part 800.14 to satisfy compliance with section 106. This process allows deferred identification and management of cultural resources under an agreement document (36 CFR Part 800.4(b)(2)). On execution (signing and approval) of the PA by the consulting parties, section 106 is deemed complete for the purpose of permits and authorizations dependent on the section 106 process (36 CFR Part 800.14(b)(2)(iii)). Therefore, execution of the programmatic agreement satisfies section 106 sufficiently to allow USACE to issue a 404 permit for a project and allows DWR and USACE to defer identification and management of historic properties until specific sites require maintenance or habitat restoration.

The PA would provide a process for performing an inventory of cultural resources at maintenance and restoration sites as they are identified, evaluating those resources, and resolving adverse effects on significant resources (historic properties). The Native American Heritage Commission, local Native American tribes, and the interested public (such as local historic preservation organizations) shall be consulted with to assist with cultural resources inventory and development of the PA. Coordination with other federal agencies providing permits and authorizations for the project would be performed so that the PA identifies these other undertakings, providing a unified compliance framework for section 106 for the project. The PA would be valid for 5 years and could be renewed at the discretion of USACE and the SHPO concurrent with renewal of the 404 permit.

Time frames for PA development vary depending on the level of agency and tribal coordination required but can generally be expected to be completed in 6 months to 2 years.

4.2.4 Central Valley Flood Protection Board

The Board has authority to enforce standards for the construction, maintenance, and protection of adopted flood control plans that will best protect the public from floods. These standards apply to the erection, maintenance, and operation of levees, channels, and other flood control works within its jurisdiction, including but not limited to standards for encroachments, construction, vegetation, and erosion control measures. The jurisdiction of the Board includes public and private lands protected by federal flood control works in the Sacramento and San Joaquin Drainage District.

A Board permit is required prior to starting the work within the Board's jurisdiction for the following:

> *The placement, construction, reconstruction, removal, or abandonment of any landscaping, culvert, bridge, conduit, fence, projection, fill, embankment, building, structure, obstruction, encroachment or works of any kind, and including the planting, excavation, or removal of vegetation, and any repair or maintenance that involves cutting into the levee, wholly or in part within any area for which there is an adopted plan of flood control, must be approved by the board prior to commencement of work (CCR section 6).*

Furthermore, restoration activities such as the installation of plants would be subject to, but not limited to, the following:

> *Any vegetation which interferes with the successful execution, functioning, maintenance or operation of the adopted plan of flood control, must be removed. If the owner does not remove such vegetation upon request, Board reserves the right to have the vegetation removed at the owner's expense (CCR section 131 (d)).*

Vegetation and vegetation maintenance standards for floodways and bypasses includes but is not limited to the following:

> *Invasive or difficult-to-control vegetation, whether naturally occurring or planted, that impedes or misdirects floodflows is not permitted to remain on a berm or within the floodway or bypass;*
>
> *The board may require clearing and/or pruning of trees and shrubs planted within floodways in order to minimize obstruction of floodflows;*

> *Trees and brush that have been cut down must be burned or removed from the floodway prior to the flood season (CCR section 131(g)).*

The state strategy to manage levee vegetation consistent with these and other CVFPB regulations is a component of the CVFPP.

As part of the permit application, the CVFPB requires documentation demonstrating that any downstream impacts (e.g., rise in water surface elevation) have been eliminated, and that no water rights are severed as a result of project construction. The Board has considered encroachment permit applications for projects in the context of a program. The permit application and Title 23 CCR can be found on the Central Valley Flood Protection Board's website (http://www.cvfpb.ca.gov/).

4.2.5 California State Lands Commission

The State Lands Commission (SLC) has jurisdiction and management control over certain public lands of the State that were received by the State from the United States. When California became a state in 1850, it acquired approximately 4 million acres of land underlying its navigable and tidal waterways. Known as sovereign lands, these lands include the beds of California's navigable rivers, lakes, and streams, as well as the State's tidal and submerged lands along the State's more than 1,100 miles of coastline and offshore islands, from the mean high tide line to 3 nautical miles offshore.

Issuance by the SLC of any lease, permit, or other entitlement for use of State lands is reviewed for compliance with the provisions of CEQA. Additionally, if the application involves lands found to contain "Significant Environmental Values" within the meaning of Public Resources Code section 6370 et seq., consistency of the proposed use with the identified values must also be determined through the CEQA review process. Pursuant to its regulations, SLC may not issue a lease for use of "Significant Lands" if such proposed use is detrimental to the identified values.

Mechanisms available to increase the efficiency of obtaining SLC leases for flood management activities may include development of a maintenance MOU or of a long-term lease or Master Lease. DWR has an existing Master Lease with SLC that may be expandable to include proposed routine maintenance and restoration activities associated with flood management. The lease application process generally takes 3 to 6 months, and an approved CEQA document is required before lease issuance.

4.3 Memoranda of Understanding and Memoranda of Agreement to Support Regulatory Compliance

In addition to single-agency MOUs and MOAs that may be used to provide mechanisms to support programmatic authorization as described above, MOUs and MOAs have been used in the Sacramento area as an effective means of formally documenting interagency understandings and approaches to mutually manage, restore, and enhance lands that contain facilities that are both maintained for flood protection purposes, and managed for fish, wildlife, and plants. These MOUs confirm the agencies' approach to authorization strategies for ongoing flood facilities maintenance in a collaborative manner that both provides adequate protection for sensitive aquatic resources, sensitive habitats, and listed species, and minimizes flood-related risks to public safety. Importantly, these MOUs clarify the agencies' understandings regarding the resolution of land management issues in areas where the maintenance and management responsibilities of the agencies overlap. It is anticipated that agencies with regulatory authority over flood management activities could also use MOUs or MOAs as mechanisms to facilitate programmatic management and authorization strategies.

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5.0 Linkage with Other Regional Permitting Efforts and Current Activities

Implementation of flood management activities considered by the CVFPP and the linked Central Valley Flood System Conservation Strategy would take place in a region that already contains several programmatic permitting and planning efforts. DWR is evaluating these efforts to identify opportunities for collaboration and to avoid unnecessary duplication of effort.

Current DWR programmatic permitting and planning efforts that are in progress include the following:

- Emergency Repairs MOU
- Small Erosion Repair Program (SERP)
- Regional Advance Mitigation Program (RAMP)
- Lower Feather River CMP

The following NCCPs and HCPS overlap with the SPA:

- Approved HCPs and HCP/NCCPs
  - East Contra Costa County HCP/NCCP
  - Natomas Regional HCP
  - San Joaquin County Regional HCP
  - South Sacramento HCP
- HCPs and HCP/NCCPs under development
  - Bay Delta Conservation Plan HCP/NCCP
  - Butte County HCP/NCCP
  - Placer County Conservation Plan, HCP/NCCP
  - Yolo Natural Heritage Program HCP/NCCP
  - Yuba and Sutter Counties HCP/NCCP
  - Solano County HCP

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6.0 Other Potentially Applicable Regulations for Which Programmatic Authorization May or May Not Be Available

In addition to obtaining permits under the programs listed previously, future projects also need to comply with other permitting requirements, including those listed below.

6.1 Federal Authorizations

Federal authorizations for which programmatic permitting mechanisms may be available only for flood management activities having a federal nexus include the following:

- Fish and Wildlife Coordination Act
- Magnuson-Stevens Fishery Conservation and Management Act for Essential Fish Habitat
- Marine Mammal Protection Act
- Migratory Bird Treaty Act
- Bald and Golden Eagle Protection Act
- Wild and Scenic Rivers Act

Federal authorizations for which programmatic permitting mechanisms may not be available include the following:

- Section 408 authorization for modification of the federal levee system

6.2 State Authorizations

Based on review of the regulations and preliminary conversations with agency staff, state authorizations for which programmatic permitting mechanisms may not be available for flood management activities include the following:

- Clean Water Act section 402 – Permit authority delegated to the Central Valley RWQCB
- Porter Cologne Water Quality Control Act
- California Department of Conservation and Surface Mining and Reclamation Act
- California Wild and Scenic River Act
- Encroachment permits from the CVFPB

6.3 Local Authorizations

Local authorizations for which it is uncertain whether programmatic permitting mechanisms may be available for flood management activities include the following:

- Grading permits
- Tree removal permits

However, flood management projects undertaken by federal or state entities will generally not be subject to local authorizations.

7.0 References

California Department of Fish and Game (DFG). 2011. Long-Term Streambed Alteration Agreement. January 6.

DFG and California Department of Water Resources, Division of Flood Management. 2006. Memorandum of Understanding for Maintenance of Flood Control Projects in the Sacramento River and Feather River Wildlife Areas. May 23.

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

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8.0 Acronyms and Abbreviations

Board ..... Central Valley Flood Protection Board
CCR ..... California Code of Regulations
CEQA..... California Environmental Quality Act
CESA ..... California Endangered Species Act
CFR..... Code of Federal Regulations
CMP ..... Corridor Management Plan
CVFPP ..... Central Valley Flood Protection Plan
CWA..... Clean Water Act
DFG ..... California Department of Fish and Game
DWR ..... California Department of Water Resources
EA ..... Environmental Assessment
EIR..... Environmental Impact Report
EIS ..... Environmental Impact Statement
EPA..... U.S. Environmental Protection Agency
ESA..... Endangered Species Act
FONSI ..... Finding of No Significant Impact
HCP ..... Habitat Conservation Plan
ITP ..... Incidental Take Permit
LSAA..... Lake and Streambed Alteration Agreement
MND..... Mitigated Negative Declaration
MOA..... Memorandum of Agreement
MOU..... Memorandum of Understanding
NCCP..... Natural Community Conservation Plan
ND..... Negative Declaration
NEPA ..... National Environmental Policy Act
NHPA ..... National Historic Preservation Act
NMFS ..... National Marine Fisheries Service
NPDES..... National Pollutant Discharge Elimination System
ORA ..... other regulatory authority

PA ..... Programmatic Agreement
PBO ..... Programmatic Biological Opinion
PEIR..... Programmatic Environmental Impact Report
PGP ..... Programmatic General Permit
PSAA ..... Programmatic Streambed Alteration Agreement
RAMP..... Regional Advance Mitigation Planning
RGP ..... Regional General Permit
RHA ..... Rivers and Harbors Act of 1899
RMA ..... Routine Maintenance Agreement
ROD ..... Record of Decision
RWQCB ..... Regional Water Quality Control Board
SAA..... Streambed Alteration Agreement
SERP ..... Small Erosion Repair Program
SHA..... Safe Harbor Agreement
SHPO..... State Historic Preservation Officer
SLC ..... California State Lands Commission
SPA..... Systemwide Planning Area
SPFC ..... State Plan of Flood Control
State..... State of California
SWRCB..... State Water Resources Control Board
USACE..... U.S. Army Corps of Engineers
USC ..... United States Code
USFWS ..... U.S. Fish and Wildlife Service

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

Jeremy Arrich, PE
Chief, Central Valley Flood Planning Office
arrich@water.ca.gov

Department of Water Resources
3464 El Camino Ave., Ste. 150
Sacramento, CA 95821

http://www.water.ca.gov/cvfmp

Edmund G. Brown Jr.
Governor
State of California

John Laird
Secretary
The California Natural Resources Agency

Mark W. Cowin
Director
Department of Water Resources

Department of Water Resources
The California Natural Resources Agency
State of California