CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Flood Control System Status Report

December 2011

Cover Photo:

Critical levee repairs are being completed along the Sacramento River.

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Flood Control System Status Report

December 2011

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Executive Summary

> **California Water Code Section 9120**
> (a) The department shall prepare and the board shall adopt a flood control system status report for the State Plan of Flood Control. This status report shall be updated periodically, as determined by the board. For the purpose of preparing the report, the department shall inspect the project levees and review available information to ascertain whether there are evident deficiencies.
>
> (b) The status report shall include identification and description of each facility, an estimate of the risk of levee failure, a discussion of the inspection and review undertaken pursuant to subdivision (a), and appropriate recommendations regarding the levees and future work activities.

The Sacramento and San Joaquin river watersheds include an extensive flood management system comprising State of California (State)-federal project facilities and other facilities that are not part of the State-federal project. All State-federal project facilities in the Sacramento and San Joaquin river watersheds are part of the State Plan of Flood Control (SPFC), as defined in the 2010 *State Plan of Flood Control Descriptive Document* by the California Department of Water Resources (DWR). SPFC facilities primarily include project levees, channels, and associated flood control structures in the Sacramento and San Joaquin river watersheds of California.[1]

This *Flood Control System Status Report* (FCSSR) describes the current status (physical condition) of SPFC facilities at a systemwide level. DWR prepared the FCSSR to meet the legislative requirements of California Water Code Section 9120, and to contribute to development of the Central Valley Flood Protection Plan (CVFPP). The CVFPP will guide future State investments through projects to address identified problems in the SPFC.

The FCSSR is primarily intended to present information on the physical condition of SPFC facilities, and to help guide future inspection, evaluation, reconstruction, and improvement of the facilities. Information contained in the FCSSR should not be used to predict how a levee or associated facilities may perform in a specific flood event. More detailed information (such as additional geotechnical explorations and analyses at a greater frequency) would be necessary to meet other purposes, such as assessing whether a levee could be certified under Federal Emergency Management Agency (FEMA) standards to provide base flood protection under the National Flood Insurance Program.

Role of Flood Control System Status Report

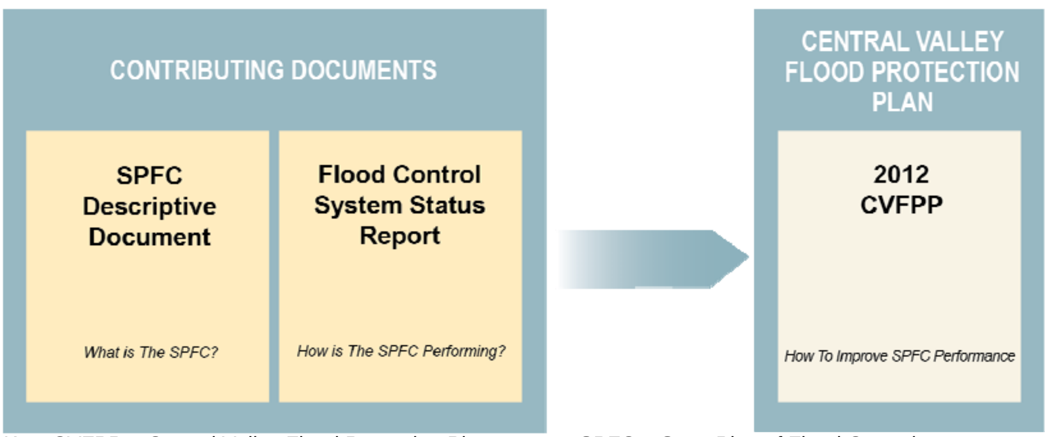
DWR is fulfilling California Water Code requirements and supporting development of the CVFPP through two contributing documents. First, the DWR 2010 *State Plan of Flood Control*

[1] State Plan of Flood Control facilities also include other elements identified in California Water Code Section 8361.

Descriptive Document identifies and describes major components of the SPFC (facilities, lands, programs, plans, conditions, modes of operations and maintenance), or *what the SPFC is*. It also fulfills part of the requirements of California Water Code Section 9120 (a) and (b). The *FCSSR* describes and analyzes the status or physical condition of SPFC facilities, or *how well the SPFC is performing*. It also fulfills requirements of California Water Code Section 9120.

Together, the two documents and additional technical studies (including the CVFPP Program Environmental Impact Report (DWR, anticipated 2012) are the foundation needed for preparing the CVFPP (Figure ES-1). In particular, the FCSSR contributes to development of the CVFPP through the following:

- Consolidates all available systemwide information from multiple DWR programs regarding SPFC physical conditions, and presents the information in a format suitable to facilitate future updates.
- Supports collaboration of DWR and the Central Valley Flood Protection Board (Board) with State, federal, regional, and local agencies in defining flood management system problems and needs, developing alternative solutions, and implementing future projects to address identified problems and improve the current condition of the flood management system.



Key: CVFPP = Central Valley Flood Protection Plan SPFC = State Plan of Flood Control

Figure ES-1. Documents Contributing to Central Valley Flood Protection Plan

In addition to meeting legislative requirements and contributing to the CVFPP, information in the FCSSR may be used to support the core functions and long-term activities of DWR's Division of Flood Management, including emergency response, facility maintenance, and inspections. Periodic updates of the FCSSR will enable DWR to track progress as ongoing inspections and evaluations are completed and more SPFC facilities are reconstructed or improved to meet current design criteria.

Need to Evaluate SPFC Status

SPFC facilities were built in increments over many decades, with many levees constructed by landowners and local entities after 1850 and through the early 1900s, before the initial federally authorized project (Sacramento River Flood Control Project) was established. The U.S. Army Corps of Engineers (USACE) accepted some of these levees into the federal project without modification, improved some, and engineered new levees in other locations. Most levees included in what is now termed the SPFC in the Sacramento River watershed were accepted, improved, or constructed by USACE between 1918 and the mid-1960s. Most SPFC levees in the San Joaquin River watershed downstream from the Merced River confluence were improved as directed by USACE between the mid-1950s and early 1970s. In the San Joaquin River watershed upstream from the Merced River confluence, most SPFC levees were improved or constructed by DWR between the 1960s and early 1970s.

SPFC facilities now face many pressures that were not known or did not exist when facilities were originally constructed. Design criteria and construction methods have become more stringent over time as understanding of geotechnical, hydrologic, and other technical aspects of flood management have improved. As a result, most facilities constructed in the early to mid-twentieth century were not designed or constructed to meet current criteria. In some cases, facilities are now obsolete or have nearly exceeded their expected service lives, and are in need of major modification or repair. Further, facilities originally constructed primarily for navigation/sediment transport and flood management are now also recognized as important for water supply conveyance, ecosystem functions, recreation, and other beneficial uses.

Approach

To evaluate SPFC conditions, DWR is considering a wide variety of factors that could influence the performance of SPFC levees, channels, and flood control structures. Information from DWR's inspection and evaluation activities are considered as high-level indicators of physical conditions relative to specified standards. For some factors, DWR's approach may differ from an approach that USACE or other agencies would use for other evaluations or purposes. In these cases, the difference is acknowledged, although only DWR's approach is used as the basis for results presented in the FCSSR.

The DWR Levee Evaluations Program, including its Urban Levee Evaluations (ULE) and Non-Urban Levee Evaluations (NULE) projects, is the primary source of information to evaluate the condition of SPFC levees. ULE and NULE both assess geotechnical conditions of levees, but urban levees are undergoing a more comprehensive evaluation because of public safety considerations for densely populated areas. Levee conditions reported in the FCSSR also rely on information from DWR's annual inspections and other available data to supplement the results of the DWR Levee Evaluations Program.

In general, channel conveyance conditions were determined by using the most recent available hydraulic modeling to evaluate whether the channels have the ability to pass design capacities presented in operations and maintenance (O&M) manuals and design profiles. Channel conditions reported also include DWR's annual inspections for vegetation and sedimentation. In addition, reported flood management structure conditions are based on DWR's annual inspections.

The FCSSR reflects existing facility conditions (including past performance) at the time the FCSSR was prepared, and some results represent initial findings of ongoing evaluations. Many ongoing inspections, geotechnical evaluations, and hydraulic evaluations will yield additional information on facility conditions. In addition, subsequent facility improvements, repairs, and reconstruction would likely affect facility conditions reported in the FCSSR. Where applicable, any changes in findings will be reflected in future updates to the FCSSR.

Findings

The flood management system has provided tremendous benefits to public safety and protection of property in the Central Valley – it has prevented many billions of dollars in flood damages since facilities were originally constructed. However, when evaluated against modern engineering and safety criteria, some SFPC facilities face a higher chance for failure during a flood event than other facilities. Table ES-1 lists factors that influence facility performance, findings related to each factor, and the relative threat posed by the factor.

The relative threat posed by each factor is a subjective representation of 1) the prevalence of the factor and 2) how much the presence of that factor would contribute to a potential facility failure. Factors identified as a "high" relative threat to SPFC facilities generally are the most prevalent and/or greatly contribute to potential facility failure. Those identified as a "low" relative threat to SPFC facilities generally are the least prevalent and/or contribute less to potential facility failure. Likewise, factors identified as a "medium" relative threat to SPFC facilities are moderately prevalent and/or contribute moderately to potential facility failure. As such, the relative threat posed by each factor is subjective in nature and serves only to help identify and prioritize the factors most likely to contribute to SPFC facility failures. Prioritizing relative threats affecting SPFC facilities does not necessarily translate directly into investment priorities. To decide which levels of investment are prudent for repairs or improvements, economic and life safety consequences associated with potential failure must also be considered. Potential consequences of facility failure are not presented in this report; they are evaluated in the CVFPP.

The overall condition of urban levees, nonurban levees, channels, and flood control structures of the SPFC can be summarized as follows:

- **Urban levees –** Approximately half of about 300 miles[2] of SPFC urban levees evaluated do not meet current levee freeboard, stability, or seepage design criteria[3] at the design water surface elevation.

[2] Additional 50 miles of SPFC urban levees are being evaluated, and results will be included in future updates.

- **Nonurban levees –** Approximately three-fifths of about 1,230 miles of SPFC nonurban levees evaluated have a high potential for failure from under-seepage, through-seepage, structural instability, and/or erosion at the assessment water surface elevation.[4] Nonurban levees were evaluated based on systematic, consistent, repeatable analyses that correlated geotechnical data with levee performance history, not relative to any current design criteria.[5]

- **SPFC channels –** Approximately half of the 1,016 miles of channels evaluated in the SPFC have a potentially inadequate capacity to convey design flows, and require additional evaluation to confirm conditions.

- **SPFC flood control structures –** None of the 32 hydraulic structures or 11 pumping plants inspected by DWR for the SPFC were rated Unacceptable during the 2009 inspections. Of the 10 SPFC bridges inspected by DWR in 2009, 2 were in need of repairs.

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[3] The design criteria used were based on the USACE 2000 *Design and Construction of Levees Engineering Manual 1110-2-1913* and DWR 2010 *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento Valley, Version 4*.

[4] Where available, 1955/57 design water surface elevations were used as the assessment water surface elevation. In the absence of 1955/57 design water surface elevations, the assessment water surface elevation was based on freeboard requirements for each levee segment (i.e., generally 3 feet below the levee crest).

[5] This approach was selected because the extent of the NULE Project is significantly greater than the ULE Project, making it difficult to conduct the same level of field explorations and geotechnical data collection performed for ULE levees.

Table ES-1. Summary of Flood Control System Status Report Findings

	Factors	Findings	Relative Threat Posed by Factor[1]
Levees	**Overall Levee Condition (multiple factors)**	• Approximately half of SPFC urban levees do not meet current levee freeboard, stability, or seepage design criteria at the design water surface elevation. • Approximately three-fifths of SPFC nonurban levees have a high potential for levee failure from under-seepage, through-seepage, structural instability, and/or erosion at the assessment water surface elevation.	See Figure ES-2
Levees	**Levee Geometry Check**	• Approximately one-third of SPFC urban levees deviate from current standard levee design prism criteria. • Levee geometry deviates significantly from the standard levee design prism criteria for some nonurban SPFC levees.	Medium
Levees	**Seepage**	• Approximately one-third of SPFC urban levees do not meet current seepage design criteria. • Almost half of SPFC nonurban levees have a high potential for levee failure from under-seepage. • Approximately one-quarter of SPFC nonurban levees have a high potential for levee failure from through-seepage.	High
Levees	**Structural Instability**	• Approximately one-fifth of SPFC urban levees do not meet current structural stability design criteria. • Approximately one-eighth of SPFC nonurban levees evaluated in the Sacramento River watershed and 1 percent in the San Joaquin River watershed have a high potential for levee failure from structural instability.	Medium
Levees	**Erosion**	• Erosion assessments for urban levees are underway, and results are not available at this time. • Almost one-seventh of SPFC nonurban levees have a high potential for levee failure from erosion.	Medium
Levees	**Settlement**	• Four known localized levee locations have settlement (localized depressions) that endangers the integrity of SPFC levees. [5]	Low
Levees	**Penetrations[2]**	• More than 6,000 penetration sites are documented in SPFC levees, and many more remain undocumented.	Medium
Levees	**Levee Vegetation**	• About 15 miles of SPFC levees are noncompliant with DWR 2007 *Interim Levee Vegetation Criteria.*[3, 5]	Low
Levees	**Rodent Damage**	• More than one-third of the 1,459 miles of SPFC levees studied had at least eight reported occurrences of burrowing activity over a 21-year study span.	Medium
Levees	**Encroachments[4]**	• 1,223 encroachment sites were identified as partially or completely obstructing visibility and access to the levee and/or within 10 feet of the landside toe.[5]	Medium
Channels	**Inadequate Conveyance Capacity**	• Approximately half of the 1,016 miles of SPFC channels evaluated are potentially inadequate to convey design flows, and require additional evaluation to confirm conditions. • Approximately one-quarter of channel design capacities reported in O&M manuals do not agree with flows specified in the design profiles.	Medium
Channels	**Channel Vegetation**	• Of 186 miles of SPFC channels inspected by DWR, one location was rated Unacceptable and 54 locations were rated Minimally Acceptable because of vegetation and obstructions.[5]	Low

Table ES-1. Flood Control System Status Report Findings (contd.)

	Factors	Findings	Relative Threat Posed by Factor[1]
	Channel Sedimentation	• Of 186 miles of SPFC channels inspected by DWR, 1 location was rated Unacceptable and 23 locations were rated Minimally Acceptable because of shoaling/sedimentation.[5]	Low
Structures	**Inadequate Hydraulic Structures**	• Of 32 SPFC hydraulic structures inspected by DWR, no structures were rated Unacceptable because of structural, vegetation/obstruction, encroachment, or erosion/sedimentation issues.[5]	Low
Structures	**Inadequate Pumping Plants**	• Of 11 SPFC pumping plants inspected by DWR, none were rated Unacceptable.[5]	Low
Structures	**Inadequate Bridges**	• Of 10 SPFC bridges inspected by DWR, 2 were in need of repairs.[5]	Low

Notes: [1] The relative threats listed in Table ES-1 were generated based on professional experience of technical staff from DWR and partner agencies.
[2] Penetrations include man-made objects that cross through or under a levee or floodwall and have the potential to provide a preferential seepage path or hydraulic connection with the waterside. Typically, a penetration is a pipe or transportation structure, such as a roadway or rail line.
[3] This finding is based on DWR 2007 *Interim Levee Vegetation Criteria* and not on USACE levee vegetation criteria. Comparison with USACE levee vegetation criteria would show more SPFC levees as noncompliant.
[4] Encroachments are any obstruction or physical intrusion by construction of works or devices, planting or removal of vegetation, or caused by any other means, for any purpose, into a flood control project, waterway area of the flood control project, or area covered by an adopted plan of flood control (California Code of Regulations Title 23 Chapter 1 Article 2 Section 4 (m)). Encroachments include boat docks, ramps, bridges, sand and gravel mining, placement of fill, fences, retaining walls, pump stations, residential structures, and irrigation and landscaping materials/facilities.
[5] Inspection results reported are from DWR's 2009 Inspections.

Key:
DWR = California Department of Water Resources
O&M = operations and maintenance
SPFC = State Plan of Flood Control
USACE = U.S. Army Corps of Engineers

The findings in Table ES-1 are relative to DWR's current criteria for use in the CVFPP. In most cases, these criteria are identical, or very similar to, USACE criteria. However, differences between DWR and USACE levee vegetation criteria are significant enough that comparison of levees with USACE criteria would likely show more SPFC levees as noncompliant with current USACE criteria. DWR and USACE continue to work to resolve these differences.

The overall physical condition of SPFC levees, considering most of the levee factors in Table ES-1, is summarized in Figure ES-2. To simplify representation of levee conditions, the figure includes ULE and NULE results that are not directly comparable because different evaluation methodologies were used for each project. The figure is intended to show broadly which levee reaches are of relatively higher, medium, and lower concern, based on physical conditions of the levees. Levees shown as purple (higher concern) on the map generally display more performance problems than those shown in green (lower concern). Results do not reflect economic or life safety consequences of flooding, which are key factors in planning system repairs and improvements. As mentioned, potential economic and life safety consequences associated with flooding are being evaluated as part of the CVFPP.

To adequately address current and increasing future demands on the SPFC, significant and sustained actions are needed to improve the performance level of SPFC facilities that exist today. This will include continued efforts at the State, federal, regional, and local levels to assess and evaluate programs and policies affecting the SPFC and conditions of non-SPFC facilities that affect performance of the flood control system. Implementing an appropriate collection of management actions in a systemwide approach to improve identified problems properly, and to improve flood management throughout the Sacramento and San Joaquin river watersheds, will take many years. It is important to recognize that improvements to the SPFC will be costly and require the active involvement of State, federal, regional, and local interests. Significant amounts of funding will be needed for future project planning, development, implementation by USACE and the State, and for O&M primarily by maintaining agencies.

Local communities (both urban and nonurban) will require significant financial and technical assistance from the State and federal governments over the next 20 to 25 years to make appropriate improvements to the SPFC. FCSSR findings provide important input on system conditions for the CVFPP. As mentioned, the CVFPP will guide future State investments through incremental projects to address identified problems in the SPFC.

Recommendations

Key FCSSR recommendations regarding future DWR work activities include the following:

- Pursue Board adoption of the findings of this FCSSR, as required by California Water Code Section 9120, and support the Board in communicating FCSSR recommendations to the California Legislature.

- Per California Water Code Section 9120(a), update the FCSSR periodically, as requested by the Board, following adoption of the 2012 CVFPP, by incorporating updated results of inspections, evaluations, and special studies.

- Continue to work with State, federal, regional, and local agencies to create a broadly supported CVFPP to guide long-term investments related to the SPFC over the next several decades.

- Build on and improve existing partnerships with federal, regional, and local agencies to develop site-specific actions for the SPFC that are consistent with the integrated, systemwide approach developed in the CVFPP.

- Continue to partner with agencies, and form new partnerships, to conduct special studies to improve understanding of the various factors that present threats to SPFC facilities. These studies include continued efforts to research the impacts of levee vegetation, assess locations and importance of levee penetrations, characterize the probability of levee failure, and other technical studies.

- Proceed with multiagency work efforts to further evaluate facility status, identify needed flood system reconstructions and improvements, and implement them, as State, federal, and local funding becomes available.
- Continue to improve data sharing and accessibility of annual inspection results for partner agencies and the public.

Figure ES-2. Composite Map of Physical Levee Conditions Based on ULE and NULE Results

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Appendices

1.0 Introduction

The Sacramento and San Joaquin river watersheds include an extensive flood management system comprising State of California (State)-federal project facilities and other facilities that are not part of the State-federal project. All State-federal project facilities in the Sacramento and San Joaquin river watersheds are part of the State Plan of Flood Control (SPFC), as defined in the *State Plan of Flood Control Descriptive Document* (DWR, 2010a). SPFC facilities primarily include project levees, channels, and associated structures in the Sacramento and San Joaquin river watersheds of California.[1]

This Flood Control System Status Report (FCSSR) describes the current status (physical condition) of SPFC facilities at a systemwide level. The California Department of Water Resources (DWR) prepared the FCSSR to meet the legislative requirements of California Water Code Section 9120, and to contribute to development of the Central Valley Flood Protection Plan (CVFPP).

The FCSSR is primarily intended to present information on the physical condition of SPFC facilities, and to help guide future inspection, evaluation, reconstruction, and improvement of the facilities. Information presented should not be used to predict how a levee or associated facilities may perform in a specific flood event. More detailed information (such as additional geotechnical explorations and analyses at a greater frequency) would be necessary to meet other purposes, such as assessing whether a levee could be certified under Federal Emergency Management Agency (FEMA) standards to provide base flood protection under the National Flood Insurance Program.

1.1 Report Purpose and Scope

In 2007, the California State Legislature directed DWR to prepare this FCSSR for the SPFC in Section 9120 of the California Water Code, which states the following:

> *§9120. (a) The department shall prepare and the board shall adopt a flood control system status report for the State Plan of Flood*

[1] State Plan of Flood Control facilities also include other elements identified in California Water Code Section 8361.

> *Control. This status report shall be updated periodically, as determined by the board. For the purpose of preparing the report, the department shall inspect the project levees and review available information to ascertain whether there are evident deficiencies.*
>
> *(b) The status report shall include identification and description of each facility, an estimate of the risk of levee failure, a discussion of the inspection and review undertaken pursuant to subdivision (a), and appropriate recommendations regarding the levees and future work activities.*

California Water Code Section 9110 (f) defines the SPFC as follows:

> *"State Plan of Flood Control" means the state and federal flood control works, lands, programs, plans, policies, conditions, and mode of maintenance and operations of the Sacramento River Flood Control Project described in Section 8350, and of flood control projects in the Sacramento River and San Joaquin River watersheds authorized pursuant to Article 2 (commencing with Section 12648) of Chapter 2 of Part 6 of Division 6 for which the board or the department has provided the assurances of nonfederal cooperation to the United States, and those facilities identified in Section 8361.*

As mentioned, the purpose of this report is to comply with California Water Code Section 9120 and contribute to CVFPP development along with other technical studies underway. DWR is fulfilling California Water Code requirements through preparation of two documents, including the FCSSR. These documents are highlighted below and illustrated in Figure 1-1. Each document also contributes to development of the CVFPP.

- ***State Plan of Flood Control Descriptive Document*** **–** The *SPFC Descriptive Document* (DWR, 2010a) identifies and describes each component of the SPFC (facilities, lands, programs, plans, conditions, modes of operations and maintenance (O&M)). This report fulfills part of the legislative requirement expressed in California Water Code Section 9120 (a) and (b).

- ***Flood Control System Status Report*** **–** This FCSSR describes and analyzes the SPFC, and makes recommendations regarding SPFC levees and future work activities.

The FCSSR specifically contributes to development of the CVFPP through the following:

- Consolidates all available systemwide information from multiple DWR programs regarding SPFC physical conditions, and presents the information in a format suitable to facilitate future updates.

- Supports the collaboration of DWR and the Central Valley Flood Protection Board (Board) with State, federal, regional, and local agencies in defining flood management system problems and needs, developing alternative solutions, and implementing future projects to address identified problems and improve the current condition of the flood management system.

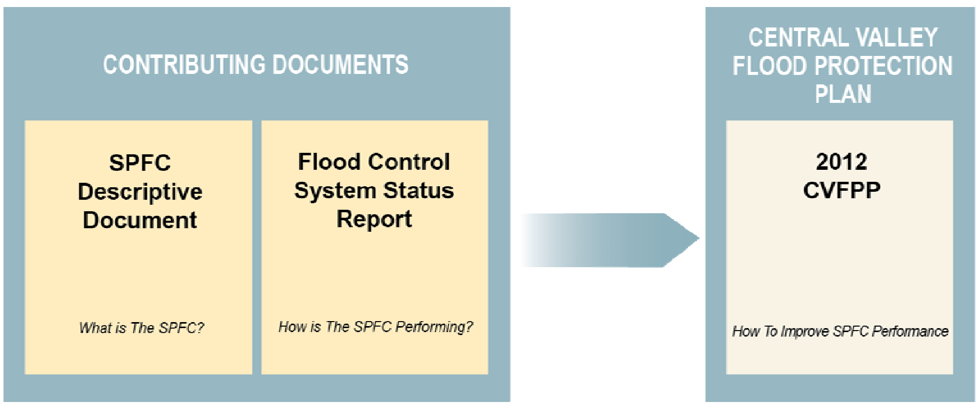

Figure 1-1. Documents Contributing to Central Valley Flood Protection Plan

In addition to meeting legislative requirements and contributing to the CVFPP, information in the FCSSR may be used to support core functions and long-term activities of DWR's Division of Flood Management, including emergency response, facility maintenance, and inspections. Periodic updates of this FCSSR will enable DWR to track progress as ongoing inspections and evaluations are completed and more SPFC facilities are reconstructed or improved to meet current design criteria.

The scope of the FCSSR is to use available information to describe the physical condition of SPFC levees, channels, and structures in the Sacramento and San Joaquin river watersheds (Figure 1-2) at a systemwide level. Information presented in this report should be viewed as the best indication of facility condition for major reaches (many miles) of SPFC facilities rather than to identify individual problems at specific SPFC facility locations.

The SPFC is only a portion of the larger system that provides flood protection for the Central Valley. Performance of SPFC facilities relies on many non-SPFC facilities constructed by U.S. Army Corps of Engineers (USACE), DWR, U.S. Department of the Interior, Bureau of Reclamation, and local agencies along many of the rivers, creeks, and streams in the

Central Valley. Major non-SPFC facilities that affect the performance of SPFC facilities (and/or provide flood risk reduction benefits to areas protected by SPFC levees) include levees that are not part of the federal project (nonproject levees), modifications and alterations to SPFC levees that have not been State-authorized, debris management facilities (such as the Yuba Goldfields), and most of the reservoirs in the Central Valley. Processes for evaluating facility additions to and removals from the SPFC are under development as part of the CVFPP.

This FCSSR reflects existing facility conditions (including past performance) at the time this FCSSR was prepared, and some results represent initial findings of ongoing evaluations. Many ongoing inspections, geotechnical evaluations, and hydraulic evaluations will yield additional information on facility conditions. In addition, subsequent facility improvements, repairs, and reconstruction would likely affect facility conditions reported in this FCSSR. Where applicable, any changes in findings will be reflected in future updates to this FCSSR.

For some factors, DWR’s approach may differ from an approach that USACE or other agencies would use for other evaluations or purposes. In these cases, the difference is acknowledged, although only DWR’s approach is used as the basis for results presented.

Figure 1-2. Sacramento and San Joaquin River Watersheds for State Plan of Flood Control

1.2 Need to Evaluate Status

SPFC facilities were built in increments over many decades, with many levees constructed by landowners and local entities after 1850 and through the early 1900s, before the initial federally authorized project (Sacramento River Flood Control Project) was established. USACE accepted some of these levees into the federal project without modification, improved some, and engineered new levees in other locations. Most levees included in what is now termed the SPFC in the Sacramento River watershed were accepted, improved, or constructed by USACE between 1918 and the mid-1960s. Most SPFC levees in the San Joaquin River watershed downstream from the Merced River confluence were improved as directed by USACE between the mid-1950s and early 1970s. In the San Joaquin River watershed upstream from the Merced River confluence, most SPFC levees were improved or constructed by DWR between the 1960s and early 1970s.

SPFC facilities now face many pressures that were not known or did not exist when the facilities were originally constructed. Design criteria and construction methods have become more stringent over time as understanding of geotechnical, hydrologic, and other technical aspects of flood management have improved. As a result, most facilities constructed in the early to mid-twentieth century were not designed or constructed to meet current criteria. In some cases, facilities are now obsolete or have nearly exceeded their expected service lives, and are in need of major modification or repair. Further, facilities originally constructed primarily for navigation/sediment transport and flood management are now also recognized as important for water supply conveyance, ecosystem functions, recreation, and other beneficial uses.

1.3 Report Overview

This FCSSR describes inspection and evaluation activities related to the SPFC, and information on the physical condition of SPFC levees, channels, and flood control structures. It also includes basic findings and recommendations regarding SPFC levees and future work activities. All map-based data presented are in geographic information system (GIS) format. Data and other information collected and evaluated from a multitude of inspection and evaluation activities are used as a basis for summarizing physical conditions with respect to SPFC facilities. The FCSSR contains the following sections:

- **Section 1 (Introduction)** provides background information, including the purpose and scope of the FCSSR, overview of documents complementary to the FCSSR, the need to evaluate the status of SPFC facilities, and this report overview.

- **Section 2 (Inspection and Evaluation Activities Related to SPFC Status)** describes annual inspection and reporting done by DWR, periodic inspections by USACE, and joint USACE-DWR inspections. Section 2 also describes in detail DWR evaluation activities underway to evaluate geotechnical and hydraulic conditions, and presents an overview of USACE evaluations. Data collected and evaluated through many of these activities are used as the basis for SPFC conditions summarized in Sections 3 through 6.

- **Section 3 (Flood Risk in Sacramento and San Joaquin River Watersheds)** presents a brief overview of flood risk, and factors that influence flood risk. This section includes an evaluation of geotechnical hazard[2] as it relates to the risk of levee failure. Geotechnical hazard information is based on analysis from the Urban Levee Evaluation (ULE) and Non-Urban Levee Evaluation (NULE) projects of DWR's Levee Evaluations Program. Geotechnical hazard is assessed considering geotechnical factors for levee performance.

- **Section 4 (Levee Status)** presents SPFC levee conditions based on data from inspections and evaluations described in Section 2, and is organized according to the following subsections, with each subsection including a discussion of status evaluation methodology, limitations, and results of the status evaluations:

  - **Levee geometry check**, with conditions summarized from results of a levee geometry check conducted by the DWR Levee Evaluations Program that compares existing levee geometry to a standard levee design prism.

  - **Seepage**, with conditions summarized from results of the DWR Levee Evaluations Program. The ULE Project evaluated compliance with current seepage design criteria for urban levees, and the NULE Project evaluated potential for levee failure from under-seepage and through-seepage.

  - **Structural instability**, with conditions summarized from results of the DWR Levee Evaluations Program. The ULE Project evaluated compliance with current structural stability design criteria for urban levees, and the NULE Project evaluated potential for levee failure from structural instability.

[2] As reported in the FCSSR, "hazard" refers specifically to geotechnical hazard when discussed in relation to the assessments performed under the ULE and NULE projects.

- **Erosion**, with conditions summarized from results of the DWR Levee Evaluations Program. The ULE Project erosion assessment is under development. The NULE Project evaluated potential for levee failure from erosion.

- **Settlement**, with conditions summarized from results of DWR 2009 annual inspections for crown surface/depressions/rutting.

- **Penetrations,**[3] with conditions summarized from locations of penetrations through levees throughout the SPFC, cataloged by the DWR Levee Evaluations Program.

- **Levee vegetation**, with conditions summarized from results of DWR 2009 annual inspections for vegetation on earthen levees based on DWR 2007 *Interim Levee Vegetation Inspection Criteria* for visibility and accessibility.

- **Rodent damage**, with conditions summarized from results of a 2009 DWR assessment of animal burrow hole persistence on SPFC levees using inspection data from 1984 through 2008.

- **Encroachments,**[4] with conditions summarized from results of DWR 2009 annual inspections for encroachments.

• **Section 5 (Channel Status)** presents SPFC channel conditions based on data from inspections and evaluations described in Section 2, and is organized according to the following subsections:

- **Channel conveyance capacity**, with conditions summarized from a comparison of design and estimated flood flow capacities for each SPFC channel. Existing capacities are estimated through systemwide modeling from the *SPFC Existing Channel Capacity Assessment Technical Memorandum* (CVFED, 2009) and project-specific modeling. Information is also presented to show where design capacities in USACE O&M manuals are inconsistent with

[3] Penetrations include man-made objects that cross through or under a levee or floodwall and have the potential to provide a preferential seepage path or hydraulic connection with the waterside. Typically, a penetration is a pipe or transportation structure, such as a roadway or rail line.

[4] Encroachments are any obstruction or physical intrusion by construction of works or devices, planting or removal of vegetation, or caused by any other means, for any purpose, into a flood control project, waterway area of the flood control project, or area covered by an adopted plan of flood control (California Code of Regulations Title 23 Chapter 1 Article 2 Section 4 (m)). Encroachments include boat docks, ramps, bridges, sand and gravel mining, placement of fill, fences, retaining walls, pump stations, residential structures, and irrigation and landscaping materials/facilities.

design profiles (e.g., 1955, 1957, 1965) (USACE, 1955a; USACE, 1957a; USACE, 1957b; and USACE, 1965).

- **Channel vegetation**, with conditions summarized from results of DWR 2009 annual inspections for channel vegetation.

- **Channel sedimentation**, with conditions summarized from results of DWR 2009 annual inspections for channel shoaling and sedimentation.

- **Section 6 (Flood Control Structures Status)** presents SPFC flood control structure conditions based on data from DWR inspection activities described in Section 2. The section is organized according to the following subsections:

  - **Hydraulic structures** (dams, weirs, drop structures, control structures, drainage structures, and outfall gates), with structural, vegetation, encroachment, and erosion/bank caving and shoaling/sedimentation conditions summarized from DWR 2009 annual inspections for hydraulic structures.

  - **Pumping plants**, with conditions summarized from DWR 2009 annual inspections for pumping plants.

  - **Bridges,** with conditions summarized from DWR 2009 annual bridge inspections.

- **Section 7 (Approach for SPFC Improvements)** describes the approach and work organization for improving existing conditions of SPFC facilities, including development of the CVFPP.

- **Section 8 (Findings and Recommendations)** presents findings from the information presented in Sections 3 through 6, and provides recommendations specific to levees and future work activities.

- **Section 9 (References)** lists sources used to prepare this FCSSR.

- **Section 10 (Acronyms and Abbreviations)** lists acronyms and abbreviations used in this FCSSR.

Appendices to the main report include the following:

- **Appendix A (Levee Status)** provides supplemental information related to levee conditions described in Section 4, including USACE periodic inspection results; historical data; recent, ongoing, and planned improvements and projects; and ongoing actions to improve future evaluations.

- **Appendix B (Channel Status)** provides supplemental information related to channel conditions described in Section 5, including a tabular list of channel capacities and conditions; recent, ongoing, and planned improvements and projects; and ongoing actions to improve future evaluations.

- **Appendix C (Flood Control Structures Status)** provides supplemental information related to flood control structure conditions described in Section 6, including recent, ongoing, and planned remedial actions, and ongoing actions to improve future evaluations.

2.0 Inspection and Evaluation Activities Related to SPFC Status

This section describes inspection and evaluation activities related to the physical condition of SPFC facilities. While regular inspections can collect large amounts of information on SPFC status quickly, visual inspections alone are inadequate to develop a comprehensive evaluation of SPFC conditions. Characterizing other factors that impact the integrity of SPFC facilities requires additional data collection and evaluations. While collection and evaluation activities can provide more detailed information on SPFC conditions than visual inspections alone, they are often time-consuming and require significant resources.

Seepage is a condition that exemplifies the need for data collection and evaluation for levees. Visual inspections can document occurrences of landside boils and/or seepage areas during high water events. However, visual inspections alone cannot provide the necessary information to assess subsurface conditions leading to landside boils and/or seepage.

2.1 Inspection and Reporting for SPFC Facilities

This section describes DWR, Board, and USACE inspection and reporting activities for SPFC facilities.

2.1.1 DWR Inspections and Reporting

The role of DWR in performing annual visual inspections is to comply with USACE inspection and maintenance requirements, and to work with maintaining agencies (including levee districts, reclamation districts, cities, counties, and other public agencies and municipalities) to oversee their maintenance of SPFC facilities. Federal Flood Control Regulations (Title 33 Code of Federal Regulations, Section 208.10) require that federal flood protection levees and floodwalls be inspected at least four times per year – immediately before the beginning of flood season, immediately after each major high water period (flood event), and otherwise at intervals not exceeding 90 days. Federal Flood Control Regulations also require that channels and floodways be inspected periodically. Pumping plants are to be inspected at intervals not to exceed 30 days during the flood season, and 90 days during nonflood seasons. In addition, inspections are often necessary at intermediate times to determine if maintenance measures for

SPFC facilities are being performed effectively. A semiannual report must then be “submitted to the District Engineer covering inspection, maintenance, of the protective works” (Title 33 Code of Federal Regulations, Section 208.10).

In compliance with these federal requirements, DWR conducts several types of inspections. DWR-generated maintenance inspection reports are described in Table 2-1.

Annual Inspection Report of the Central Valley State-Federal Flood Protection System

DWR conducts two comprehensive levee inspections (spring and fall) and one channel and flood control structure inspection each year (summer). Maintaining agencies conduct their own levee inspections in winter and summer and report their results to DWR. DWR and other maintaining agencies also patrol and inspect all SPFC levees during and after high water events. DWR inspections identify status of the features (e.g., encroachments, animal burrows, vegetation, and their types and locations) and document their maintenance conditions in the form of ratings. DWR reports the results for individual issues according to maintaining agency, levee unit, and levee mile. Based on results of these inspections, DWR and other maintaining agencies plan their maintenance activities and work toward improving ratings before the next inspection.

Beginning in 2007, USACE required DWR to use the checklist in the USACE *Flood Damage Reduction System Inspection Report* when inspecting the flood management system (2007). During 2007 inspections, DWR began adapting to the new USACE checklist.

USACE has significantly increased federal inspection requirements in recent years to improve knowledge of system conditions. The federal policies and programs require engineering evaluations (such as invasive inspections of penetrations) that present compliance challenges for DWR and other maintaining agencies. DWR continues to work with USACE to improve inspections, and coordinates with USACE through an Inspection Program Working Group established in May 2009 (DWR, 2009a).

Table 2-1. Description of DWR-Generated Maintenance Inspection Reports

Report	Levees	Channels	Flood Control Structures	Description
Annual Inspection Report of the Central Valley State-Federal Flood Protection System	√	√	√	Annual report prepared by DWR based on DWR's fall levee, channel, and flood control structure inspections.
AB 156 Local Agency Annual Report	√			Annual report prepared by DWR and submitted to the Board by December 31 of each year, based on information submitted to DWR by maintaining agencies by September 30 of each year.
Monthly Reports to the Board	√	√	√	DWR verbal presentations outlining inspection activities.
Levee Mile Report	√			Reports generated by DWR from inspections detailing maintenance issues found during inspections. One report is generated for each unit and includes photos of issues noted.
Annual Supplemental Erosion Survey of the San Joaquin River Flood Control System	√			Annual report prepared by DWR based on supplemental inspections conducted by DWR personnel. These surveys are summarized in the Annual Inspection Report of the Central Valley State-Federal Flood Protection System.
Annual Hydraulic Structure Inspection Report			√	Report generated by DWR from annual inspection of hydraulic structures maintained by DWR in accordance with the California Water Code.
Annual Bridge Inspection Report			√	Report generated from annual inspection of bridges maintained by DWR in accordance with the California Water Code.

Source: DWR, 2010b

Key:
AB = Assembly Bill
Board = Central Valley Flood Protection Board
DWR = California Department of Water Resources

Since 2008, a field computer interface inspection tool and georeferenced database have been used during DWR inspections that allow DWR to efficiently capture and compile inspection data and results. Specific criteria and rating descriptions used for inspection items are appended to the *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (DWR, 2010b) and described in Sections 4 through 6 and Appendix A of this FCSSR. These criteria provide the bases for inspection results contained in DWR maintenance inspection reports (Table 2-1) and elsewhere in this FCSSR.

Each inspection item (e.g., obstructive tree, erosion site, encroachment site) receives one of three possible ratings from DWR based on its condition:

- **Acceptable (A) –** No immediate work required, other than routine maintenance. The flood protection project will function as designed and intended, with a high degree of reliability, and necessary cyclic maintenance is being adequately performed.
- **Minimally Acceptable (M) –** One or more conditions exist in the flood protection project that needs to be improved or corrected. However, the project will essentially function as designed except with a lesser degree of reliability than the project could provide.
- **Unacceptable (U) –** One or more conditions exist that may prevent the project from functioning as designed, intended, or required.

The Minimally Acceptable and Unacceptable ratings generally highlight where minor and serious maintenance issues have been observed. Only Minimally Acceptable and Unacceptable ratings are presented in this FCSSR.

Assembly Bill 156 Local Agency Annual Report

In addition to regular DWR levee, channel and flood control structure inspections, California Assembly Bill 156 (Laird, 2007) amended California Water Code Section 9141 and requires local agencies to submit information to DWR for the levees they maintain by September 30 each year. In turn, DWR is required to summarize this information in an annual report to the Board by December 31 each year. DWR prepared the first (Assembly Bill 156) *Local Agency Annual Report* in 2008 and continues to update the report annually (DWR, 2009a).

Monthly Reports to the Board

DWR provides monthly reports to the Board, as requested by the Board. Monthly reports are verbal, and outline recent inspection activities.

Levee Mile Report

DWR prepares a Levee Mile Report for each levee unit inspected by DWR and maintaining agencies during spring, summer, and fall inspections. A Levee Mile Report details maintenance conditions found during an inspection, and includes photos of some problems noted. Maintaining agencies use Levee Mile Reports to plan and conduct maintenance activities, and emergency response agencies use data from the reports to evaluate planned actions during future floods.

Annual Supplemental Erosion Survey of the San Joaquin River Flood Control System

The San Joaquin River Flood Control System Erosion Survey monitors and documents the condition of erosion sites annually. The erosion surveys include land-based and waterside surveys during the summer. These findings are contained in the *Annual Supplemental Erosion Survey of the San Joaquin River Flood System* (DWR, 2010e). Additional details on this survey are described in Appendix A, Section A-5.

Annual Hydraulic Structure Inspection Report

Annual maintenance inspections are conducted for hydraulic structures (including pumping plants) maintained by DWR. DWR operates and maintains hydraulic structures specified in Section 8361 of the California Water Code and hydraulic structures within State maintenance areas. These inspections identify any repairs, improvements, and/or replacements needed to comply with USACE operations and maintenance requirements and other guidelines. Formalized checklists and inspection criteria are used during each inspection and photographs taken. The annual Hydraulic Structure Inspection Report contains detailed descriptions of the structural integrity of each structure, a prioritized list of repairs (if any), a map illustrating the location of the structures, and a copy of each inspection checklist with updated photographs (DWR, 2010c).

Annual Bridge Inspection Report

In 2008, DWR initiated the Bridge Inspection Program to standardize inspection and evaluation of bridges maintained by DWR in accordance with Section 8361 of the California Water Code. Before 2008, inspection and reporting of these bridges was conducted based on Title 33 Code of Federal Regulations, Section 208.10 requirements. The DWR program was initiated to assess in more detail the condition of bridges for conveyance capacity because of their age. The goals of the program are to provide for safe passage for floodfight operations, and to meet local transportation and inspection needs. The Annual Bridge Inspection Report includes detailed descriptions of each bridge’s condition, inspection ratings, photographs, and recommendations for repair, improvement and/or replacement (if any).

DWR Inspection Data in FCSSR

DWR inspection data are presented in FCSSR Sections 4 through 6 according to status factors described in Section 3. Note that inspection data included in this FCSSR are for status factors not considered in systemwide evaluations (Section 2.2). Inspection data are also contained in Appendix A as supplemental information for factors evaluated more comprehensively in systemwide evaluations. Inspection data are based on results of the 2009 inspections, and are located in this FCSSR and Appendix A as follows:

- Levee Seepage (Appendix A, Section A-3)
- Levee Structural Instability (Appendix A, Section A-4)
- Levee Erosion (Appendix A, Section A-5)
- Levee Settlement (Crown Surface/Depressions/Ruttings) (Section 4.5)
- Levee Vegetation (Section 4.7)
- Levee Rodent Damage (Appendix A, Section A-7)
- Levee Encroachments (Section 4.9)
- Channel Vegetation (Section 5.2)
- Channel Sedimentation (Section 5.3)
- Hydraulic Structures (Section 6.1)
- Pumping Plants (Section 6.2)
- Bridges (Section 6.3)

2.1.2 USACE Inspections and Reporting

The primary purpose of USACE inspections is to determine whether federal and nonfederal flood protection facilities meet federal maintenance requirements. This determination has a major bearing on the eligibility for federal rehabilitation assistance under Public Law 84-99. All USACE inspections incorporate instructions from the most recent USACE inspection checklist, in the *Flood Damage Reduction Segment/System Inspection Report* (2009a).

Linking USACE inspection results to eligibility for Public Law 84-99 rehabilitation assistance has increased the significance of USACE inspections in recent years. A levee system[1] must maintain an Acceptable or Minimally Acceptable rating to retain an "Active Status" in the USACE Rehabilitation and Inspection Program. Levees with an Active Status

[1] In this context, a levee system or flood damage reduction system is a complete and independent unit made up of one or more flood damage reduction segments that collectively provide flood damage reduction to a defined area. Failure of one segment within a system constitutes failure of the entire system.

before a flood event are eligible for federal assistance after a flood event to repair damages caused by a flood (as authorized by Public Law 84-99).

There are three types of USACE inspections:

1. **Initial Eligibility Inspections**, which are conducted at the request of a local sponsor for initial inclusion into the USACE Rehabilitation and Inspection Program.

2. **Continuing Eligibility Inspections**, or routine inspections, which are conducted annually or biannually.

3. **Periodic Inspections**, which are conducted on a 5-year interval and include collecting existing historical documents (e.g., manuals, as-built drawings, previous reports) and conducting field inspections (USACE, 2009a).

Initial eligibility inspections are performed to establish acceptable and minimum performance levels for nonfederal flood control works to gain an Active Status rating in the USACE Rehabilitation and Inspection Program.

For SPFC facilities, USACE Continuing Eligibility Inspections have been based on DWR annual inspection findings. Based on DWR inspection information, USACE may conduct follow-up inspections with site visits in certain areas before determining its inspection ratings. These follow-up inspection ratings take precedence over DWR inspection results in determining Public Law 84-99 eligibility. USACE has identified several levee systems as inactive in the Public Law 84-99 Rehabilitation Assistance program because of issues that USACE inspections have shown could negatively impact levee performance in a high water event. Maintaining agencies for these levee systems are encouraged to implement any corrective actions noted by USACE inspections so that their levees can be reinstated in the Public Law 84-99 Rehabilitation Assistance Program.

USACE began conducting Periodic Inspections for SPFC facilities in summer 2009. When conducted, Periodic Inspection ratings have precedence over Continuing Eligibility Inspection ratings, and are used to determine the status of facilities in the Public Law 84-99 Rehabilitation Assistance Program. USACE Periodic Inspection “report cards” for 10 SPFC levee systems are provided in Appendix A, Section A-1. These report cards summarize findings of USACE Periodic Inspections.

USACE provides inspection results to project sponsors and FEMA. When a levee system previously certified by USACE undergoes a Periodic Inspection, USACE reviews the FEMA certification according to inspection results. USACE procedures for levee system evaluations in support of FEMA certification have been consolidated in the document, Engineering Circular (*EC) 1110-2-6067 – USACE Process for the NFIP Levee System Evaluation* (USACE, 2010a).

2.1.3 Joint DWR, Board, and USACE Inspections and Reporting

DWR, the Board, and USACE cooperate on project-specific inspections such as the Sacramento River Bank Protection Project erosion surveys. USACE, with the Board's sponsorship, has contracted for waterside erosion surveys of the Sacramento River Flood Control Project since 1998. Each year, DWR, the Board, and the USACE Sacramento District conduct a field reconnaissance review of levee erosion sites for the Sacramento River Flood Control Project.

The *2009 – Field Reconnaissance Report of Bank Erosion Sites and Site Priority Ranking: Sacramento River Flood Control Levees, Tributaries and Distributaries* (USACE and DWR, 2010) includes an inventory of levee erosion sites. The findings of this report are included in the DWR Levee Mile Reports and Annual Inspection Report and are included in Section 4.4 of this FCSSR.

2.2 Evaluation of SPFC Facilities

This section describes DWR and USACE evaluation activities for SPFC facilities. As mentioned, landside inspection data are limited to what is visible from the crown of a levee. Several other characteristics that impact the integrity of the SPFC require additional evaluations. Inherent characteristics of SPFC facilities that cannot be observed in visual inspections include the following:

- Subsurface soil conditions
- Underwater levee structure
- Levee geometry
- Compliance with geotechnical design criteria for levees
- Channel conveyance capacity

These characteristics are assessed through evaluation activities, as described below.

2.2.1 DWR Evaluations

DWR is conducting site-specific geotechnical evaluations of levees through the Levee Evaluations Program. DWR is also conducting hydraulic evaluations of channel conveyance capacity through the Central Valley Floodplain Evaluation and Delineation Program and DWR Maintenance Program. Similar detailed evaluations of flood control structures are not being conducted because information from enhanced visual inspections provides sufficiently detailed status information.

Geotechnical Evaluations

As part of developing the CVFPP, DWR is evaluating geotechnical hazards associated with levee failure in areas where levees protect urban and nonurban areas, as generally defined by Proposition 1E. The DWR Levee Evaluations Program is evaluating approximately 2,000 miles of SPFC levees and appurtenant non-SPFC levees in the Central Valley (approximately 1,580 miles of SPFC levees and 420 miles of non-SPFC levees). The program is divided into two projects, the ULE Project and NULE Project, each of which is further divided into multiple study areas.

The ULE Project is evaluating approximately 350 miles of SPFC levees and approximately 120 miles of appurtenant non-SPFC levees protecting areas with populations exceeding 10,000. The NULE Project is evaluating approximately 1,230 miles of SPFC levees and approximately 300 miles of appurtenant non-SPFC levees in the Central Valley in areas with a population of less than 10,000. Levees evaluated by ULE and NULE are shown in Figure 2-1. Appurtenant non-SPFC levees are defined as those (1) that abut SPFC levees, (2) whose performance may affect the performance of SPFC levees, or (3) that provide flood risk reduction benefits to areas also being protected by SPFC features.

The goals of the ULE and NULE projects are to determine whether levees meet defined geotechnical criteria and, where needed, to identify repair and improvement measures, including cost estimates, to meet desired geotechnical criteria. The methodology, criteria and results from the ULE and NULE projects are described in more detail in Section 3.3, Risk of Levee Failure.

Tables 2-2 and 2-3 summarize key deliverables of the ULE and NULE projects, respectively.

Figure 2-1. Levees Evaluated by ULE and NULE Projects

Table 2-2. ULE Project Deliverables

Project Deliverable	Description
Data Technical Review Memorandum	Assesses known and unknown geotechnical conditions in a study area and documents levee performance during past flood events
Preliminary Geotechnical Data Report	Presents results of initial field exploration and laboratory testing programs
Preliminary Geotechnical Evaluation Report	Identifies locations for supplemental evaluation through preliminary geotechnical analyses of seepage and stability conditions
Supplemental Geotechnical Data Report	Presents results of the supplemental field and laboratory exploration program that addresses any significant data gaps
Final Geotechnical Evaluation Report	Presents additional analysis to evaluate levee conditions based on available data and to provide conceptual remediation and costs

Table 2-3. NULE Project Deliverables

Project Deliverable	Description
Data Technical Review Memorandum	Assesses known and unknown geotechnical conditions in a study area and documents levee performance during past flood events
Geotechnical Assessment Report	Presents results of comprehensive data collection and preliminary levee assessment
Remedial Alternatives and Cost Estimating Report	Identifies conceptual repair and improvement alternatives and cost estimates to correct identified problems
Geotechnical Data Report	Presents results of field and laboratory exploration and testing
Geotechnical Overview Report	Presents additional analysis to evaluate levee conditions based on available data and provides conceptual repair and improvement costs

Hydraulic Evaluations

Hydraulic evaluations help identify and evaluate SPFC channel conveyance capacity conditions. As mentioned, DWR is conducting hydraulic evaluations through the Central Valley Floodplain Evaluation and Delineation Program and DWR Maintenance Program.

The DWR Central Valley Floodplain Evaluation and Delineation Program provided the primary source of SPFC channel conveyance capacity data. The DWR Central Valley Floodplain Evaluation and Delineation Program is gathering updated topographic, hydrologic, and hydraulic data, which will be used to develop new mathematical models to understand flood risk and evaluate channel conveyance capacity in the Central Valley on a systemwide level. Systemwide modeling generally characterizes impedance to flow, but is not designed to evaluate subtle changes in channels as a result of sediment deposition, in-channel vegetation, and/or other obstruction in channels. Once complete, these models will support evaluation and design of potential actions and projects to help manage flood risk. Meanwhile, preliminary data gathered by the DWR Central Valley Floodplain Evaluation and Delineation Program was used to evaluate channel status in Section 5.1 of this FCSSR.

The new hydraulic models for major rivers, tributaries, and overbank areas associated with the SPFC (expected to be completed in 2012) will be used to evaluate flood risks in the Sacramento and San Joaquin river watersheds and system performance during storm events of differing severity, and to delineate potential extent of flooding. The models will be supported by additional physical data, analytical tools, and work products, including the following:

- Detailed aerial photographs and topographic data for a major portion of the Central Valley
- Detailed light detection and ranging (LiDAR) topographic data for the majority of SPFC levees
- Bathymetry surveys and surveys of bridges and structures for major rivers and tributaries in the Central Valley
- Supplemental field surveys of structures, stream gages, and channel cross sections for major rivers and tributaries in the Central Valley

Project-specific modeling conducted by the DWR Maintenance Program provided a second source of channel conveyance capacity data in the Sacramento River watershed, presented in Section 5.1. DWR is responsible for maintaining channel flow capacity for Sacramento River Flood Control Project channels, and for performing channel-specific maintenance activities identified in the USACE O&M manuals, including channel clearance, if required to maintain design flow capacity. The goal of the DWR Maintenance Program is to accurately characterize Sacramento River Flood Control Project channel hydraulics, and to identify needed maintenance activities for each of the Sacramento River Flood Control Project channels and bypasses prescribed in California Water Code Section 8361. Project-specific models help systematically prioritize channel vegetation management and sediment management activities by determining whether a channel capacity inadequacy is driven by sedimentation, channel vegetation, subsidence, flow constrictions caused by bridge crossings, or other factors. Where available, project-specific hydraulic modeling results from projects conducted by other agencies were used as the source of channel conveyance capacity data.

For systemwide and project-specific modeling, characterization of a channel's current conveyance capacity and identification of channels requiring maintenance are also derived from a hydraulic investigation that includes development of a one-dimensional HEC-RAS hydraulic model. Inadequacies in a channel's conveyance capacity are determined based on design flows and stages depicted in the 1957 USACE *Levee and Channel Profiles, File Number 50-10-334* (1957 Design Profile). For channels not covered in the Sacramento River watershed by the 1957 Design Profile and those in the San Joaquin River watershed, the as-constructed plans were used to determine the design stage.

DWR is developing Channel Evaluation Reports for each of the Sacramento River Flood Control Project channels and bypasses prescribed in California Water Code Section 8361. The reports present an evaluated channel's current conveyance capacity, identify locations needing maintenance, and develop channel management plans to safely convey the design flow without encroaching on specified stage and level of freeboard.

Note that there are some differences between how DWR is currently evaluating existing channel conveyance capacities as part of both the Central Valley Floodplain Evaluation and Delineation Program and its Maintenance Program, and how USACE evaluates channel conveyance capacities for planning studies. DWR defines the maximum safe channel capacity using a deterministic approach to delineate floodplains along the Sacramento and San Joaquin rivers, and evaluating specific maintenance projects. This approach considers remaining freeboard and levee stability with respect to geotechnical conditions. USACE uses a risk-based approach that assigns a probability of failure based on defined levee stability parameters and estimated frequency of river stages.

To evaluate baseline hydraulic conditions as part of ongoing studies of the SPFC for the CVFPP, DWR uses a risk-based approach more similar to USACE's approach. Risk-based approaches are better for evaluating flood risk, but their accuracy depends on having sufficient geotechnical and hydrologic data to support the analysis.

2.2.2 USACE Evaluations

USACE is also conducting numerous site-specific evaluations in support of flood control civil works projects in the Central Valley. Examples of recent projects include the American River Watershed Common Features Project, Marysville Ring Levee Project, South Sacramento County Streams Project, West Sacramento Levee Improvement Program and Lower San Joaquin Feasibility Study.

In addition to site-specific evaluation studies, USACE (in sponsorship with the Board) has conducted a comprehensive system evaluation for the Sacramento River Flood Control Project. Contents of the technical studies conducted for each phase of the system evaluation are summarized in Table 2-4.

Table 2-4. Sacramento River Flood Control System Evaluation Technical Studies

Technical Study	Description
Historic Levee Embankment Problem Areas	Locations of levee breaks, seepage, boils, sinkholes, slope failures, erosion damage
Levee Crown Surveys	Levee crown elevations
Cross-Section Surveys	Comparison of existing cross sections with original design and construction cross sections
Design Water Surface Profiles	Comparison of levee crown elevations with design water surface profiles
February 1986 High Water Mark Profiles	Comparison of February 1986 high water mark profile with design water-surface profile
Hydrology	Discharge-frequency relationships, rating curves, assessment of ability of channels to convey design flow within design water surface elevation
Geotechnical	Soil sample analysis, review of soil maps and aerial photographs, slope stability analysis, and assessment of potential for damage due to seepage and piping
Design Freeboard	Levee reaches with inadequate design freeboard
Design Flow	Locations of design flow inadequacies
Level of Flood Protection	Recurrence intervals for February 1986 peak flood stages based on engineering and geotechnical considerations
Economics	Flooded areas (floodplains), and estimated flood damages

The Sacramento River Flood Control System Evaluation was conducted by USACE from 1988 to 1995; resulting evaluation reports are listed in Table 2-5.

Table 2-5. Sacramento River Flood Control System Evaluation Reports

Phase	Report Title	Month/Year
1	Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Sacramento Urban Area	May 1988
2	Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Marysville/Yuba City Area	January 1990
3	Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Mid-Valley Area	December 1991
4	Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Lower Sacramento Area	September 1993
5	Sacramento River Flood Control System Evaluation, Initial Appraisal Report – Upper Sacramento Area	May 1995

Following the evaluations listed in Table 2-5, USACE and the Board constructed projects for each of the five areas to remediate identified problem locations and restore levees to design standards, while addressing seepage. Where levees did not meet design standards and problems did not result from lack of maintenance, levee remediation projects were proposed after evaluation. Remediation that could be economically justified was conducted, but some identified problem locations were left unremediated if remediation could not be economically justified. Also, work was performed according to design criteria at the time, which, in some cases, were less stringent than current design criteria.

Additional information on levee conditions after the Sacramento Flood Control System Evaluation is included in Section 4.0, “Levee Status.”

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3.0 Flood Risk in Sacramento and San Joaquin River Watersheds

SPFC levees along the Sacramento and San Joaquin rivers and their tributaries reduce the frequency of flooding on lands along these rivers. Since their construction, these levees and associated facilities have helped promote public safety and prevent billions of dollars of flood-related damages that would have occurred if the levees were not in place. However, portions of these levees have failed occasionally, resulting in significant property damage and loss of life. In addition, new development behind the levees places more lives and property in areas that face flood hazards, leading to higher flood risk because of higher consequences that would result if a flood occurs.

Opposite sides of a river reach can have different flood risks because of different consequences of failure

This section presents a general overview of flood risk within the Sacramento and San Joaquin river watersheds. For the CVFPP, flood risk is defined as the long-term average consequences of flood inundation within an identified area given a specified climate condition, land use condition, and flood management system (existing or planned) in place. The consequences may be direct or indirect economic cost, loss of life, environmental impact, or other specified measures of flood effect. Flood risk is a function of flood hazard,[1] loading,[2] exposure,[3] and consequences. Elements of flood hazard, loading, exposure, and consequences include hydrology, hydraulics, levee performance (or fragility) curves, and economic and life safety consequences, which are discussed in the CVFPP and supporting documentation. As described in this FCSSR, "hazard" refers specifically to geotechnical hazard when discussed in relation to the hazard assessments performed by the ULE and

[1] Flood hazard is defined by FEMA as any flood event or condition with the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, environmental damage, business interruption, or other loss. Flood hazard is a function of hydrology and hydraulics (e.g., rising or rapidly flowing water in a channel).

[2] In the context of flood risk, loading describes the frequency and magnitude of flooding. It is commonly described with a discharge-frequency function that identifies the probability that discharge at a specified location will exceed a specified value.

[3] Exposure is a description or measure of the relationship between natural flood hazard and the consequences of flooding. Exposure is related to the performance of levees.

NULE projects. The geotechnical hazard data presented are used to meet the FCSSR legislative requirement related to the risk of levee failure (Section 1.1) and to develop levee performance curves for evaluating exposure for the baseline condition in the CVFPP. Therefore, ULE and NULE data related to risk of levee failure in this FCSSR do not reflect the complete definition of flood risk, which, as mentioned, includes hydrology, hydraulics, levee performance curves, and economic or life safety consequences of flooding.

Levee performance for the ULE project is evaluated against hazard classifications relative to established levee design criteria. Levee performance for the NULE project is evaluated as hazard categories, which are qualitative indicators of the potential for levee failure. The ULE and NULE project assessments contained in this report represent a preliminary analysis of levee conditions based on initial phases of evaluations under both projects. Subsequent phases of the ULE and NULE projects will include additional geotechnical explorations along significant portions of the ULE and NULE levees, and more detailed analyses, which may alter the assessments presented in this report.

3.1 Flood Risk

Many Californians, especially those in deep floodplains in the Central Valley, face a significant chance of harm and damage caused by floods. Facilities of the SPFC play an important role in public safety and protection of property. This FCSSR is one of several ways whereby DWR is improving awareness of flood risk among people who live and work in areas protected by SPFC facilities.

Levees with the highest likelihood of failure do not necessarily present the greatest risks to society. The consequences that could occur if a levee fails are an important component of flood risk. Therefore, floods in urban areas typically pose the greatest risks because of the large number of people that could be harmed and the value of the properties that could be damaged. Areas with greater populations will generally also have greater economic consequences.

Regardless of how well flood facilities are designed, constructed, maintained, and operated, there is always a residual chance of failure. Improvements to existing flood facilities can reduce the probability of flooding, but not eliminate it.

Figures 3-1 and 3-2 show FEMA floodplains in the Sacramento River watershed and San Joaquin River watershed that have a 0.2 percent (or 1 in

500) chance or greater of flooding in any year (FEMA, 1996). Although larger areas can be inundated during more extreme floods, the maps show a good indication of areas that are vulnerable to floods.

Figure 3-1. FEMA Floodplains with Annual 0.2 Percent Chance of Flooding in Sacramento River Watershed

Figure 3-2. FEMA Floodplains with Annual 0.2 Percent Chance of Flooding in San Joaquin River Watershed

Levee stability concerns

Estimates of basin-wide flood economic damages in the Central Valley were developed and documented for the first time in the December 2002 *Sacramento and San Joaquin River Basins California Comprehensive Study Interim Report* (USACE and DWR). These damages included estimated losses to structures, their contents, agricultural crops, and several other damage categories. They were presented as expected annual damages which represents long-term average annual flood damage for a given area under all possible flood events. Recently, basin-wide flood damage estimates have been updated based on current physical conditions as part of the 2012 CVFPP and include potential losses to business. It is currently expected that annual flood damages in the Sacramento River basin will average over $300 million. In the San Joaquin River basin, annual flood damages are expected to average nearly $30 million. Life safety consequences are also being evaluated as part of the 2012 CVFPP. Estimates of flood risk will be periodically updated in future versions of the CVFPP.

3.2 Factors That Influence Flood Risk

Uses of SPFC facilities have changed since the first federal project authorization. Originally, flood management in the Sacramento River watershed was closely tied to management and transport of mining debris generated in upstream mountain and foothill areas. Channels were designed to flush out and move mining debris downstream to keep the channels open for navigation and to convey floodwater. While this legacy system has generally worked well to prevent flooding, it was never intended to serve the multiple purposes society has now, such as flood protection for rapidly developing floodplains; long-term sustainability; and the public trust purposes of natural resource preservation, water supply, and recreation.

Factors related to the physical condition of SPFC facilities are described in three broad categories: levee status factors, channel status factors, and flood control structure status factors.

3.2.1 Levee Status Factors

Levee problems are evaluated in the FCSSR according to the following status factors:

- **Inadequate Levee Geometry (Levee Geometry Check) –** Levee crest elevations that are too low, crest widths that are too narrow, and levee side slopes that are too steep can reduce levee stability and lead to failure.

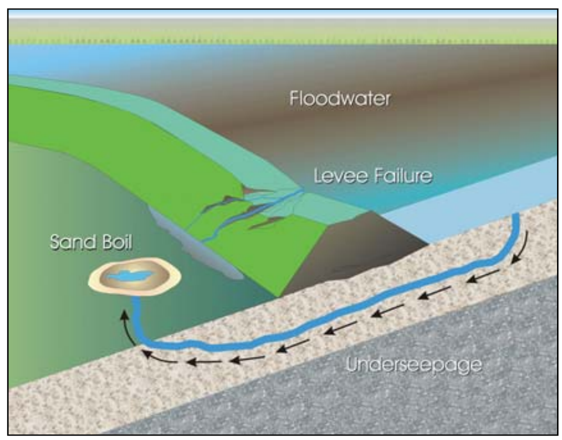
- **Seepage –** Seepage under a levee foundation or through a levee can reduce levee stability and lead to failure.

- **Structural Instability** – Slides, sloughs, slope depressions or bulges can reduce levee stability and lead to failure.

- **Erosion –** Levee and bank erosion can directly reduce levee cross sections and shorten seepage paths, leading to failure.

- **Settlement –** Levee settlement or land subsidence over years can result in levee crest elevations lower than designed, reducing freeboard or causing water to overtop a levee.

- **Penetrations –** Irrigation and drainage pipes, utilities, and other structures through levees may create seepage paths. Seepage along the penetrations, or through deteriorating penetrations, could wash away levee material and lead to failure. Lack of positive closure devices on pipes penetrating levees can also lead to localized flooding.



Levee under-seepage

- **Levee Vegetation** – Vegetation on levees can interfere with floodfighting efforts and maintenance by reducing visibility and accessibility. The extent that levee vegetation impacts levee integrity is the subject of ongoing research.

- **Rodent Damage** – Burrowing animals can create holes in levees that can create seepage paths and lead to levee failure.

- **Encroachments** – Encroachments (such as debris, fences, and structures) on SPFC facilities can interfere with floodfighting efforts and maintenance and, in some cases, reduce levee stability, which can lead to levee failure.

3.2.2 Channel Status Factors

Some SPFC channels may have insufficient capacities to safely convey design flood flows because of the following factors:

- **Inadequate Channel Conveyance Capacity –** Channels can have lower than designed flow capacity because of insufficient levee height or obstructions. Insufficient levee height can reduce the effective cross-sectional flow area. Similarly, obstructions such as bridges, sediment deposits, pilings, docks, marinas, and increased channel roughness from vegetation can also reduce the effective cross-sectional flow area and increase water levels, leading to levee overtopping.

- **Channel Vegetation –** Vegetation can decrease channel capacity, and vegetative debris can collect at bridges and other in-channel structures, restricting and redirecting flow and lead to levee overtopping.

- **Channel Sedimentation –** Deposits of sediment carried by floodwaters can reduce the cross-sectional areas of flood channels, leading to levee overtopping.

3.2.3 Flood Control Structure Status Factors

The SPFC relies on successful operation of the following flood control structures:

- **Hydraulic Structures –** Weirs, drainage structures, control structures, diversion structures, drop structures, outlet or outflow structures, and siphons/intakes must be maintained so that they serve their design purpose.

- **Pumping Plants –** Pumping plants must be maintained so that they serve their design purpose.

- **Bridges –** Bridges must be maintained so that they serve their design purpose and do not restrict flows through channels.

3.3 Risk of Levee Failure

As mentioned, the DWR Levee Evaluations Program is evaluating approximately 2,100 miles of SPFC levees and appurtenant non-SPFC levees in the Central Valley (approximately 1,520 miles of SPFC levees and 520 miles of appurtenant non-SPFC levees). The goals of the ULE and NULE projects are to determine whether levees meet defined geotechnical criteria and, where needed, to identify repair and improvement measures, including cost estimates, to meet desired geotechnical criteria. Therefore, the ULE and NULE projects assess hazards related to levee performance but do not provide a complete analysis of exposure or evaluate consequences of levee failure. The remaining elements of risk of levee failure for urban and nonurban levees, particularly levee performance curves and life safety and economic consequences, are being analyzed in the CVFPP.

As mentioned, levee performance for the ULE Project is evaluated as hazard classifications relative to established levee design criteria. For the NULE Project, levee performance is evaluated as hazard categories, which show potential for levee failure. This approach was selected because the extent of the NULE Project is considerably greater than that of the ULE Project, making it difficult to conduct the same level of field explorations and geotechnical data collection performed for the ULE levees.

The following subsections provide more detailed information on the methodologies used to assess levee conditions under the ULE and NULE projects, descriptions of the criteria that define hazard, and a summary of overall hazard of levee segments based on those criteria. This information is used in Section 4 to discuss levee conditions in more detail, based on individual status factors.

3.3.1 Urban Levee Evaluations – Methodology and Results

The ULE Project involves evaluation of approximately 350 miles of SPFC and 120 miles of appurtenant non-SPFC urban levees, protecting populations greater than 10,000. ULE non-SPFC levee data were not available while this FCSSR was being written. ULE SPFC levees included in the evaluations are shown in Figure 2-1.

ULE Approach

The overall strategy for DWR urban levee evaluations is impacted by two legislative and executive actions. New California Government Code sections added by Senate Bill 5 in 2007 require cities and counties within the Sacramento-San Joaquin Valley to provide, require, or demonstrate an urban level of flood protection for areas located within a FEMA floodplain that are urban or urbanizing before making certain land use decisions. An urban level of flood protection means the level of protection that is necessary to withstand flooding that has a 1 in 200 chance of occurring in any given year. In addition, the Governor's 2006 Emergency Order S-18-06 "fast-tracked" the ULE Project, with the goal of quickly identifying significant levee deficiencies that require repair.

ULE Project study areas are generally based on urban areas identified by Proposition 1E.[4] Proposition 1E defined an urban area as "any contiguous area in which more than 10,000 residents are protected by Project Levees." This means that a project levee failure could flood the residences of more than 10,000 people in a single area. Levees providing protection to areas meeting this definition of an existing urban area are considered urban levees under the ULE Project.

ULE Project evaluations are being implemented in five major steps:

1. **Historical Data Collection –** Available levee data are collected, and State, USACE, and local experts are interviewed. Geomorphology studies are also conducted. For each study area, results are documented in a Technical Review Memorandum, which generally assesses known conditions and potential conditions suggested by available data, as well as levee performance during past flood events. Based on results of the historical data collection, Steps 2 and 3 may not be performed in study areas that have already undergone significant investigation by USACE and/or local stakeholders; in this case, screening efforts proceed to Steps 4 and 5.

2. **Initial Field Investigation –** Initial field exploration (limited to the levee crown) and laboratory testing programs are conducted and documented in a Phase 1 Geotechnical Data Report.

3. **Preliminary Analysis –** Each ULE study area is then broken into separate segments based on similar geologic and geotechnical conditions identified in the Technical Review Memorandums and Phase 1 Geotechnical Data Reports; preliminary geotechnical analyses of seepage and stability are conducted; and areas for supplemental evaluation are identified based on those analyses.

4. **Supplemental Investigation –** Based on the results of analyses performed during Step 3, and particularly its correlation with past performance, a supplemental field and laboratory exploration program

[4] The definition of urban area in Proposition 1E differs from the definition provided in new California Government Code sections added by Senate Bill 5 in 2007. California Government Code Section 65007 defines an urban area as a "developed area in the Sacramento-San Joaquin Valley in which there are 10,000 residents or more." Therefore, ULE Project study areas may include a mix of urban and nonurban areas, as defined by California Government Code Section 65007, because some urban levees protect adjacent nonurban areas. Furthermore, some urbanizing areas protected by levees are being evaluated under the NULE Project. An urbanizing area is defined in California Government Code Section 65007 as a "developed area or an area outside a developed area in the Sacramento-San Joaquin Valley that is planned or anticipated to have 10,000 residents or more within the next 10 years. For more information, also see California Government Code Sections 65007, 65302.9, 65860.1, 65865.5, 65962, and 66474.5.

is developed and implemented to address any significant data gaps. This work is documented in a Supplemental Geotechnical Data Report.

5. **Final Screening** – Additional analyses are conducted to evaluate levee conditions based on available data. As necessary, conceptual remediation and corresponding costs are identified on a segment-by-segment basis for each study area. Analyses and conceptual remediation are documented in a Geotechnical Evaluation Report.

During the preliminary analysis phase and the final screening phase, analyses are conducted to assess the performance of each ULE levee segment against performance criteria for the following four failure modes:

- Freeboard
- Levee geometry
- Steady state seepage (reported as seepage)
- Steady state stability (reported as structural instability)

The performance criteria for categories used in these assessments are based on the USACE *Design and Construction of Levees Engineering Manual* (EM) *1110-2-1913* (2000) and the DWR *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley, Version 4* (2010d). Although freeboard is not technically a failure mode, it is a performance criterion identified in the above documents and, therefore, the ULE approach considers freeboard in assessing overall hazard classifications.

Based on these analyses, each ULE levee segment is assigned one of the following hazard classifications for each potential failure mode:

- **Meets Criteria (M) –** Levees in this classification meet or exceed criteria.
- **Marginal (MG)[5] –** Levees in this classification are marginal in meeting criteria.

[5] The Hazard Classification of MG (marginal) is assigned when results are sufficiently close to established design criteria that, considering the rating is based on preliminary data that are subject to change as analyses are completed, it is not possible to determine with confidence whether the result would be M or DNM if more detailed data were available. Thus, a levee segment that receives a Hazard Classification of MG is not necessarily more vulnerable to failure during a flood event, but is more likely to need additional evaluation or repair than a levee segment rated as Hazard Classification M.

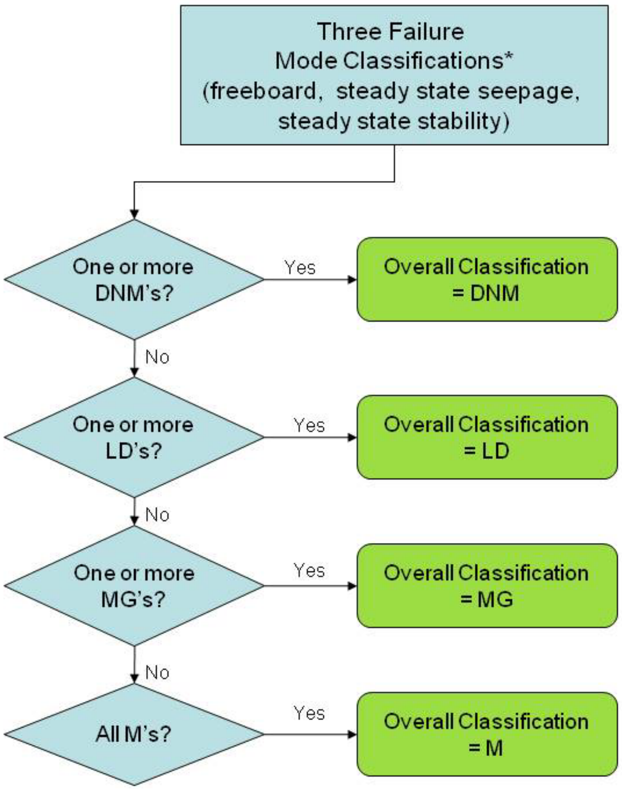
- **Does Not Meet Criteria (DNM) –** Levees in this classification do not meet criteria. These levees require the most immediate attention for repair or replacement.

- **Lacking Sufficient Data (LD) –** Levees in this classification lack sufficient data to be placed into one of the above three classifications.

Results from the ULE Project are being developed in two phases. The first phase presents preliminary criteria-based results for freeboard, levee geometry, seepage, and stability for the 1955 and 1957 design water surfaces (as presented in this FCSSR) (USACE, 1955b; USACE, 1957a; 1957b). By December 2012, the second phase will present criteria-based results for the 200-year surface water profile and final results for the 1955 and 1957 design water surfaces.

ULE hazard classifications for levee geometry, seepage, and stability are discussed in detail in Section 4. ULE freeboard classifications are described in Appendix A, Section A-2.

An overall classification was assigned to each ULE levee segment based on the collective performance for freeboard, steady state seepage, and steady state stability, as shown in Figure 3-3. For example, each ULE levee segment was assigned a hazard classification for each of the failure modes. If any of the hazard classifications is DNM (does not meet criteria), then the overall hazard classification is DNM. If any of the hazard classifications is LD (lacking sufficient data), then the overall hazard classification is LD. If all of the hazard classifications are M (meets criteria), then the overall hazard classification is M. One or more MGs result in an overall hazard classification of MG. Levee geometry classification was not included in the overall classification because the ULE geometry check was performed as a first step in an evaluation of erosion hazard that is not yet complete. ULE classifications do not reflect recent levee improvements for which geotechnical data are not available or have not been provided. When new geotechnical data become available, the data will be incorporated into future updates to this FCSSR.



Note:
* Levee geometry classification was not included in the overall classification because the ULE geometry check was performed as a first step in an evaluation of erosion hazards that is not yet complete.
Key:
DNM = Does Not Meet Criteria
LD = Lacking Sufficient Data
M = Meets Criteria
MG = Marginal

Figure 3-3. ULE Overall Levee Segment Hazard Classification Decision Tree

Levee geometry, rodent damage, penetrations, settlement, encroachments, and levee vegetation data were not considered in the assignment of ULE overall hazard classifications.

The following section describes the overall hazard classifications for various levee segments in the ULE study areas.

Summary of Overall Hazard Classification

The preliminary analysis phase is significantly complete, and hazard classifications have been assigned to ULE levee segments, segregated into the following 14 study areas (north to south):

- Sutter
- Marysville

- Reclamation District 784
- Woodland
- Davis
- Natomas
- Natomas East Main Drainage Canal
- West Sacramento
- American River
- Sacramento River (east levee Sacramento River from American River to Freeport)
- Bear Creek (San Joaquin County)
- Calaveras River
- Reclamation District 404
- Reclamation District 17

Geotechnical Evaluation Reports will be prepared for all 14 study areas. Table 3-1 summarizes overall hazard classifications for 297 miles of ULE SPFC levees. Evaluations of approximately 50 miles of ULE SPFC levees are still underway as this FCSSR is being prepared. As described above, ULE non-SPFC levee data were not available for inclusion in this FCSSR.

Table 3-1. Summary of ULE Overall Hazard Classification

	Overall Hazard Classification				Total
	Meets Criteria (M)	Marginal (MG)	Does Not Meet Criteria (DNM)	Lacking Sufficient Data (LD)	
ULE Levees in Sacramento River and San Joaquin River Watersheds					
ULE SPFC Levee Miles Evaluated	130	9	151	7	297
Percentage of ULE SPFC Levees Evaluated	44%	3%	51%	2%	100%

Key:
SPFC = State Plan of Flood Control
ULE = Urban Levee Evaluations

Overall, almost half of ULE SPFC levees meet criteria (Hazard Classification M) at the design water surface elevation. In some urban areas, substantial segments of levees meet criteria, but also have substantial segments of levees that do not meet criteria (Hazard Classification DNM). For example, portions of the urban levees surrounding the Natomas area of

Sacramento have been recently improved to meet criteria. Other portions of the Natomas urban levees are planned for improvement but currently do not meet criteria. Approximately half of ULE SPFC levees do not meet criteria at the design water surface elevation. These levees require the most immediate attention for repair or replacement. Levees in Yuba City, Marysville, Davis/Woodland, and Lathrop mostly do not meet criteria. Although the evaluation did not take into account improvements for the Marysville ring levee that are currently under construction, once these improvements are complete and data are available, results will be incorporated into future updates to this FCSSR.

Overall hazard classifications of SPFC ULE levee segments in the Sacramento River and San Joaquin river watersheds are shown in Figure 3-4.

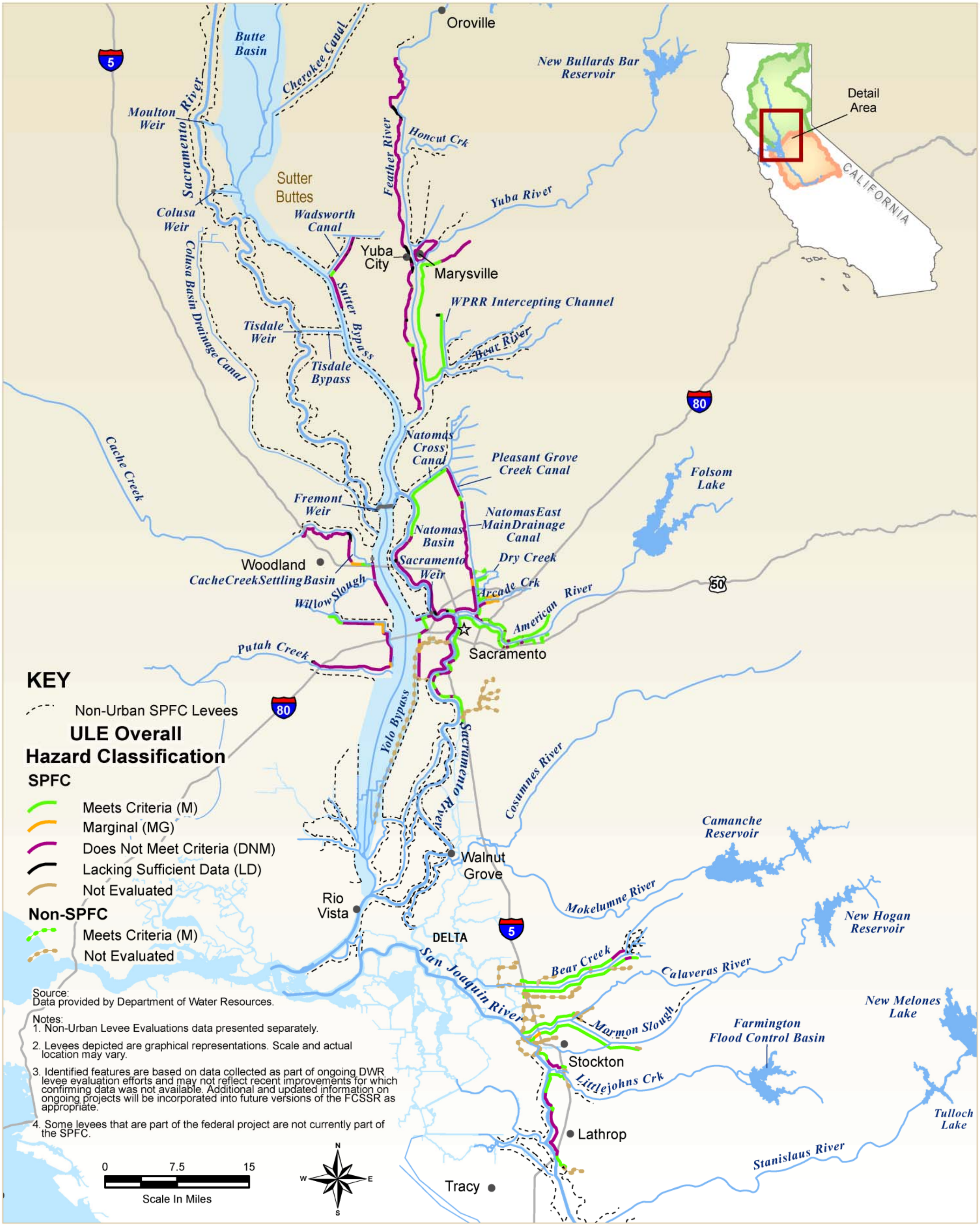


Figure 3-4. ULE Overall Hazard Classifications in Sacramento and San Joaquin River Watersheds

3.3.2 Non-Urban Levee Evaluations – Methodology and Results

The NULE Project encompasses approximately 1,230 miles of SPFC nonurban levees and 300 miles of appurtenant non-SPFC nonurban levees. Nonurban SPFC and non-SPFC levees included in the evaluations are shown in Figure 2-1.

NULE Approach

Levees within the NULE Project are being evaluated using a two-phase approach. Phase 1 consisted of nonintrusive studies for SPFC and appurtenant non-SPFC nonurban levees using readily available data supported by surface geomorphology studies. The NULE levees were evaluated on systematic, consistent, repeatable analysis that correlated geotechnical data with levee performance history, and not relative to any design criteria. Phase 2 consisted of supplemental studies, which were performed for selected nonurban levees, and involve field investigations combined with more detailed geotechnical analyses. To facilitate evaluation, NULE levees were divided into segments along reclamation district, levee district, and maintenance area boundaries; key physical features (e.g., bypasses, tributaries); and channel sides (i.e., left bank/right bank). NULE Phase 1 included evaluating the following different types of data:

- Existing subsurface information
- Historical performance
- Historical records from National Archives in San Bruno, California, and selected local sources such as university libraries
- Records available at State agencies and data contained in the California Levee Database
- Data (including interviews) obtained from maintaining agencies and other local levee agencies
- Geologic and geomorphic conditions (including existing Quaternary geologic mapping)
- Surface mapping
- Vintage aerial photography (stereo-paired imagery collected in 1937)
- Vintage topographic maps (1907 – 1915)

- LiDAR topographic surveys
- Assessment water surface elevations (where available, 1955/1957 design water surface profiles were used for Phase 1 assessments)
- Animal burrow persistence data
- Levee penetrations logs
- Maintenance ratings

These data are managed by DWR in a project-specific electronic database to systematically catalog project data and provide quick and efficient data access during levee hazard assessments. The data are used to develop levee construction and performance history, evaluate levee geometry and other features potentially impacting geotechnical performance, evaluate levees and levee foundation composition and associated conditions, and assess geotechnical levee hazard indicators.

To facilitate a consistent assessment approach, the NULE Project developed a Levee Assessment Tool. The Levee Assessment Tool is a systematic, repeatable process for assessing levee hazard indicators and past levee performance. Details of Levee Assessment Tool development and implementation are provided in the technical memorandum, *Levee Assessment Tool* (URS, 2010). The assessment teams used geometric, geologic, and historical performance data from GIS to select a cross section for analysis within each NULE levee segment. The Levee Assessment Tool was used at this cross section to assess the entire segment. Each NULE levee segment was evaluated at the assessment water surface elevation. Where available, the 1955/57 design water surface elevations, as defined by the 1953 *Memorandum of Understanding* (USACE and Board, 1953), were used as the assessment water surface elevation. In the absence of 1955/57 design water surface elevations, the assessment water surface elevation was based on freeboard requirements for each levee segment (i.e., generally 3 feet below the levee crest).

In addition to the geotechnical hazard assessments, other assessments were performed based on levee geometry and water surface elevation. These included a freeboard check and a geometry check comparison to the levee design prism. Collected data also were reviewed to identify occurrences of levee overtopping.

Four geotechnical failure modes were evaluated by NULE. (Note that the NULE geotechnical failure modes differ from the four failure modes evaluated by ULE, because of different methodology.) NULE geotechnical failure modes include the following:

- Under-seepage
- Through-seepage
- Slope stability (reported as structural instability)
- Erosion

Based on Phase 1 evaluations, each levee segment was assigned to one of the following hazard categories for each geotechnical failure mode:

- **Low –** When water reaches the assessment water surface elevation, there is a relatively low potential for levee failure or the need to floodfight to prevent levee failure.

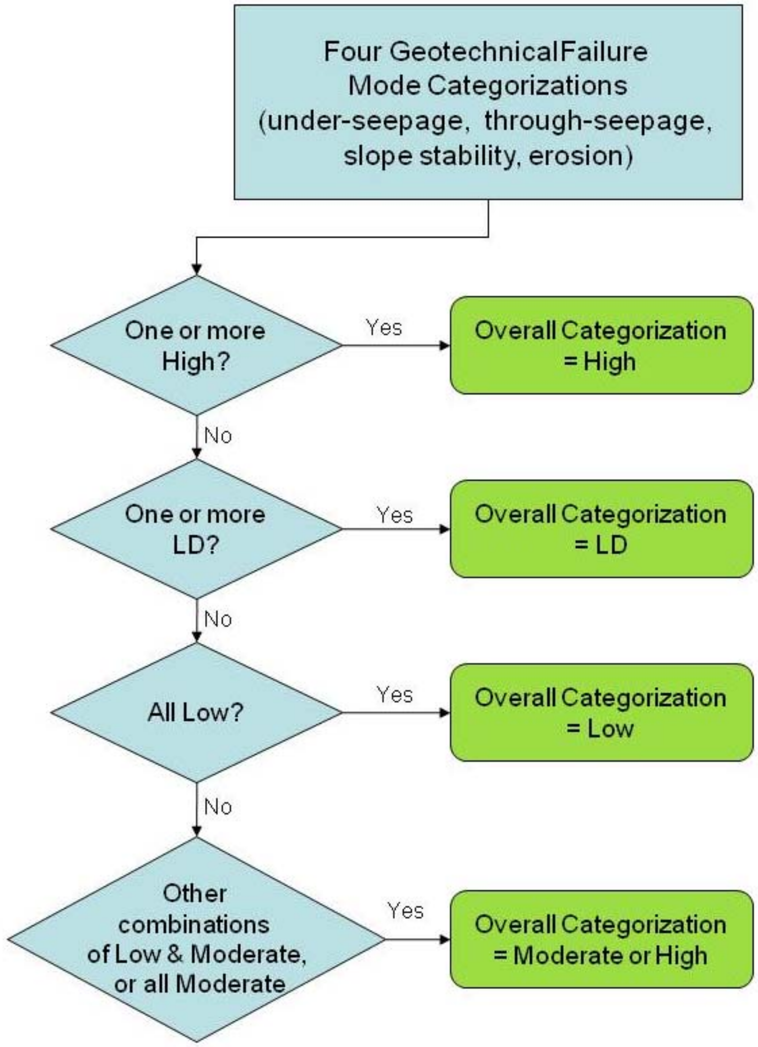
- **Moderate –** When water reaches the assessment water surface elevation, there is a relatively moderate potential for levee failure or the need to floodfight to prevent levee failure.

- **High –** When water reaches the assessment water surface elevation, there is a relatively high potential for levee failure or the need to floodfight to prevent levee failure. **These levees are in the most danger of failure**.

- **Lacking Sufficient Data –** Sufficient data are currently lacking regarding past performance or hazard indicators.

The category "Lacking Sufficient Data" indicates that the available data do not resolve potential discrepancies between expected performance of a levee and actual performance, or that the existing data are contradictory or ambiguous. The category does not indicate that insufficient data were available to assess the NULE levee segment. Where assessment data were not available, the NULE levee segment was not assessed.

An overall hazard category was assigned to each NULE levee segment, considering the collective performance for the geotechnical failure modes, including under-seepage, through-seepage, slope stability, and erosion, as shown in Figure 3-5. The decision tree acknowledges that there may be levee segments with a combination of moderate or low hazards that may cumulatively represent a high overall hazard categorization.



Key:
LD = Lacking Sufficient Data

Figure 3-5. NULE Overall Levee Segment Hazard Categorization Decision Tree

Penetrations and rodent damage data included in this FCSSR were considered in the assignment of through-seepage hazard categorization. Levee geometry check, settlement, encroachment, and levee vegetation data were not considered in the assignment of NULE overall hazard categorization because the NULE Project focused on geotechnical evaluations.

Summary of Overall Hazard Categorization

Table 3-2 summarizes NULE overall hazard categorizations for SPFC levees and non-SPFC levees. The total number of NULE levee miles assigned to each NULE hazard category (Low, Moderate, High, and Lacking Sufficient Data) are summarized for the North (Sacramento River watershed) NULE and South (San Joaquin River watershed) NULE study areas, and both study areas combined, as described below.

The *Geotechnical Assessment Report, North NULE Study Area* (DWR, 2011a), documents study methodology and results for NULE levees in the Sacramento River watershed. The overall hazard categorizations for SPFC and non-SPFC levees in the North NULE Study Area are shown in Figure 3-6. The *Geotechnical Assessment Report, South NULE Study Area* (DWR, 2011b), documents study methodology and results for NULE levees in the San Joaquin River watershed. The overall hazard categorizations for SPFC and non-SPFC levees in the South NULE Study Area are shown in Figure 3-7.

Table 3-2. Summary of NULE Overall Hazard Categorization

NULE Study Area	Overall Hazard Categorization				Total
	Low	Moderate	High	Lacking Sufficient Data	
North NULE Study Area (Sacramento River Watershed)					
North NULE SPFC Levee Miles Evaluated	30	287	428	89	834
Percentage of North NULE SPFC Levees Evaluated	4%	34%	51%	11%	100%
North NULE Non-SPFC Levee Miles Evaluated	14	32	27	21	94
Percentage of North NULE Non-SPFC Levees Evaluated	15%	34%	28%	23%	100%
South NULE Study Area (San Joaquin River Watershed)					
South NULE SPFC Levee Miles Evaluated	39	65	291	3	398
Percentage of South NULE SPFC Levees Evaluated	10%	16%	73%	1%	100%
South NULE Non-SPFC Levee Miles Evaluated	6	15	120	69	210
Percentage of South NULE Non-SPFC Levees Evaluated	3%	7%	57%	33%	100%
Combined North and South NULE Study Areas					
NULE SPFC Levee Miles Evaluated	69	352	719	92	1,232[1]
Percentage of NULE SPFC Levees Evaluated	6%	29%	58%	7%	100%
NULE Non-SPFC Levee Miles Evaluated	20	47	147	90	304
Percentage of NULE Non-SPFC Levees Evaluated	7%	15%	48%	30%	100%

Note:
[1] Rounds down to 1,200 miles.
Key:
NULE = Non-Urban Levee Evaluations
SPFC = State Plan of Flood Control

Overall, approximately three-fifths of NULE SPFC levees have a High hazard category at the assessment water surface elevation. Only about one-sixteenth of the NULE SPFC levees have a Low hazard category. In the Sacramento River watershed, NULE SPFC levees categorized as Low are primarily along tributaries; none of the NULE SPFC levees along the Sacramento River are categorized as Low. In the San Joaquin River watershed, NULE levees categorized as Low are primarily along tributaries, with some short segments along the San Joaquin River.

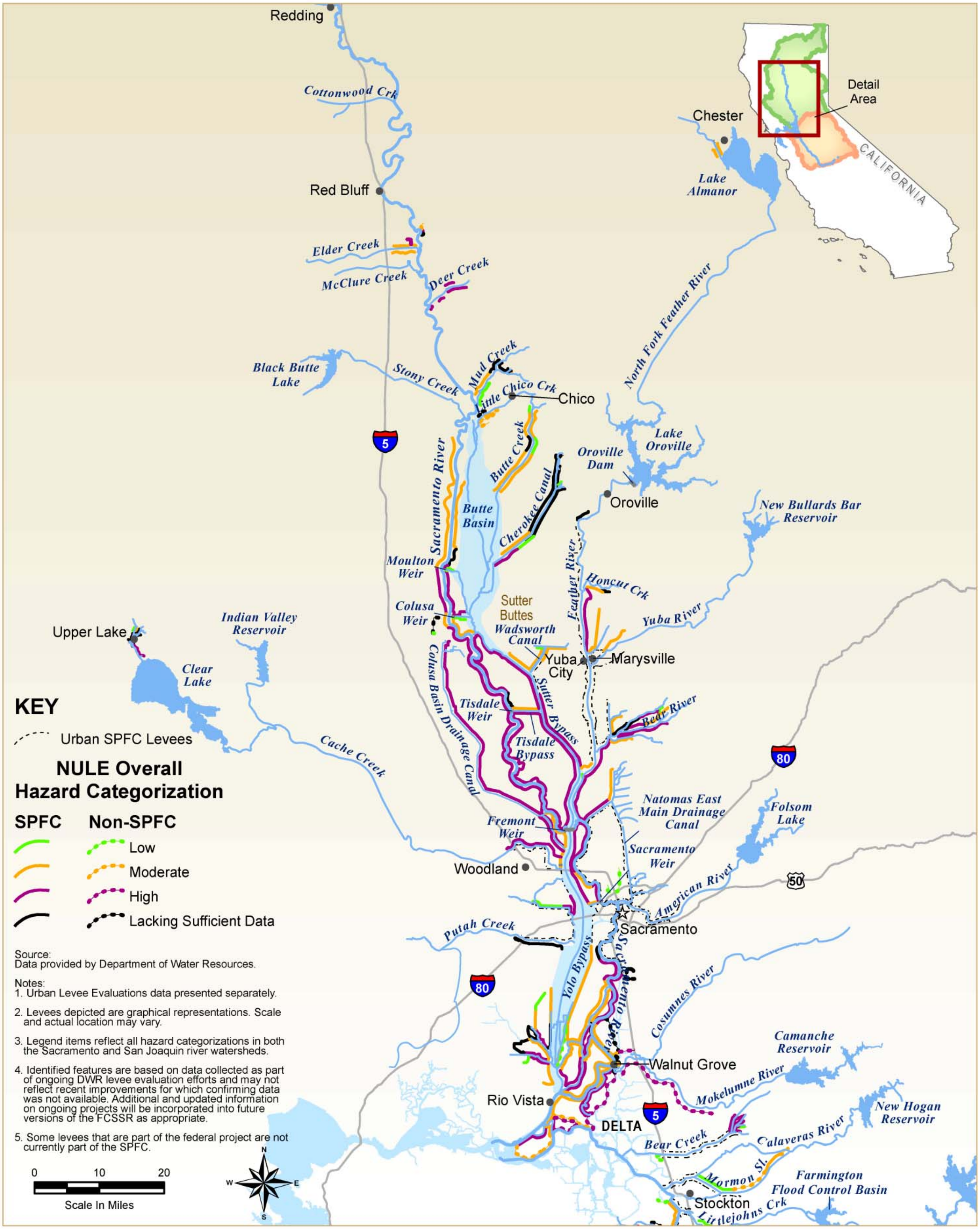


Figure 3-6. North NULE Overall Hazard Categorizations in Sacramento River Watershed

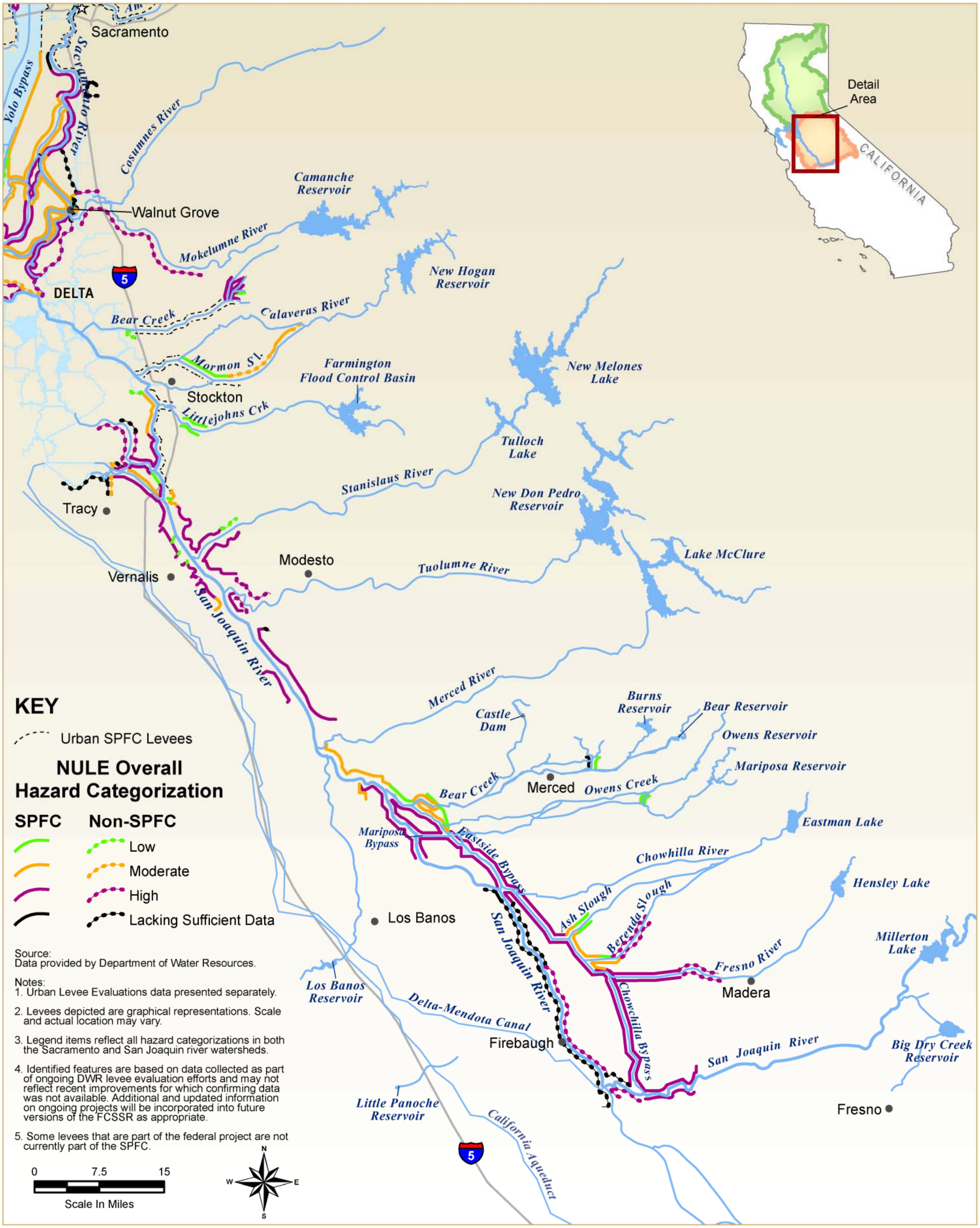


Figure 3-7. South NULE Overall Hazard Categorizations in San Joaquin River Watershed

3.3.3 Urban and Non-Urban Levee Evaluations Methodology Summary

Figure 3-8 summarizes the process for developing the ULE overall hazard classification and NULE overall hazard categorization for ULE and NULE levees, respectively.

ULE levee segments were evaluated for four failure modes (freeboard, levee geometry, steady state seepage, steady state stability) based on DWR and USACE design criteria. Results from three of the four failure modes (freeboard, steady state seepage, and steady state stability) were considered in assigning a ULE overall hazard classification using the ULE Overall Levee Segment Hazard Classification Decision Tree (see Figure 3-3). For the NULE Project, NULE levee segments were evaluated for four geotechnical failure modes (under-seepage, through-seepage, slope stability, and erosion) based on the potential for levee failure at the assessment water surface elevation. The results from all four geotechnical failure modes were considered in assigning NULE overall hazard categorization using the NULE Overall Levee Segment Hazard Categorization Decision Tree (see Figure 3-5).

As mentioned, levee geometry was considered in the ULE overall hazard classifications as a proxy for assessing the erosion failure mode because the ULE erosion analyses have not yet been completed and the collected geometry data represents the initial step in that analysis. Freeboard was considered in the ULE overall hazard classifications, but not in the NULE overall hazard categorizations because the ULE approach compared collected data against current design criteria, which included freeboard criteria. The NULE approach, however, was based on a qualitative assessment of the potential for levee failure.

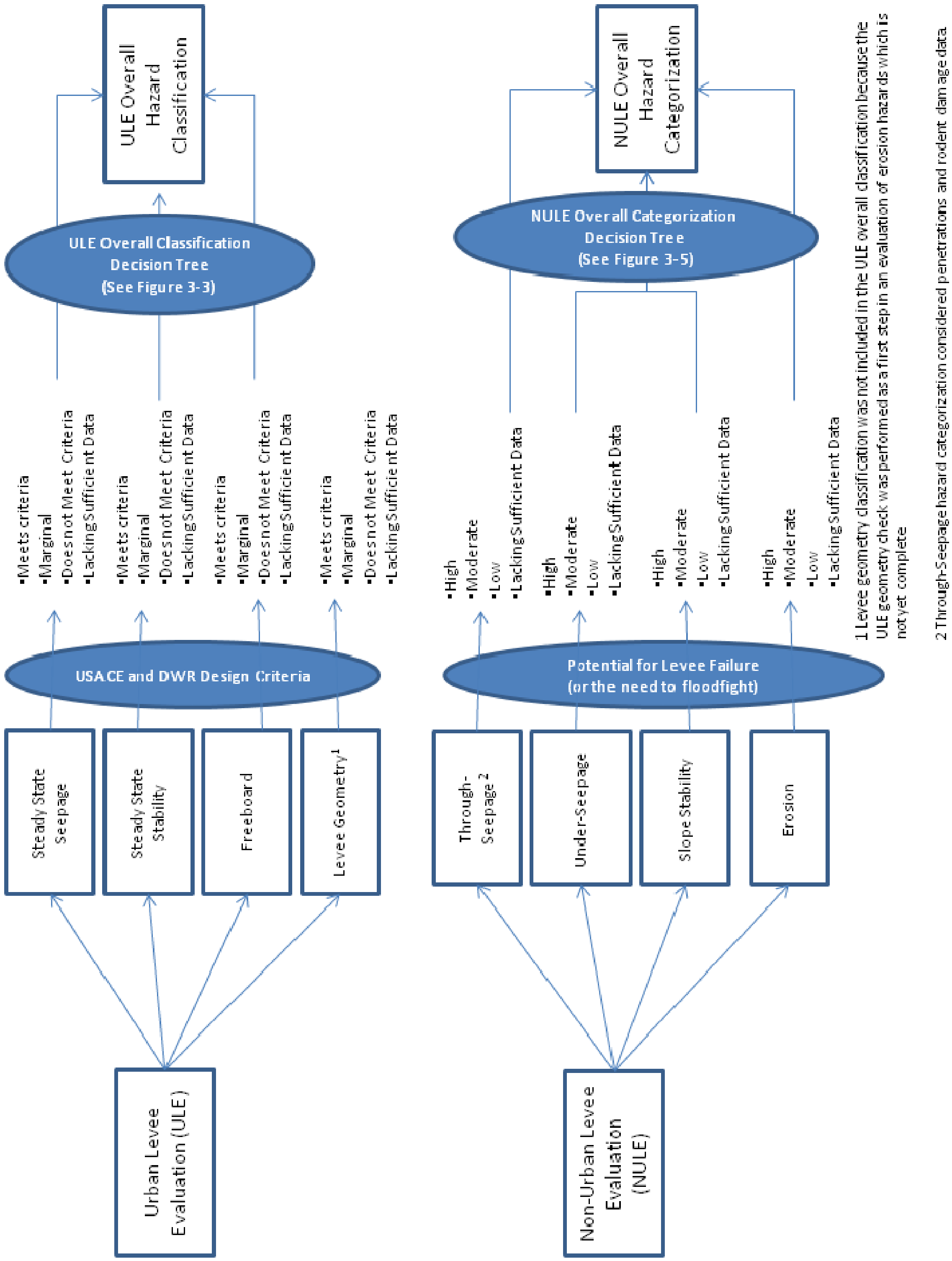


Figure 3-8. Process for ULE Overall Hazard Classifications and NULE Overall Hazard Categorizations

4.0 Levee Status

SPFC levees have provided tremendous benefits to public safety and protection of property in the Central Valley since facilities were originally constructed. However, the current physical condition of SPFC levees has been adversely affected by the following: pervious sandy and gravelly layers in levees or levee foundations, early twentieth-century construction practices, lack of modern design criteria at time of design, levee alignments that exacerbate erosion, facility obsolescence, deferred maintenance, and other items unrelated to flood management, such as groundwater extraction and land use.

Many levees were constructed by local interests before federal and State authorization of the flood control projects, using material dredged from adjacent rivers. These materials, which may be soft or contain coarse, permeable sediments subject to underseepage, were then placed on untreated ground in the late nineteenth and early twentieth centuries. Subsequently, some of these levees were improved while others remained as constructed by local interests, when adopted into the federal flood control project and SPFC in the mid-twentieth century.

Even with regular maintenance, and capital improvement projects that have been implemented through the late twentieth century and early twenty-first century, the foundations and core of many levees (some more than 100 years old) are of unknown integrity. Thousands of penetrations have been installed under and through levees over the years, many of which remain unpermitted and potentially threatening to levee integrity. Also, groundwater extraction and some land use practices have caused land subsidence that adversely affects levee foundations and crown elevations. In addition, insufficient SPFC property rights and easements for flood management adversely affect maintenance in some locations. Finally, funding limitations have placed further strain on SPFC levees by causing some maintenance to be deferred.

After the 1986 flood in the Central Valley, the USACE Sacramento District was authorized to conduct a comprehensive analysis of the long-term integrity of the Sacramento River Flood Control Project in partnership with the Board; this analysis was called the *Sacramento River Flood Control System Evaluation* (USACE, 1988; USACE, 1990; USACE, 1991; USACE, 1993; USACE, 1995). The USACE Sacramento District determined that some reaches of levee had structural problems which, if not remediated, would put thousands of people in the Central Valley at risk who rely on levees for their safety and protection of their property from floods. Key results of the *Sacramento River Flood Control System Evaluation* analysis were as follows:

- High flood flows in 1986 severely stressed levees to the point that a levee failure in Linda (and several other near failures) occurred, demonstrating that the SPFC facilities could not be assumed to be as reliable as previously thought.

- Investigations found that several reaches of levee had geotechnical problems, mostly relating to stability, seepage, and piping potential (described in Section 4.2). These conditions stemmed from the time of construction and were present when the facilities were turned over by USACE to the Board for O&M. Remedial levee reconstructions and improvements are required for the SPFC to function at its original intended design level.

- Levee maintenance evaluations found that while there were some minor instances of poor maintenance, inadequate maintenance was not the primary cause of structural problems with the levees.

Since this analysis, the USACE Sacramento District and the Board have reconstructed selected levee segments protecting urban and rural areas in locations where estimated benefits exceeded the estimated reconstruction costs, as summarized in Table 4-1. Capital improvement projects and extraordinary O&M have also been conducted by maintaining agencies.

Table 4-1. Approximate Length of Levees Reconstructed After Sacramento River Flood Control System Evaluation

Study Area	Approximate Total Length of Levees Reconstructed
Sacramento Urban Area	32 miles
Marysville/Yuba City Area	26.4 miles
Mid-Valley Area	18.3 miles
Lower Sacramento River Area	0.4 miles
Upper Sacramento River Area	3.8 miles
Total	**80.9 miles**

Flood events in 1995 and 1997 reemphasized that the levee system needed additional levee reconstructions and improvements to achieve the desired level of flood protection. As a result of poor performance with respect to levee under-seepage during the 1997 flood, the USACE Sacramento District convened a panel of experts that recommended modifications to

USACE levee under-seepage evaluations and design. The USACE Sacramento District adopted most of the panel's recommendations, and issued new guidance in *Engineering Technical Letter 1110-2-569 Design Guidance for Underseepage* (2005) and the *Geotechnical Levee Practice Standard Operating Procedures for the USACE Sacramento District* (2008).

Per the new guidance, it became evident that a new USACE system evaluation was needed to evaluate levee under-seepage according to new USACE criteria. As discussed in Section 3.3, DWR has been conducting levee evaluations of levee under-seepage (and other failure modes) against current criteria in coordination with USACE and other partner agencies since 2007 for the ULE Project. These efforts are building on the findings of previous analyses by USACE, have advanced additional levee improvement projects in several areas, and are supporting development of the CVFPP.

This section describes current SPFC levee conditions using a combination of data from the DWR Levee Evaluations Program, DWR inspection data, and a DWR animal burrowing persistence study (DWR, 2009b). As part of the systemwide analysis, information on appurtenant non-SPFC levees is also included in data provided by the NULE Project. Table 4-2 lists levee status factors considered for the FCSSR, data used, and location of the data in the FCSSR. In addition to the ULE and NULE hazard assessments described in Sections 3 and 4, the ULE and NULE projects collected and cataloged historical seepage, erosion, structural instability and settlement occurrences in a GIS database; much of this information is located in Appendix A. For example, ULE/NULE hazard assessment data for seepage is included in Section 4.2, and historical seepage occurrences and annual inspection results for seepage are included in Appendix A, Section A-3.

Table 4-2. Levee Status Factors Data Summary

Levee Status Factor	Data in FCSSR	Location of Data in FCSSR	Considered in ULE Overall Hazard Classification (Section 3)	Considered in NULE Overall Hazard Categorization (Section 3)
Levee Geometry Check • Levee Geometry Check • Freeboard	ULE/NULE Geometry Check	Section 4.1	No	No
	ULE/NULE Freeboard Check	Appendix A, Section A-2	Yes	No
Seepage[1]	ULE/NULE Hazard Assessments	Section 4.2	Yes	Yes
	ULE/NULE Historical Seepage Occurrences	Appendix A, Section A-3	Yes	Yes
	DWR Annual Inspections	Appendix A, Section A-3	No	No
Structural Instability	ULE/NULE Hazard Assessments	Section 4.3	Yes	Yes
	ULE/NULE Historical Levee Slope Instability Occurrences	Appendix A, Section A-4	Yes	Yes
	DWR Annual Inspections	Appendix A, Section A-4	No	No
Erosion	NULE Hazard Assessment	Section 4.4	No	Yes
	ULE/NULE Historical Erosion Occurrences	Appendix A, Section A-5	No	Yes
	DWR Annual Inspections	Appendix A, Section A-5	No	No
Settlement	DWR Annual Inspections	Section 4.5	No	No
	ULE/NULE Historical Sinkhole and Subsidence Occurrences	Appendix A, Section A-6	No	No
Penetrations	ULE/NULE Levee Penetration Locations	Section 4.6	No	Yes
Levee Vegetation	DWR Annual Inspections	Section 4.7	No	No
Rodent Damage	Animal Burrowing Persistence Study	Section 4.8	No	Yes
	DWR Annual Inspections	Appendix A, Section A-9	No	No
Encroachments	DWR Annual Inspections	Section 4.9	No	No

Note:
[1] NULE hazard assessment includes under-seepage and through-seepage. ULE hazard assessment includes a steady state seepage analysis of both under-seepage and through-seepage.
Key:
DWR = California Department of Water Resources
FCSSR = Flood Control System Status Report
NULE = Non-Urban Levee Evaluations
ULE = Urban Levee Evaluations

Levee status factors considered in assignment of ULE overall hazard classifications included freeboard, seepage, and slope stability. Levee status factors considered in assignment of NULE overall hazard categorizations included seepage (both under-seepage and through-seepage), slope stability, and erosion. The ULE and NULE projects evaluated other factors, as described, but overall classifications and categorizations were based on evaluation of these factors.

Supporting information related to levee status is included in Appendix A, Section A-1, that encompasses multiple levee status factors:

- Historical levee breach and overtopping locations, to show where levees have failed in the past because of any combination of factors.
- Local projects under DWR's Early Implementation Program and USACE/Board projects locations, to show current projects in planning, design, or implementation phases. Early Implementation Program projects are projects that are proceeding in advance of the CVFPP. USACE/Board projects are projects underway that the Board participates in and cost-shares with USACE that reconstruct or improve SPFC facilities in the Sacramento and San Joaquin river watersheds.
- Description of other modifications to SPFC facilities for which the State has not provided nonfederal assurances of cooperation to the federal government, or that are not yet authorized by the Board for acceptance into the SPFC.

4.1 Levee Geometry Check

Although physical processes such as erosion may alter levee geometry, many SPFC levees do not comply with current minimum geometry criteria because levee geometry criteria used at the time of construction varied. Before congressional authorization of flood control projects in the Central Valley, levees were constructed to variable geometry criteria by local interests. After congressional authorization, USACE improved levee geometry in some locations before turning flood control projects over to the Board for O&M. Minimum levee geometry criteria have previously been specified by various USACE and State guidance documents, such as USACE *Design and Construction of Levees Engineering Manual 1110-2-1913* (2000), Title 23. Waters Division 1. Central Valley Flood Protection Board California Code of Regulations, 1953 *Memorandum of Understanding Respecting the Sacramento River Flood Control Project* (USACE and Board, 1953) and USACE Sacramento District *Geotechnical Levee Practice Standard Operating Procedures REFP10L0* (2008).

Not all existing SPFC levees have been constructed or improved to levee geometry design criteria as specified in USACE and State guidance documents. For example, the 1953 Memorandum of Understanding Respecting the Sacramento River Flood Control Project (only applicable for Sacramento River Flood Control Project improvements authorized by the Flood Control Acts of 1917, 1928, 1937, and 1941 – also known as the "Old Project") lists 55.6 miles of levees that were exempted from meeting levee geometry design criteria. In addition, the *1953 Memorandum of Understanding* acknowledged that the levee design criteria were not fully implemented for the "Major and Minor Tributary Project" Sacramento River Flood Control Project improvements authorized by the Flood Control Acts of 1944 and 1950. The *Standard O&M Manuals* for both the Sacramento River Flood Control Project and Lower San Joaquin River and Tributaries Project state that "some bypass levees and some river levees do not have the standard slopes or crown widths" (USACE, 1955a; USACE, 1959). Updates or exceptions to minimum levee geometry criteria are noted in as-constructed drawings attached to unit-specific O&M manuals, where available.

Furthermore, after levee construction, repeated occurrences of erosion, settlement (both localized settlement and regional settlement from the consolidation of underlying strata), and seepage have contributed, and continue to contribute, to changes in levee geometry that cannot be addressed by routine levee maintenance activities.

The DWR *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley Version 4* (2010d) includes criteria for urban levee geometry. The Board is also currently updating levee geometry criteria.

4.1.1 Status Evaluation Methodology

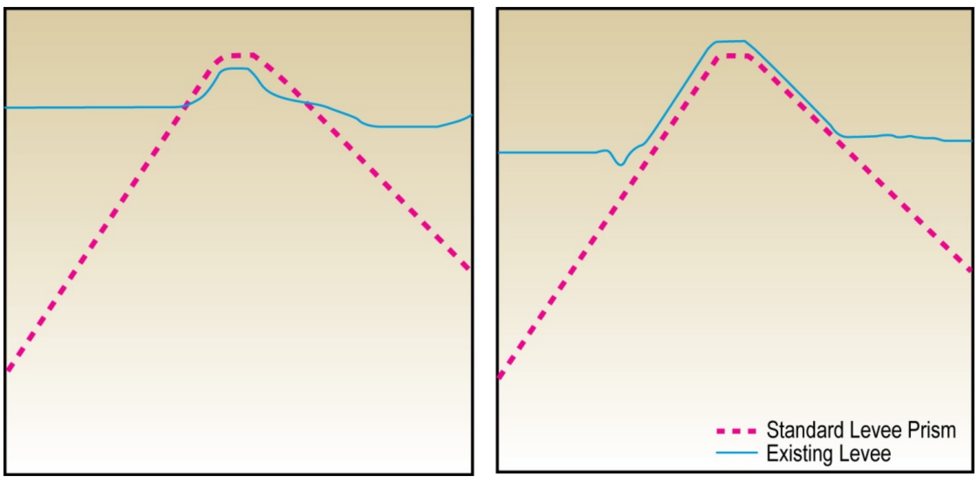
The DWR Levee Evaluations Program conducted a levee geometry check of ULE and NULE levees that compared existing levee geometry at regular cross-section intervals with a standard levee design prism.

The standard levee design prism for the Sacramento River is based on the *1953 Memorandum of Understanding* levee design criteria (USACE and Board, 1953). Unit-specific levee design geometry (levees exempted from the *1953 Memorandum of Understanding* or constructed after 1951) was not accounted for as part of the evaluation. The standard levee design prism for the San Joaquin River is based on available design data, or a standard prism with a 12-foot-wide crown, and waterside and landside slopes of 3H:1V and 2H:1V, respectively, when design data were unavailable.

The standard levee design prism was plotted using GIS; the GIS plot was then overlain on levee topography derived from LiDAR survey data.

The check was performed at a cross section spacing of 500-foot intervals and 100-foot intervals for the Sacramento and San Joaquin river watersheds, respectively. LiDAR survey data were collected for ULE and NULE levees in 2007.

Figure 4-1 demonstrates a levee cross section that deviates from the standard design prism and a levee cross section that conforms to the standard levee design prism.



Levee Cross Section That Deviates from Standard Levee Design Prism | **Levee Cross Section That Conforms to Standard Levee Design Prism**

Figure 4-1. Levee Cross Section Geometry Check Illustrations

Urban Levee Evaluations Project

As mentioned, levee performance for the ULE project was evaluated against hazard classifications relative to established levee design criteria. For the ULE Project, ULE levee segments were evaluated to determine if cross sections met the standard levee design prism geometry criteria, and are presented in the following hazard classifications:

- Meets Criteria (M)
- Marginal (MG)
- Does Not Meet Criteria (DNM)
- Lacking Sufficient Data (LD)

ULE geometry check results were not considered in assignment of the ULE overall hazard classification in Figure 3-4.

Non-Urban Levee Evaluations Project

For the NULE Project, the percentage of a NULE levee segment with an existing geometry smaller than the standard design prism was estimated and reported; this is the percentage of a levee that deviates from the standard design prism. For example, a levee with a 60 percent deviation from the standard levee design prism means that 60 percent of the levee segment was smaller than the standard levee design prism, meaning 60 percent of the levee segment did not meet levee geometry criteria.

The percent of levee deviating from the standard levee design prism was calculated through qualitative analysis on a cross-section-by-cross-section basis. The percentage of levee segment with existing geometry that did not fit within the standard levee design prism was estimated and reported. Levees with wide crests could pass the levee geometry check even with slopes steeper than those indicated by the standard levee design prism. Engineering judgment was used to assess whether inadequacies indicated from GIS analysis were the result of true geometric inadequacy, misalignment of the design prism, and/or LiDAR-indicated levee centerline. For more information on the NULE geometry check, see the *Geotechnical Assessment Reports for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and 2011b).

NULE geometry check results were not considered in the assignment of an NULE overall hazard categorization in Figure 3-6 and Figure 3-7. Instead, other levee geometry parameters, such as head-to-levee base-width ratio, levee height, and levee landside slope angle, were considered in assignment of NULE under-seepage, through-seepage and stability hazard categorizations, which, in turn, impacted the NULE overall hazard categorization in Figure 3-6 and Figure 3-7.

4.1.2 Limitations of Status Evaluations

ULE Project levee geometry check results presented in this section are preliminary and represent findings of the first of a multitiered process being applied by DWR to assess levee geometry inadequacies and erosion hazards, results of which will be incorporated into Geotechnical Evaluation Reports being prepared for individual ULE study areas (see Section 4.4.1 for more details). Although ULE levee geometry results are preliminary, they are presented in this section as a proxy for erosion analyses in the absence of additional erosion hazard analyses that will be conducted under the ULE Project. Levee geometry check results are an imperfect indicator of erosion hazard because a wide variety of factors in addition to erosion could cause a levee to have inadequate levee geometry.

The levee geometry check presented in this FCSSR was limited to a comparison between existing levee geometry and standard levee design prisms described in Section 4.1.1, and does not assess the cause of any deviations noted for ULE or NULE levees. While deviation from standard geometry may be caused by erosion, it also could reflect a levee that was not constructed to the standard levee design prism, or a levee that has degraded because of settlement or other post-construction events. The levee geometry check does not reflect any prior-approved deviations, such as updates or exceptions to minimum levee geometry standards noted in unit-specific O&M manuals. Unit-level evaluation of a levee's geometry based on its construction specifications was not part of this levee geometry check. Estimates of the extent of deviation from standards (depth or severity) are also not included in the FCSSR for ULE or NULE levees. Because of the limitations above, ULE levee segments identified in Figure 4-2 as "Does Not Meet Criteria" warrant further assessment of potential erosion hazards and do not necessarily reflect the need for levee improvement.

The results shown in the figures do not reflect recent reclassification of certain ULE levee segments along Bear Creek near Stockton from urban to nonurban SPFC levees.

4.1.3 Results of Status Evaluations

Results of the levee geometry check for the ULE and NULE projects are summarized below. ULE and NULE levee freeboard check results, and additional information on recent levee remedial actions/improvements (including locations of levee raises, widening, and levee reconstructions), current and ongoing repairs/improvements, and ongoing actions to improve future evaluations of levee geometry are included in Appendix A, Section A-2.

Urban Levee Evaluations Project

Results of the geometry check for SPFC ULE levees are shown in Figure 4-2. The majority of SPFC ULE levees along the Feather River, American River, and Sacramento River north of the City of Sacramento were found to meet standard levee design prism geometry criteria. Approximately one-third of SPFC ULE levees deviate from current standard levee design prism geometry. These levees were located along bypass features and associated tributaries to the west, and along the Sacramento River south of Sacramento. Results for SPFC ULE levees in the San Joaquin River watershed and elsewhere in the Sacramento River watershed varied.

Non-Urban Levee Evaluations Project

Results of the geometry check for NULE levees are shown in Figures 4-3 and 4-4. The percentages mapped are the percentage of each NULE levee segment that deviated from standard levee design prism geometry. Compliance with minimum levee geometry criteria varied across the

Sacramento and San Joaquin river watersheds. Results suggest that the San Joaquin river watershed and Sacramento River have the highest percentage of levees that conform to standard levee design prism geometry. Further, levees along the bypasses and along the tributary streams to the Sacramento River in the northern Sacramento River watershed have the lowest percentage of NULE levee segments that conform to standard levee design prism geometry. Results elsewhere along NULE levees are variable.

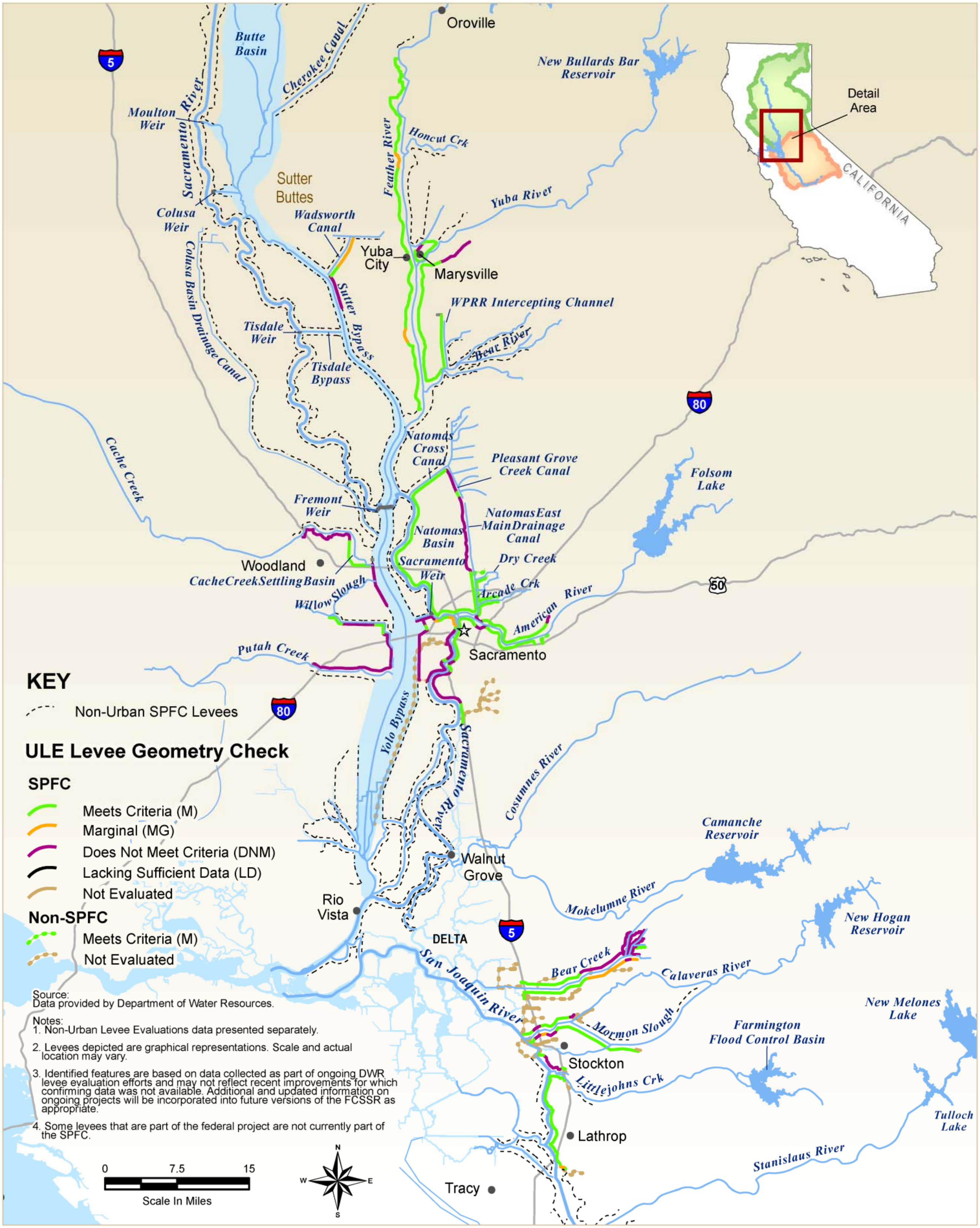


Figure 4-2. ULE Levee Geometry Check

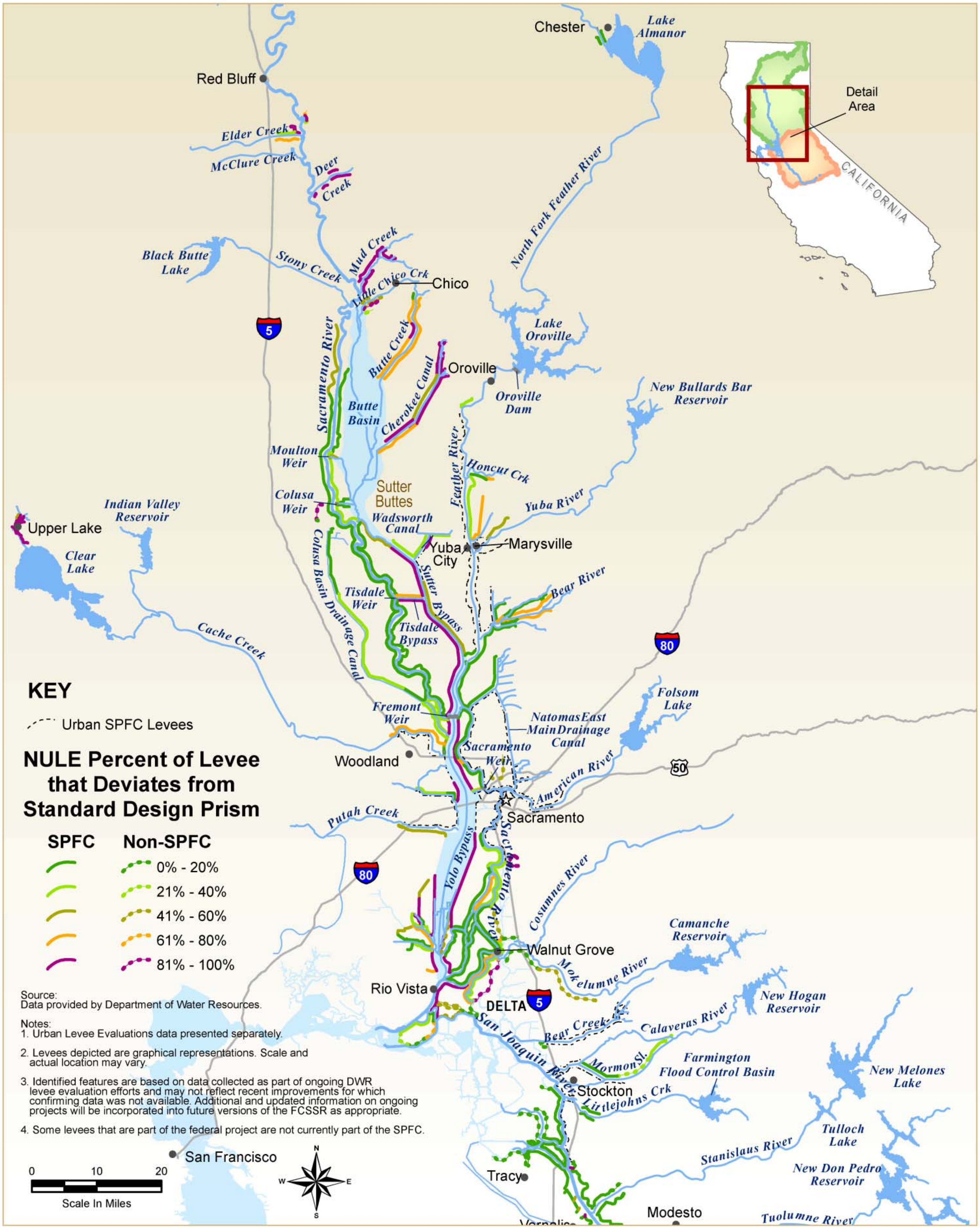


Figure 4-3. NULE Levee Geometry Check in Sacramento River Watershed

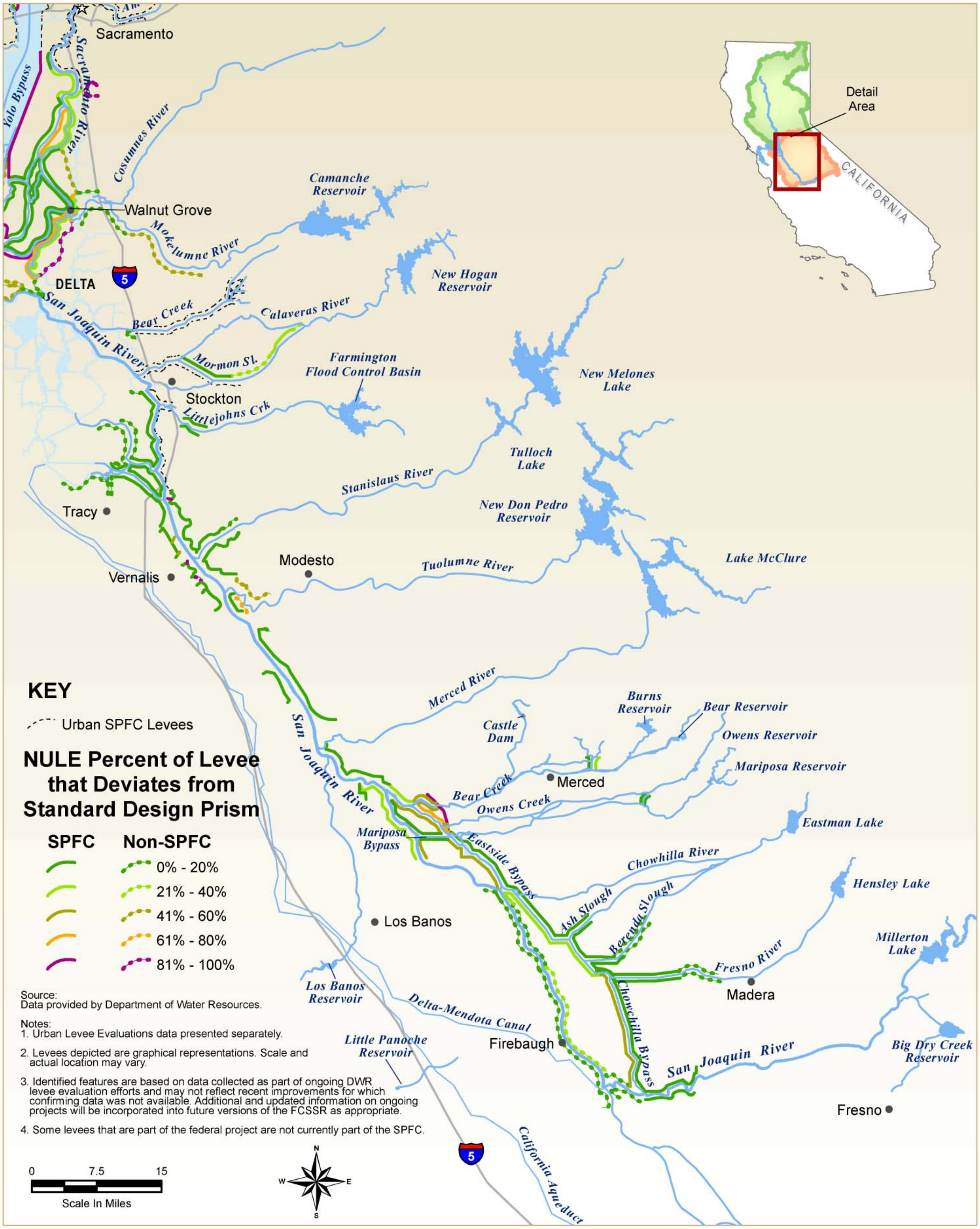


Figure 4-4. NULE Levee Geometry Check in San Joaquin River Watershed

4.2 Seepage

Seepage problems for levee systems are commonly divided into two distinct categories – under-seepage and through-seepage. Under-seepage occurs when permeable foundation material or native soils beneath the base of a levee present a pathway for water to move under a levee and exit at the surface near or beyond the landside levee toe. Through-seepage occurs when water moves from a waterway through a levee. When water moving through or under the levee carries with it foundation soil or levee materials, piping action may result in settlement of the levee or erosion of the landside toe or slope and cause the levee to breach during high water.

Levee seepage is often associated with pervious sandy and gravelly layers in a levee or levee foundation, early twentieth-century construction practices, and lack of any seepage design criteria at the time of construction. Many SPFC levees were built by landowners and local entities in the late nineteenth century and early part of the twentieth century without benefit of current design criteria or construction practices. These levees were typically constructed without consideration for foundation stability, suitability of levee material, or placement procedures. Many levees were constructed using sandy materials and were placed on top of riverine deposits that often contained pervious sandy or gravelly layers. As a result, many SPFC levees are susceptible to under-seepage or through-seepage. A number of other factors may increase the potential for seepage, including the presence of erodible fill, rodent burrows, or other penetrations that exit from the landside levee slope or foundation, potentially causing the levee to erode or degrade.

Engineering practices to address seepage have evolved significantly over time. USACE levee seepage design criteria and construction practices were originally developed to address through-seepage only, but were revised after the 1950s to address growing concerns about under-seepage. Therefore, many existing levees do not comply with current USACE levee under-seepage criteria because the levees were constructed before the revised criteria were adopted. Conflicting guidance between old and new seepage design criteria has resulted in inconsistent levels of protection for different levee projects (CESPK Levee Task Force, 2003).

Most recently, USACE has been updating seepage criteria in *Engineering Manual 1110-2-1913 Engineering and Design – Design and Construction of Levees* (USACE, 2000); further updates to USACE seepage criteria are expected. The DWR *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley Version 4* (DWR, 2010d) contain more rigorous seepage design criteria than the current USACE guidance. This is because USACE guidance applies to all levees, and the DWR interim levee design criteria only apply to levees protecting urban and urbanizing areas.

4.2.1 Status Evaluation Methodology

DWR used different methods to assess the potential for seepage under the ULE and NULE projects, reflecting different scopes, objectives, and funding availability for the projects.

Urban Levee Evaluations Project

As mentioned, levee performance for the ULE project was evaluated against hazard classifications relative to established levee design criteria To assess seepage along ULE levees, DWR performed a quantitative analysis that assessed under-seepage and through-seepage concurrently. A steady state seepage computer model used for this effort (SEEP/W) incorporated existing and new geotechnical data and analyses from borings drilled at regular intervals along the entire urban levee system. The model estimates an exit gradient for under-seepage at the design water surface elevation and allows assessment of potential through-seepage conditions, which are then compared against accepted criteria, as specified in the USACE *Design and Construction of Levees Engineering Manual 1110-2-1913* (USACE, 2000) and the DWR *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley Version 4* (DWR, 2010d).

ULE Project evaluations included assessing each ULE levee segment and assigning each segment to one of the following hazard classifications for steady state seepage:

- Meets Criteria (M)
- Marginal (MG)
- Does Not Meet Criteria (DNM)
- Lacking Sufficient Data (LD)

Non-Urban Levee Evaluations Project

For the NULE Project, levee performance was evaluated as hazard categories, which show potential for levee failure. As part of Phase 1 of the NULE Project, levee assessments were performed for under-seepage and through-seepage based on comparing available geologic and geotechnical data and documented performance records. Detailed methodology and results are contained in the *Geotechnical Assessment Reports for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and 2011b).

NULE Project Phase 1 studies included assessing each NULE levee segment and assigning each segment to one of the following hazard categories for through-seepage and under-seepage as two geotechnical failure modes:

- Low
- Moderate
- High
- Lacking Sufficient Data

4.2.2 Limitations of Status Evaluations

Limitations of seepage hazard assessments for ULE and NULE are summarized below.

Urban Levee Evaluations Project

The steady state seepage hazard classifications presented in this FCSSR for the ULE levees are based on analyses of preliminary data collected as part of the ULE Project, and do not reflect data collected from supplemental field explorations performed in 2009 and 2010. Data from these efforts will enhance levee seepage analytical results because the efforts were focused on data gaps identified based on results of the initial data collection effort, as presented in this FCSSR. Thus, results presented here may change based on the outcomes of supplemental investigations and analyses. New information will be incorporated into Geotechnical Evaluation Reports being prepared for each individual study area.

Although the analytical methodology used for this seepage hazard assessment (Section 4.2.1) is similar to that used in designing local levee improvement projects, its recommended use is limited to identifying potential geotechnical hazards to urban levees and to guide future evaluations and levee improvements; it does not represent the level of effort that would be necessary to certify a levee under the FEMA National Flood Insurance Program, which would require geotechnical explorations and analyses at greater frequency.

Non-Urban Levee Evaluations Project

NULE seepage hazard categories provided in the NULE *Geotechnical Assessment Reports for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and DWR, 2011b) represent a preliminary analysis of levee seepage conditions and are only sufficient to guide subsequent NULE field activities, and to prepare preliminary alternatives (and associated cost estimates) necessary for levee repairs and improvements to attain acceptable levee performance. Results of an assessment are not meant to be used to determine how a levee or associated system may perform in a flood event. Because of limitations identified above, seepage hazard categories for NULE levees are not used to evaluate compliance with current levee design criteria.

4.2.3 Results of Status Evaluations

Results of seepage hazard assessments for ULE and NULE are summarized below. Additional information on levee inspection results, historical levee seepage occurrences, recent remedial actions, ongoing and planned repairs and improvements, and ongoing actions to improve future evaluations for seepage are included in Appendix A, Section A-3. Also, USACE periodic inspection results for seepage in 10 USACE levee systems are included in Appendix A, Section A-1.

Urban Levee Evaluations Project

Results of the ULE steady state seepage hazard classifications are shown in Figure 4-5. Based on these results, SPFC ULE levee segments that generally meet seepage criteria include the rehabilitated portions of the Reclamation District 784 levees in Yuba County, the American River levees, the Natomas East Main Drainage Canal and Cross Canal levees, and Bear Creek levees in San Joaquin County. The longest segments that do not meet seepage criteria are along the west side of the Feather River. Results elsewhere among the ULE Project levees varied. Overall, approximately one-third of SPFC ULE levees evaluated do not meet current seepage design criteria.

Non-Urban Levee Evaluations Project

Results of the NULE under-seepage and through-seepage hazard categorizations are shown in Figures 4-6 through 4-9. Figures 4-6 and 4-7 show the under-seepage hazard categorizations for NULE levees in the Sacramento and San Joaquin river watersheds, respectively. Figures 4-6 and 4-7 show that approximately one-third of SPFC NULE levees in the Sacramento River watershed and almost two-thirds in the San Joaquin River watershed have a high under-seepage hazard. Figures 4-8 and 4-9 show through-seepage hazard categorizations for NULE levees in the two watersheds. In general, through-seepage is less prevalent than under-seepage; approximately one-eighth of SPFC NULE levees in the Sacramento River watershed and approximately half in the San Joaquin River watershed have a high through-seepage hazard.

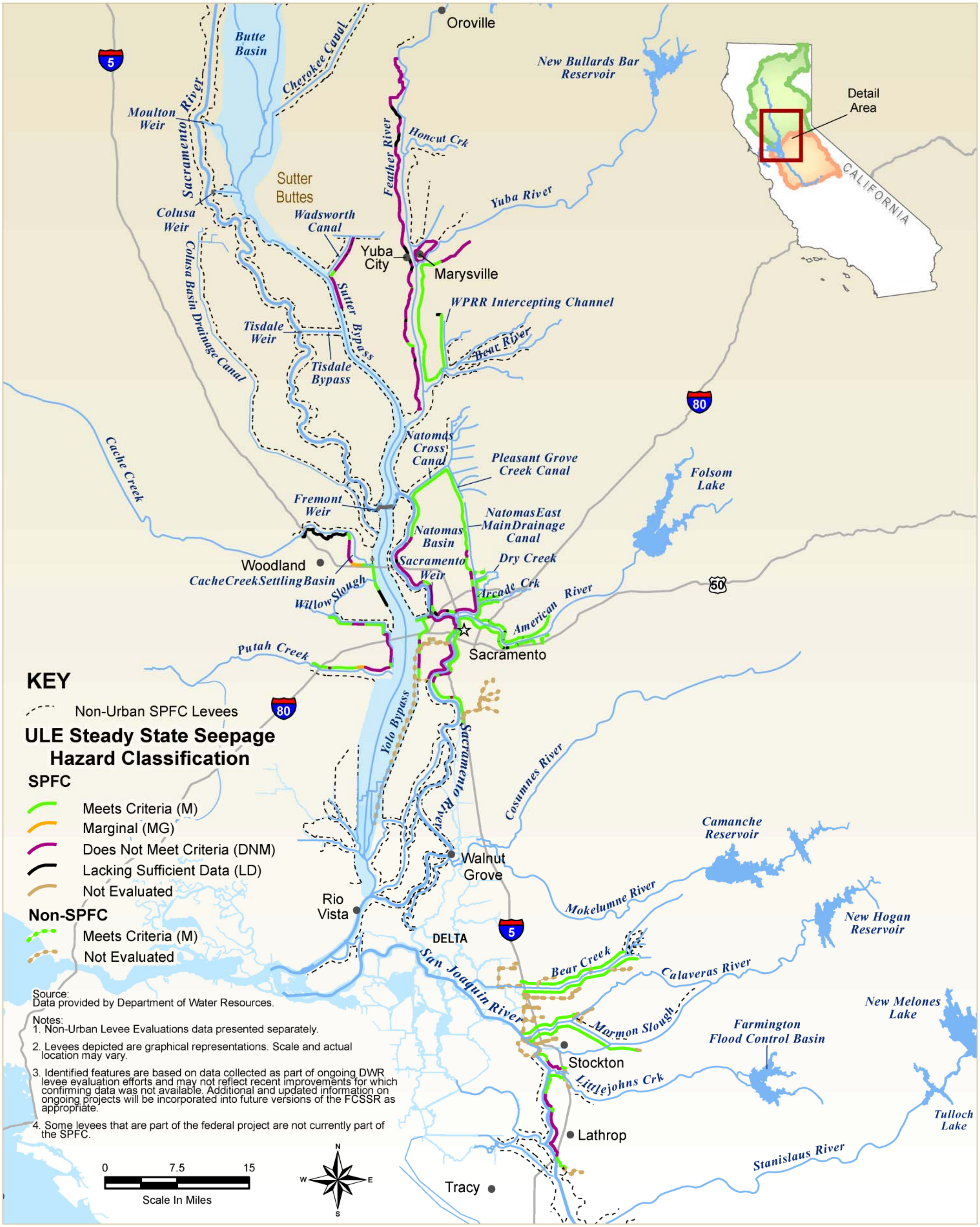


Figure 4-5. ULE Steady State Seepage Hazard Classifications

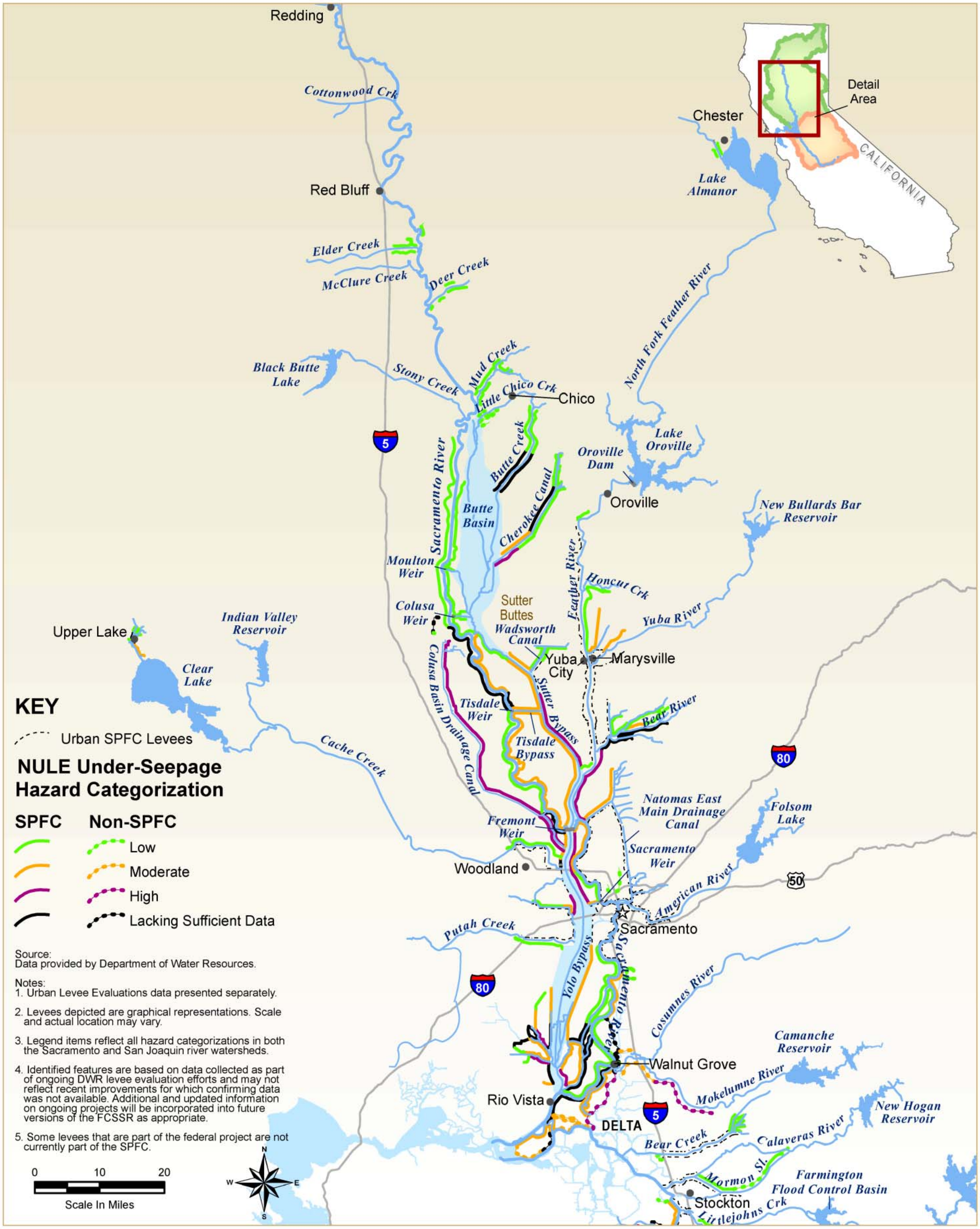


Figure 4-6. NULE Under-Seepage Hazard Categorizations in Sacramento River Watershed

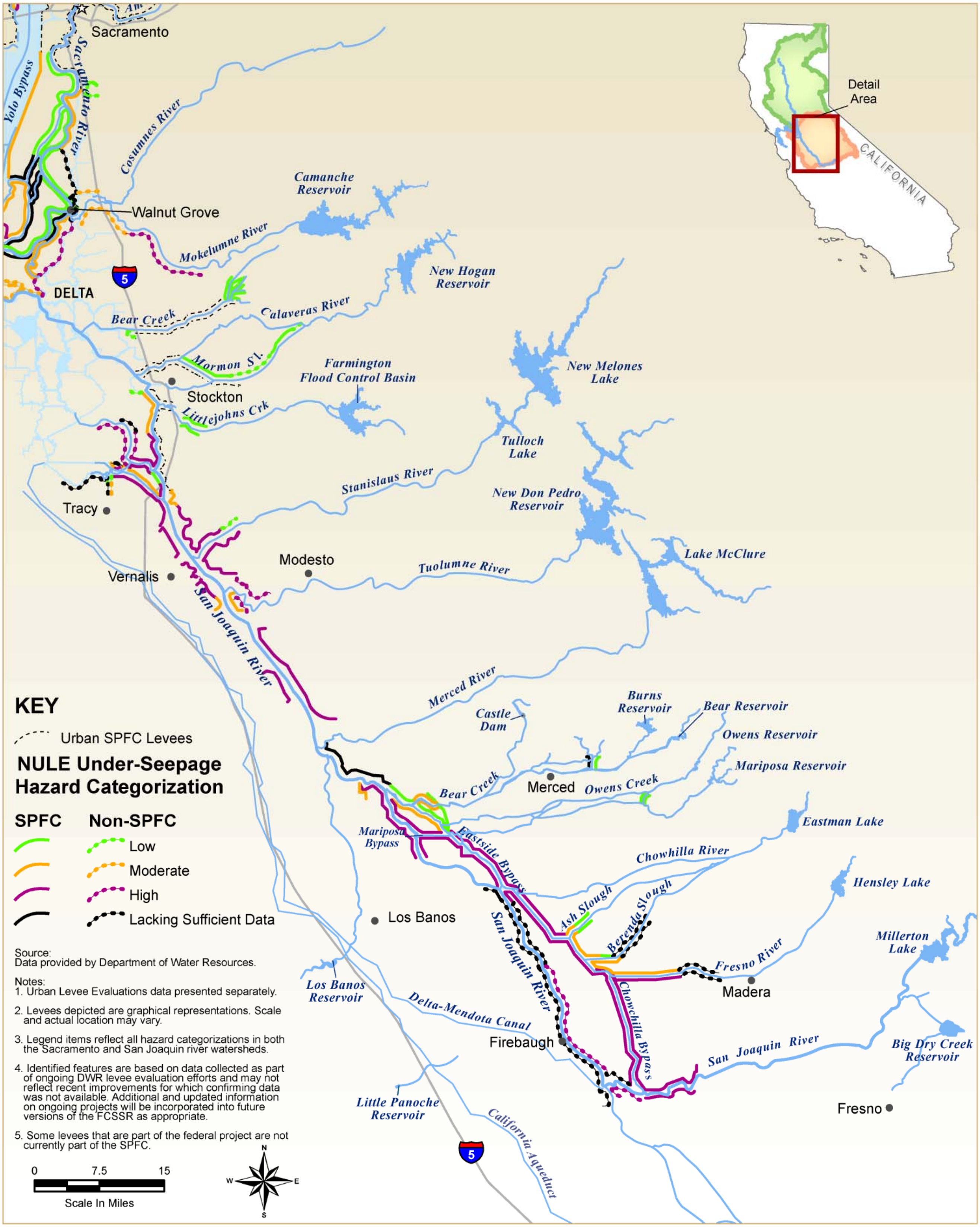


Figure 4-7. NULE Under-Seepage Hazard Categorizations in San Joaquin River Watershed

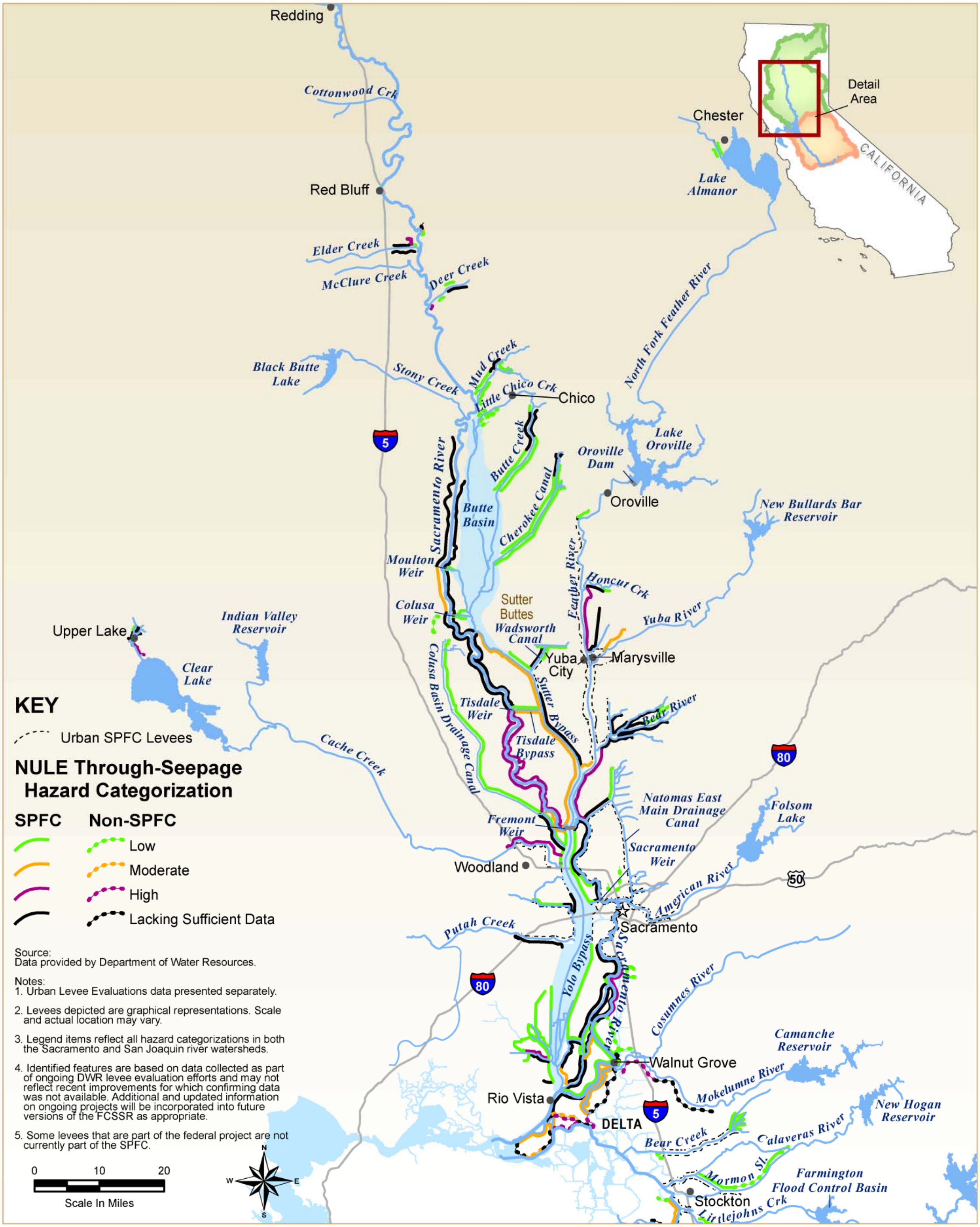


Figure 4-8. NULE Through-Seepage Hazard Categorizations in Sacramento River Watershed

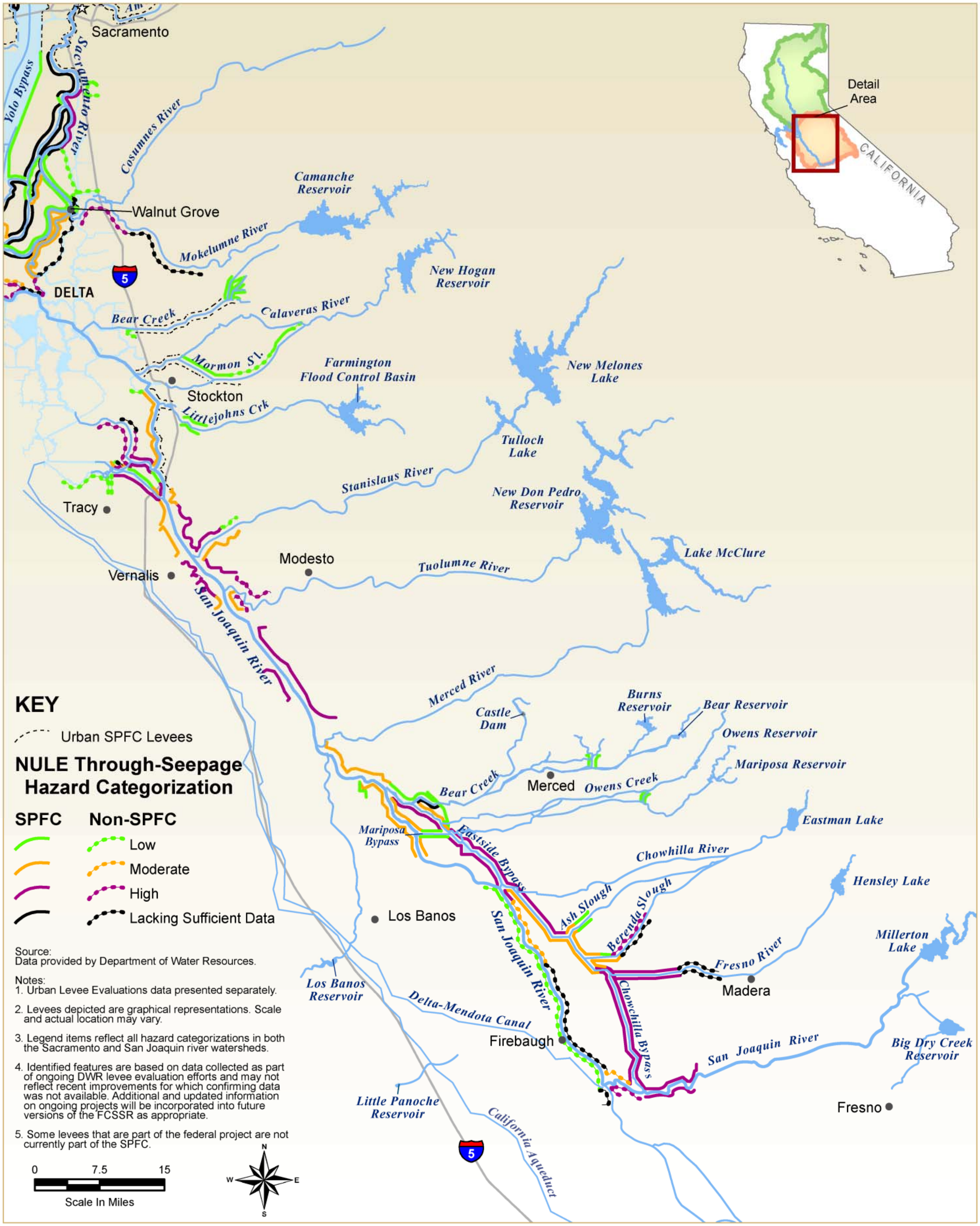


Figure 4-9. NULE Through-Seepage Hazard Categorizations in San Joaquin River Watershed

4.3 Structural Instability

Structural instability is characterized by slides, sloughs, cracking, slope depressions, or bulges that could pose a threat to levee integrity. Structural instability is often associated with soft or dispersive soils in a levee or its foundation, or with design and construction practices used for the construction of levees in the late nineteenth and early twentieth centuries. Deferred maintenance may also influence structural instability, but to a much lesser extent. As indicated previously, many SPFC levees were built by landowners and local entities without benefit of current design or construction practices. New stability analyses may be necessary for existing levees, particularly for older levees constructed before adoption of current criteria.

4.3.1 Status Evaluation Methodology

DWR used different methods to assess the potential for structural instability for the ULE and NULE projects, reflecting different scopes, objectives, and funding availability for the projects.

Urban Levee Evaluations Project

To assess structural instability along SPFC ULE levees, DWR performed a quantitative analysis of steady state slope stability that produced hazard classifications relative to established design criteria. Analytical models used for this effort incorporated topography from LiDAR surveys of the urban levee system, and existing and new geotechnical data from explorations conducted at regular intervals along the urban levee system. The models were used to calculate a factor of safety at the design water surface elevation, which was then compared against accepted geotechnical criteria, as specified in the USACE *Design and Construction of Levees Engineering Manual 1110-2-1913* (2000) and the DWR *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley Version 4* (2010d). As part of the ULE Project, levee assessments were performed for steady state slope stability to determine if the levees met geotechnical criteria at the design water surface elevation. Similar to hazard assessments for seepage, DWR assessed each ULE levee segment and assigned each segment to one of the following hazard classifications:

- Meets Criteria (M)
- Marginal (MG)
- Does Not Meet Criteria (DNM)
- Lacking Sufficient Data (LD)

Non-Urban Levee Evaluations Project

For the NULE Project, levee performance was evaluated as hazard categories, which show potential for levee failure. As part of Phase 1 of the NULE Project, levee hazard assessments were performed for slope stability based on a comparison of available geologic and geotechnical data and documented performance records. Similar to assessments for levee seepage, the slope stability hazard categorization identified in the initial NULE phase included assessing each NULE levee segment and assigning each segment to one of the following hazard categories:

- Low
- Moderate
- High
- Lacking Sufficient Data

4.3.2 Limitations of Status Evaluations

Limitations of structural instability hazard assessments for ULE and NULE are summarized below.

Urban Levee Evaluations Project

The hazard classifications presented in this FCSSR for the ULE Project levees are based on analyses of preliminary data collected as part of the project, and do not reflect data collected from supplemental field explorations performed in 2009 and 2010. Data from these efforts will enhance levee slope stability analytical results because the efforts were focused on data gaps identified based on results of the initial data collection effort, as presented in this FCSSR. Thus, results presented here may change based on the outcomes of supplemental investigations and analyses. New information will be incorporated into Geotechnical Evaluation Reports being prepared for each individual study area.

Although the analytical methodology used for this slope stability hazard assessment (Section 4.3.1) is similar to that used in designing local levee improvement projects, its recommend use is limited to identifying potential geotechnical hazards to urban levees and to guide future evaluations and levee improvements; it does not represent the level of effort that would be necessary to certify a levee under the FEMA National Flood Insurance Program, which would require geotechnical explorations and analyses at greater frequency.

Non-Urban Levee Evaluations Project

As mentioned, the hazard categories provided in the NULE *Geotechnical Assessment Reports for the North NULE Study Area and South NULE*

Study Area (DWR, 2011a and DWR, 2011b) represent a preliminary analysis of levee conditions and are only sufficient to guide the subsequent NULE field activities and prepare preliminary alternatives (and associated cost estimates) necessary for levee repairs and improvements to attain acceptable levee performance. Results of an assessment are not meant to be used to determine how a levee or associated system may perform in a flood event. Because of limitations identified above, slope stability hazard categories for NULE levees are not used to evaluate compliance with current levee design criteria.

4.3.3 Results of Status Evaluations

Results of structural instability hazard assessments for ULE and NULE are summarized below. For additional information on inspection results, historical levee slope instability locations, recent remedial actions, ongoing and planned remedial actions/improvements, and ongoing actions to improve future evaluations, see Appendix A, Section A-4. Also, USACE periodic inspection results for slope stability in 10 USACE levee systems are included in Appendix A, Section A-1.

Urban Levee Evaluations Project

Results of the ULE Project steady state stability hazard classifications are shown in Figure 4-10. Based on these results, an estimated one-fifth of SPFC ULE levees do not meet geotechnical criteria for slope stability at the design water surface elevation. In general, SPFC ULE levees in the San Joaquin river watershed, along the American River, and along rehabilitated reaches of the Natomas basin and east of the Feather River meet slope stability criteria. Results along the remaining SPFC ULE levees vary.

Non-Urban Levee Evaluations Project

Slope stability hazard categories are shown in Figures 4-11 and 4-12. As shown, there is generally a higher slope stability hazard for levees in the Sacramento River watershed compared to the San Joaquin River watershed. Approximately one-eighth of SPFC NULE levees in the Sacramento River watershed and 1 percent in the San Joaquin River watershed have a high slope stability hazard.

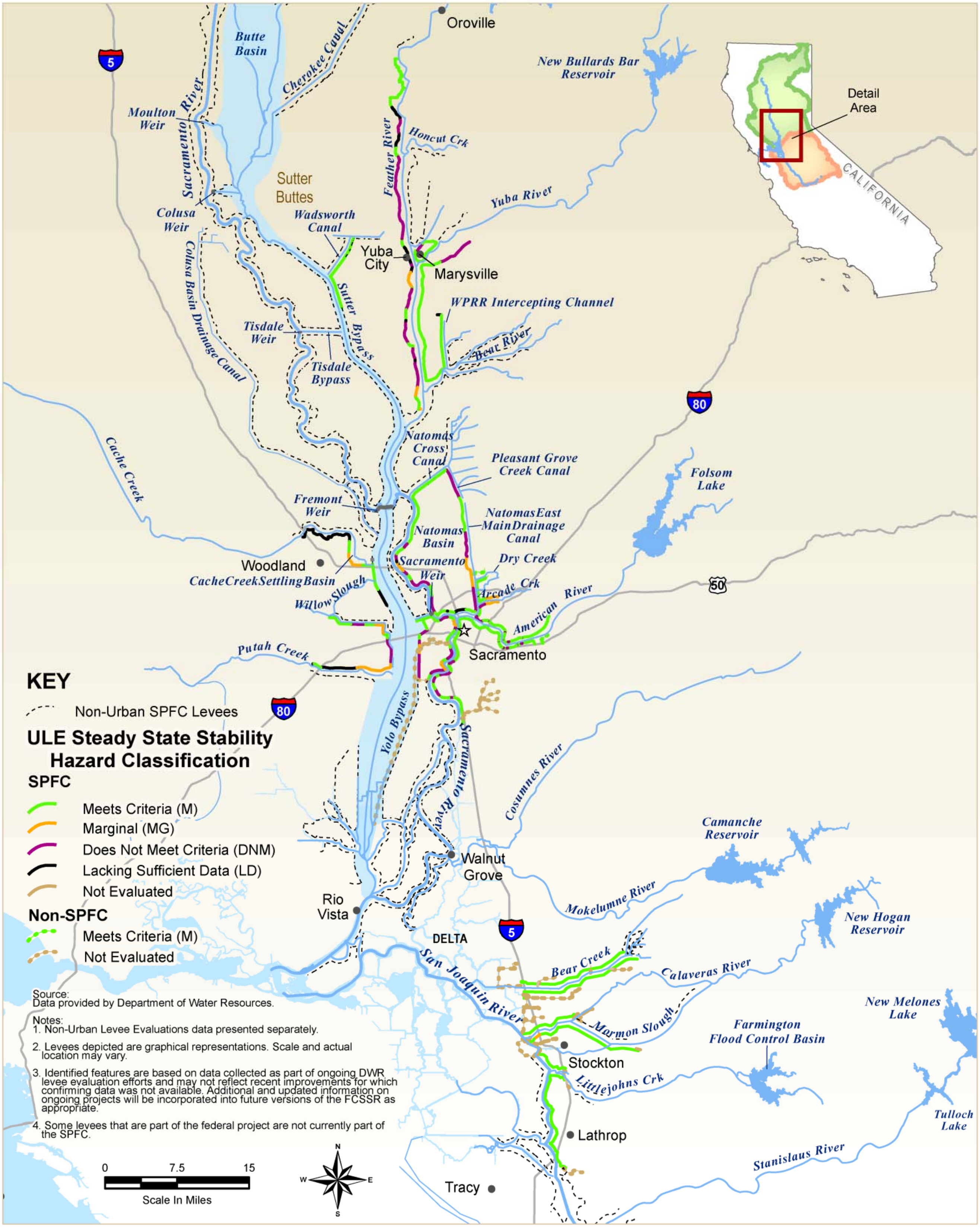


Figure 4-10. ULE Steady State Stability Hazard Classifications

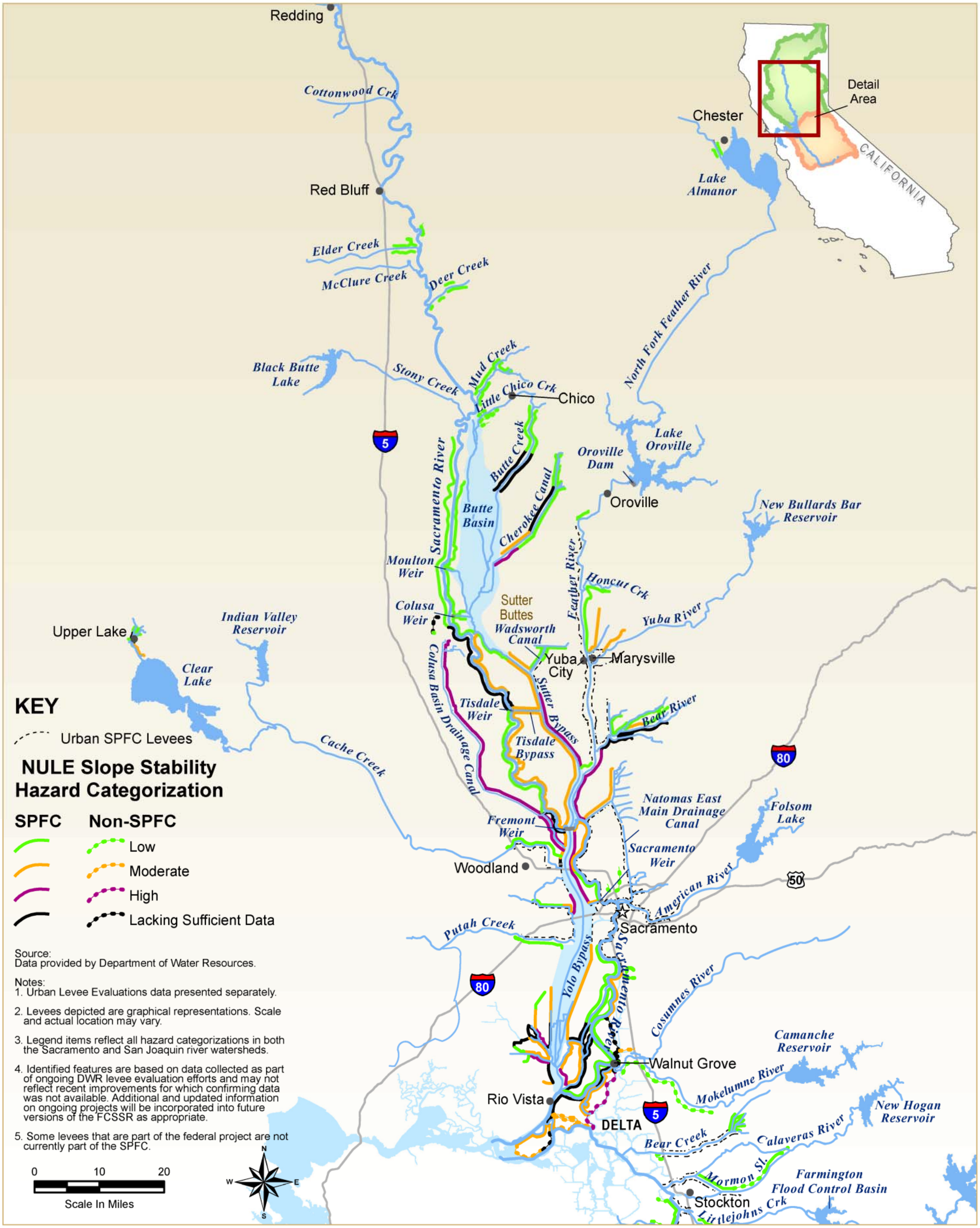


Figure 4-11. NULE Slope Stability Hazard Categorizations in Sacramento River Watershed

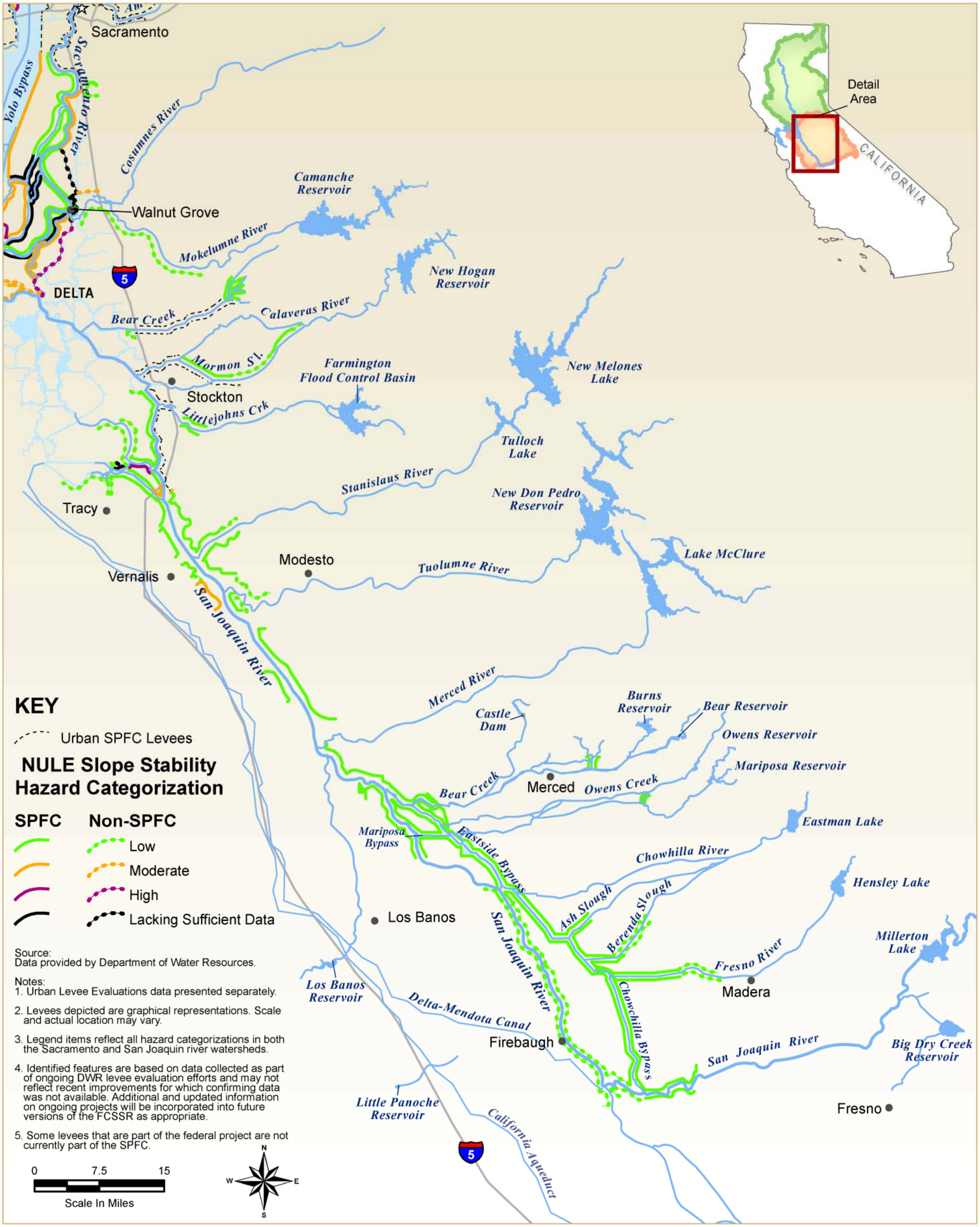


Figure 4-12. NULE Slope Stability Hazard Categorizations in San Joaquin River Watershed

4.4 Erosion

Levee erosion problems are primarily the result of lack of modern engineering criteria and construction standards for levees at the time of construction, resulting in unsuitable levee materials and narrow levee alignments in many locations. Deferred maintenance also contributes to erosion problems in some locations. Many early levees were not engineered to meet modern criteria and were constructed with readily available materials dredged from an adjacent river.

In many levee reaches of the Sacramento River system, levee alignments were designed and constructed close to the natural bank to flush out sediments that had accumulated in the system from hydraulic mining activities in the late 1800s. Decisions to construct levees close to channels more than 100 years ago shaped the location and alignment of SPFC levees today. By about 1912, an estimated 87 percent of the 494 miles of river levees in what is now the Sacramento River Flood Control Project had already been constructed on the valley floor. This effectively fixed the location and alignment of these levees for construction of the Sacramento River Flood Control Project. For instance, on the mainstem Feather River, existing levees controlled the location and alignment of approximately 77 percent of the Sacramento River Flood Control Project levees. In addition, some reclamation levees had already been built by 1912, which fixed the location and alignment of some of the bypass levees (Kochis, 1969).

By the mid-twentieth century, high velocity flows had largely scoured hydraulic mining sediment from the system, and erosion was recognized as a problem. As a result, many levees have been critically damaged and many more will continue to erode. Weakened levee geometry, poor soil materials, leaking pipes that penetrate levees, high flow velocity, and wave action have further exacerbated erosion problems.

Deferred maintenance can also contribute to erosion problems. Erosion repair and bank protection need to be conducted in a timely manner to prevent further erosion and possible levee failure. Some erosion can be attributed to rainfall on the levee, causing rounding off of the shoulders and movement of the toe, and should be addressed through maintenance activities; other erosion is attributable to the river’s erosive forces, and should be addressed by bank protection projects.

4.4.1 Status Evaluation Methodology

DWR used different methods to assess the potential for erosion for the ULE and NULE projects, reflecting different scopes, objectives, and funding availability for the projects.

Urban Levee Evaluations Project

For the FCSSR, the levee geometry check described in Section 4.1 serves as a preliminary proxy for levee erosion problems. This is primarily because erosion-specific levee hazard assessments for SPFC ULE levees are underway and results are not available for this document. After erosion analyses are completed using a multitiered evaluation process, the information will be reported in various Geotechnical Evaluation Reports and future versions of the FCSSR. It is anticipated that the multitiered evaluation process will consider levee geometry, potential for wind-wave action, and past erosion history as part of the first tier analysis. ULE levee segments that appear to have potentially moderate or high erosion hazard based on the first tier analysis will be assessed under second tier analyses, when levee surface materials and river flow velocities will be compared, wave shear stress will be evaluated, and a field reconnaissance will be conducted to verify past performance. ULE levee segments that appear to have potentially moderate or high erosion hazard based on the second tier analyses will be assessed under a third tier analysis, which will classify levees as having a low, moderate, or high erosion hazard.

Non-Urban Levee Evaluations Project

For the NULE Project, levee performance was evaluated as hazard categories, which show potential for levee failure. The NULE Project performed hazard assessments for levee erosion using past performance information from previous annual erosion studies prepared by DWR and USACE, information compiled from other reports, interviews with levee maintenance officials, and field reconnaissance. In addition to these documented occurrences of erosion, evidence of erosion was researched through review of topographic contours of levee waterside slopes. Results are documented in *Geotechnical Assessment Reports for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and DWR 2011b). Phase 1 of the NULE Project included assessing each NULE levee segment and assigning each segment to one of the following hazard categories:

- Low
- Moderate
- High
- Lacking Sufficient Data

4.4.2 Limitations of Status Evaluations

Limitations of erosion hazard assessments for ULE and NULE are summarized below.

Urban Levee Evaluations Project

At present, the ULE Project has not completed evaluations specifically for erosion hazards of ULE Project levees. However, because the levee geometry evaluation performed for the ULE Project (described in Section 4.1.3) may indicate potential erosion hazards, it may be considered a proxy for erosion hazards, as mentioned. Because inadequate levee geometry may occur from a variety of conditions, including erosion, the results of that geometry check should be considered a conservative evaluation of the potential hazards associated with erosion. A more specific evaluation of erosion hazards, as described in Section 4.4.1, will be provided in the Geotechnical Evaluation Reports being prepared by DWR for each individual study area as part of the ULE Project.

Non-Urban Levee Evaluations Project

As mentioned, the hazard categories provided in the NULE *Geotechnical Assessment Reports for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and DWR, 2011b) represent a preliminary analysis of levee conditions, and are sufficient only to guide subsequent NULE field activities and prepare preliminary alternatives (and associated cost estimates) necessary for repairs and improvements to achieve acceptable levee performance. Results of these levee erosion hazard assessments are not meant to be used to determine how a levee or associated system may perform in a flood event or whether levees comply with current levee design criteria.

4.4.3 Results of Status Evaluations

Results of levee erosion hazard assessments for the ULE and NULE projects are summarized below. For additional information on levee inspection results, historical erosion occurrences, recent remedial actions, ongoing and planned repairs and improvements, and other actions to improve future evaluations, see Appendix A, Section A-5. Also, USACE periodic inspection results on levee erosion/bank caving for 10 USACE levee systems are included in Appendix A, Section A-1.

Urban Levee Evaluations Project

As mentioned, the ULE Project has not completed hazard assessments specifically for levee erosion. However, the levee geometry evaluation performed for the ULE Project, described in Section 4.1, is a proxy for potential erosion hazards.

Non-Urban Levee Evaluations Project

Estimates of NULE levee erosion hazard categorizations for the Sacramento River and San Joaquin river watersheds are shown in Figures 4-13 and 4-14, respectively. Approximately one-seventh of SPFC NULE levees in the Sacramento River watershed were categorized as having a high erosion hazard. NULE levee segments with high erosion hazard in the Sacramento River watershed are predominantly located in the area between the City of Sacramento and the Bear River in Yuba County.

The majority of NULE levees in the San Joaquin River watershed were categorized as having a low erosion hazard. The approximately one-eighth of SPFC NULE levee segments with high erosion hazard are predominantly located on the lower San Joaquin River (downstream from the Tuolumne River confluence), Berenda Slough, and Fresno River.

Figure 4-13. NULE Erosion Hazard Categorizations in Sacramento River Watershed

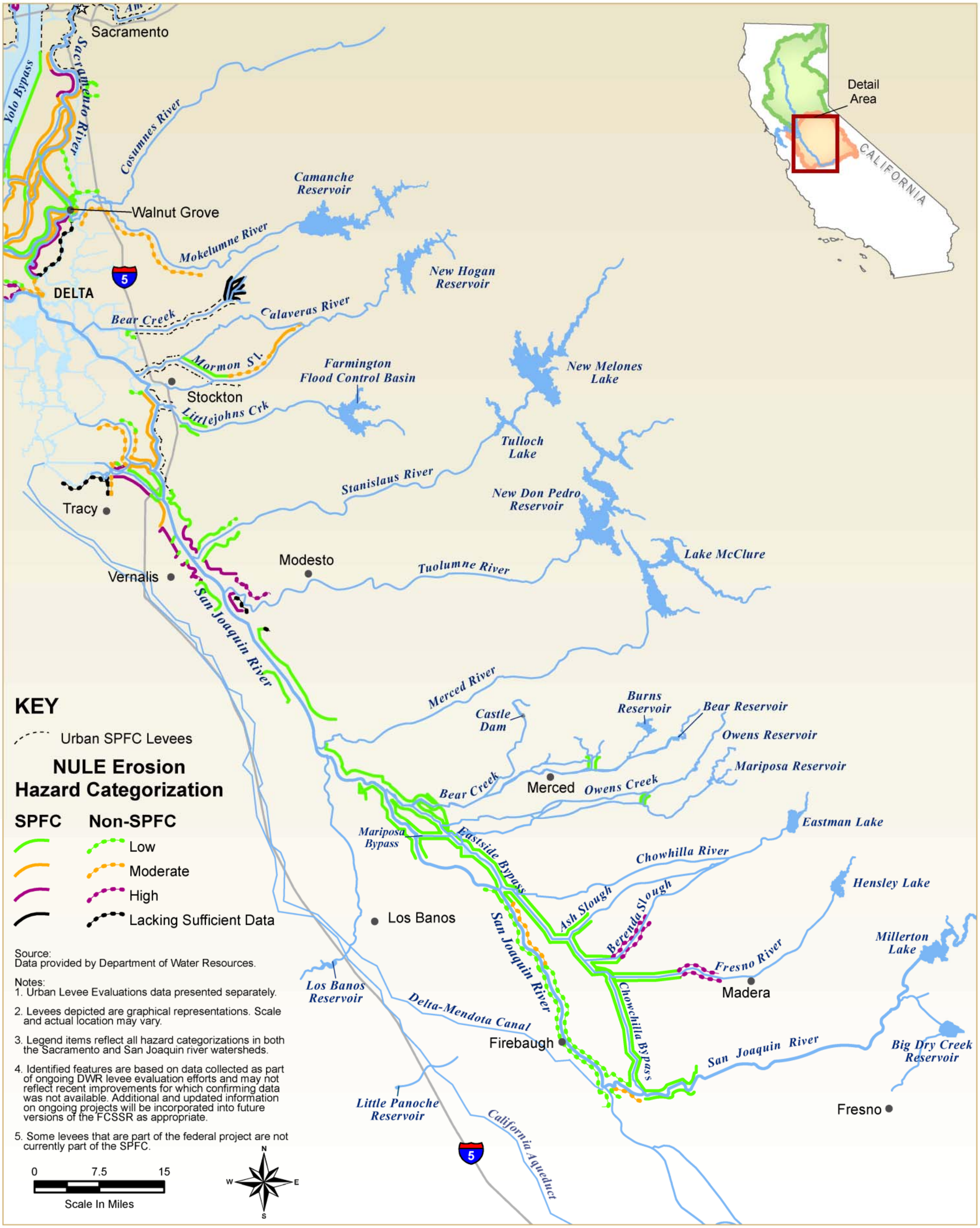


Figure 4-14. NULE Erosion Hazard Categorizations in San Joaquin River Watershed

4.5 Settlement

Settlement problems exist where areas along the crest of a levee are lower than the design elevation. Three types of settlement problems affect SPFC levees: land subsidence, consolidation settlements, and localized depressions. Each of the settlement types is caused by different factors.

Land subsidence occurs in some regions from factors outside flood management, including groundwater extraction, natural gas, and peat oxidation, that have occurred over large areal extents rather than in localized places. Regional land subsidence contributes to settlement of levee foundations.

Consolidation settlement results from consolidation of underlying strata during and after levee construction because of the weight of the overlying levee structure. Consolidation settlement is generally applicable to levee embankments or levee raises soon after they have been constructed. Because most SPFC levees have been in place for nearly 100 years, it is likely that most primary consolidation settlement has already occurred; additional consolidation settlement in these locations is not expected. However, settlement of levees constructed on peat or other soft soils can occur gradually over time.

Localized depressions are surface manifestations of an underlying problem in a levee embankment, and are most often the result of internal voids and cavities. Such depressions and sinkholes are more hazardous to levees than long-term consolidation settlements because the collapse of voids present within a levee or its foundation can pose immediate threats to the levee embankment. Presence of localized depressions can be affected by soft, dispersive soils in a levee or levee foundation, early twentieth-century design and construction practices, and lack of any levee settlement criteria at the time of construction. In addition, many existing levees do not comply with current USACE levee settlement criteria because the levees were constructed before adoption of these criteria. Deferred maintenance problems from animal burrows or leaky pipes that penetrate a levee or levee foundation can also increase the vulnerability of a levee to localized depressions. In addition, localized depressions can be increased by erosion or seepage. Finally, localized depressions can result from vehicle travel on the levee during wet conditions, resulting in rutting and displacement of levee soils.

4.5.1 Status Evaluation Methodology

Settlement conditions described in this report consider only localized depressions. DWR visually inspects SPFC levees for crown surface depressions and rutting at least two times per year, and reports results annually. Table 4-3 shows the DWR inspection rating descriptions for crown surface/depressions/rutting on earthen levees.

Table 4-3. Levee Inspection Rating Descriptions for Crown Surface/Depressions/Rutting on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	The road is in all-weather condition. There are no ruts, potholes, or other depressions on the levee, except minor depressions caused by levee settlement. The levee crown, embankments, and access road crowns are well established and drain properly without any ponded water.
Minimally Acceptable (M)	Some minor depressions in the levee crown, embankment, or access roads that will not pond water and do not threaten the integrity of the levee, or some additional road material may be necessary.
Unacceptable (U)	There are depressions greater than 6 inches deep that will pond water, endangering the integrity of the levee, or significant additional road material is needed.

Source: DWR, 2010b

4.5.2 Limitations of Status Evaluations

The ULE and NULE projects did not assess settlement hazard in detail. Results from DWR’s crown surface/depressions/rutting inspections presented here were not considered in assigning ULE and NULE overall hazard classifications and categorizations, respectively. However, levee settlement is included in this FCSSR as a levee status factor because it can potentially reduce levee freeboard or compromise levee integrity.

As mentioned, DWR’s levee inspections focus on identifying localized depressions and do not identify settlement problems from land subsidence or consolidation settlement. A typical levee inspection occurs from the crown of a levee. Thick vegetation and wide berms can obstruct an inspector’s view of levee depressions. A more thorough evaluation of settlement conditions would include consideration of subsurface conditions to identify problems, and a systemwide review of existing levee crown elevation compared to levee design elevation.

4.5.3 Results of Status Evaluations

Minimally Acceptable and Unacceptable levee crown surface/depressions/rutting inspection ratings from the *2009 Annual Inspection Report* (DWR, 2010b) are shown in Figures 4-15 and 4-16.

DWR inspections identified four locations of localized levee settlement that affect the integrity of levees (i.e., ratings of Unacceptable).

For additional information on levee sinkhole and subsidence data collected by the NULE Project, recent, ongoing, and planned repairs and improvements, and ongoing actions to improve future evaluations, see Appendix A, Section A-6. Also, USACE periodic inspection results for levee settlement and depressions/rutting for 10 USACE levee systems are included in Appendix A, Section A-1.

Figure 4-15. 2009 Crown Surface/Depressions/Rutting Inspection Ratings in Sacramento River Watershed

Figure 4-16. 2009 Crown Surface/Depressions/Rutting Inspection Ratings in San Joaquin River Watershed

4.6 Penetrations

Penetrations include man-made objects that cross under or through a levee or floodwall and can create a preferential seepage path or hydraulic connection with the waterside. Typically, a penetration is a pipe or transportation structure, such as a roadway or rail line. Many penetrations are or were used for agricultural irrigation and are located in both urban and nonurban areas. Many penetrations were installed after levee construction and were therefore often not accounted for as part of original levee design. Other penetrations were constructed first and levees were built on top.

Penetrations can be potential pathways for seepage

In most cases, penetrations were not modified to meet criteria at the time a levee was constructed. Numerous old and sometimes abandoned penetrations were not installed using current criteria that regulate how penetrations can be placed through levees. These criteria are found in Code of California Regulations Title 23, Article 8, Section 123. Many penetrations were included as part of the flood control project and turned over to maintaining agencies for maintenance. The Board has a partially complete levee penetrations inventory indicating that more than 6,000 penetrations exist through SPFC levees; many existing penetrations are still unidentified. Documentation of historical abandonment of penetrations is limited.

As mentioned, penetrations can be potential pathways for seepage, and may contribute to levee failure. In some instances, if backfill surrounding penetrations is more permeable than levee soils, a seepage pathway can develop. Susceptibility to seepage is particularly acute from older penetrations, which are prone to corrosion or collapse. Metal pipes can corrode, creating holes and leaks. These penetrations can induce the levee embankment to erode, creating areas of weakness or internal voids. This internal erosion often remains hidden until a surface expression develops, such as a sinkhole or localized depression (see Section 4.5, "Settlement," for discussion of localized depressions).

In many instances, however, internal erosion has no surface expression and the threat to a levee remains undetected. Challenges to evaluating the threat to levee integrity from levee penetrations include the high number of penetrations in the Sacramento and San Joaquin river watersheds, limited existing documentation, and the significant time and expense required for invasive inspections.

Damage to levee embankments from penetrations can contribute to seepage, stability, and settlement problems. If the phreatic surface[1] intersects an internal levee embankment cavity during a high water event, internal erosion may accelerate, and potential for development of a levee breach will increase. Levee seepage, stability, and settlement problems are discussed in Sections 4.2, 4.3, and 4.5, respectively.

4.6.1 Status Evaluation Methodology

DWR levee inspectors currently do not inspect penetrations in detail as part of their annual levee inspections. DWR has implemented a utility crossing inventory program that will identify, locate, and visually inspect existing penetrations over the next 3 to 5 years. As part of this effort, DWR is currently identifying and documenting existing penetrations and developing a rating system or criteria to incorporate penetrations into inspection ratings.

Because the utility crossing inventory program is currently under development, data presented in this report are limited to documentation of known penetrations from existing sources, and the FCSSR does not include assessing potential structural threats to levees. Data from DWR levee penetration logs, which list the number and approximate locations of pipes penetrating the levees, were supplemented by interviews with representatives from local agencies and landowners as part of the ULE and NULE projects.

4.6.2 Limitations of Status Evaluations

As mentioned, DWR is currently cataloging levee penetrations. Additional penetrations data, including data from DWR's Delta Levees Electro-Magnetic Anomaly Program, will be assessed under the ULE and NULE projects and incorporated into future updates of the FCSSR.

Efforts are also ongoing to develop criteria to evaluate risks associated with penetrations. Although records exist for many permitted penetrations, physical characteristics of the penetration (e.g., pipe dimension, material, use) were not documented consistently, and records stem from several different sources. Therefore, data presented here represent only a summary of the locations of known penetrations, and not an assessment of potential risks posed by those penetrations.

[1] The phreatic surface is the location where pore water pressure is under atmospheric conditions. The phreatic surface normally coincides with the water table.

As discussed in Section 3.3.2, penetrations data were some of the qualitative data inputs incorporated in assigning a NULE through-seepage hazard categorization and therefore were also a consideration in the NULE overall hazard categorization. Penetrations data were not considered in assessing an overall hazard classification for ULE levees because ULE seepage hazards were assessed with numerical computer models incorporating site-specific geotechnical data from soil borings. Therefore, penetrations data presented in this FCSSR represent a compilation of NULE levee penetrations and only a partial compilation of ULE levee penetrations. Penetrations for ULE levees are being documented as part of the ULE Project; new data will be included in future updates of the FCSSR.

4.6.3 Results of Status Evaluations

Figures 4-17 and 4-18 show documented levee penetrations for the Sacramento and San Joaquin river watersheds, respectively. Data show that penetrations are prevalent throughout the entire levee system. As mentioned, the initial DWR inventory shows more than 6,000 penetrations through SPFC levees. In the Sacramento Valley, existing data include the greatest density of penetrations along the Sacramento River levees upstream from the Sutter Bypass and downstream from the City of Sacramento, with fewer penetrations documented along the Feather River levee system, along the smaller tributary stream levees, and along the bypass levees[2]. In the San Joaquin Valley, penetrations have been identified throughout the San Joaquin River levees between Stockton and Fresno.

For additional information on recent levee remedial actions, ongoing and planned remedial actions, and ongoing actions to improve future evaluations, see Appendix A, Section A-7.

[2] Since compilation of ULE levee penetrations is still ongoing, it is uncertain whether fewer penetrations exist in these areas or whether penetrations exist but have not been documented yet.

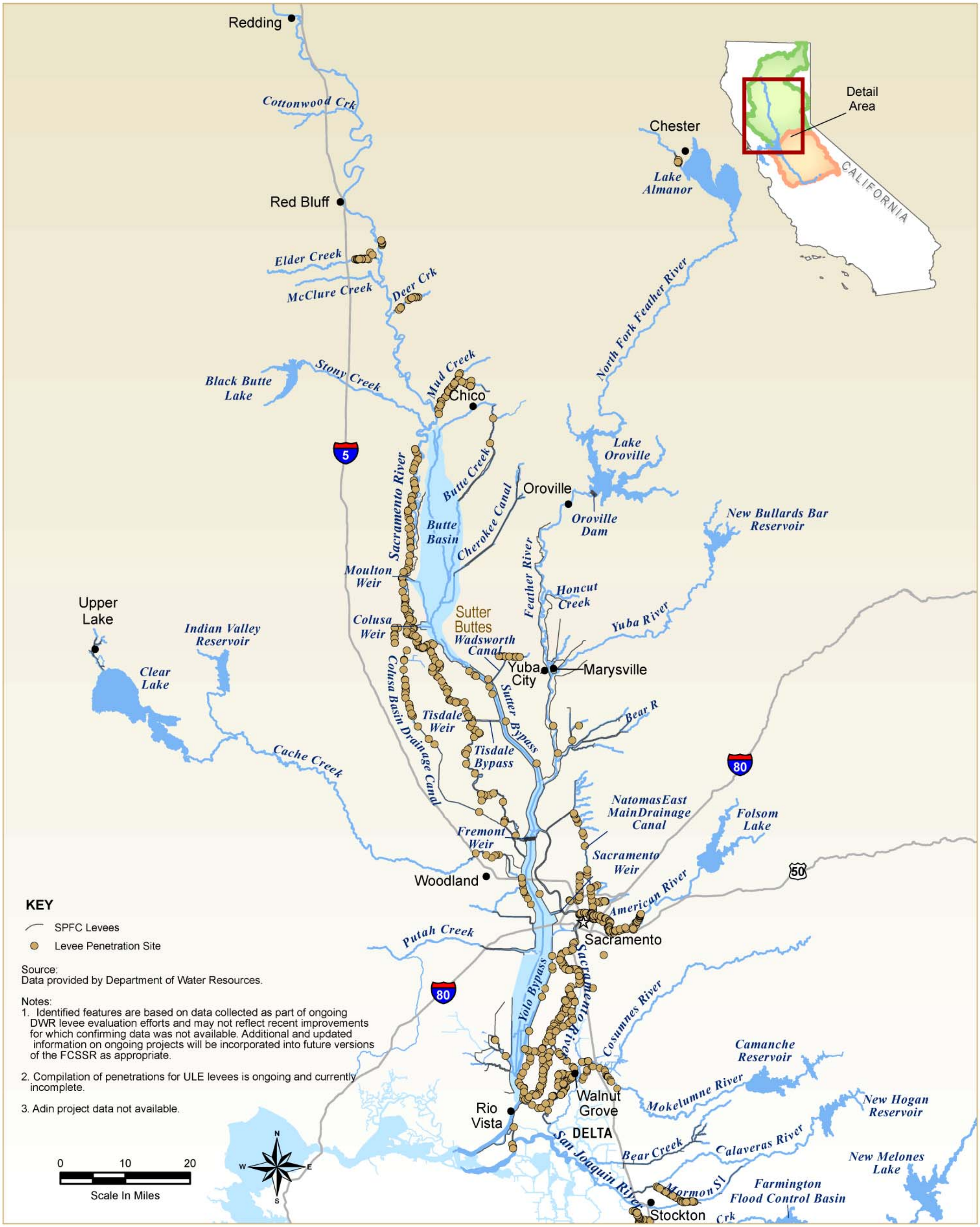


Figure 4-17. Levee Penetrations in Sacramento River Watershed

Figure 4-18. Levee Penetrations in San Joaquin River Watershed

4.7 Levee Vegetation

This section discusses vegetation management on levees (channel vegetation management is discussed in Section 5.2). Levee vegetation policy is described in greater detail in the CVFPP.

It should be noted that State and federal agencies have differing perspectives on levee vegetation criteria and the extent to which levee vegetation policies have evolved over time. The following reflects DWR's perspective on levee vegetation criteria.

When the Memorandum of Understanding between USACE and the Board was signed for the Sacramento River Flood Control Project in 1953, woody vegetation was already an integral component of the levees. For many decades, USACE's approach to vegetation on levees was to allow some vegetation, willows, and other suitable growth, where this vegetation could prevent erosion and wave wash. The Sacramento River Flood Control Project and Lower San Joaquin River and Tributaries Project Standard O&M manuals allow some vegetation to remain on levee waterside slopes to prevent erosion and wave wash (USACE, 1955a and USACE, 1959).

Over the last several years, USACE's enforcement of its policies regarding vegetation on levees has become more stringent. In April 2007, a Draft USACE White Paper provided specific guidance for USACE best management practices for vegetation management. USACE later issued the *Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures* (Engineering Technical Letter 1110-2-571) (2009b) on April 10, 2009. These guidelines limit growth (brush, weeds, or trees) to smaller than 2 inches in diameter.

In August 2007, DWR and the Board created the California Levees Roundtable, a partnership of maintaining agencies, USACE, FEMA, and resources agencies to generate procedures for vegetation management that are supported by the regulatory agencies and allow maintaining agencies to fulfill their public safety responsibilities. To address levee visibility and inspection issues presented by vegetation on levees, DWR adopted interim levee vegetation inspection criteria in fall 2007. These criteria are being used in the short term until they can be revised, using best available science. On February 27, 2009, the California Levees Roundtable issued a joint collaborative document titled *California Central Valley Flood System Improvement Framework* (California Levee Roundtable, 2009), which was intended to provide interim guidance on best vegetation management practices until the CVFPP is adopted.

4.7.1 Status Evaluation Methodology

DWR interim levee vegetation inspection criteria for visibility and accessibility form the primary basis in this report for identifying levee vegetation problems. *DWR Interim Levee Vegetation Criteria* (2007) comply with the standard contained in the *Central Valley Flood System Improvement Framework* document created in collaboration with USACE, DWR, and other agencies (California Levees Roundtable, 2009).

USACE levee vegetation standards limit uncontrolled vegetation growth (brush, weeds, or trees) to no greater than 2 inches in diameter on levee slopes or crowns, or within 15 feet of the landward toe. *DWR Interim Levee Vegetation Criteria* (2007) allow vegetation beyond 20 feet from the waterside hinge point; grass and weeds must be less than 12 inches in height, and trees must be trimmed 5 feet above ground or 12 feet above the crown road, with thinning to allow clear visibility and floodfight access. The *DWR Interim Levee Vegetation Criteria* (2007) can be found in Appendix A, Section A-8.

As described in Section 2.1.1, DWR visually inspects SPFC levees for levee vegetation and tree trimming/thinning at least two times per year and reports results annually. Table 4-4 shows DWR inspection rating descriptions for vegetation on earthen levees. Table 4-5 shows DWR inspection rating descriptions for trimming/thinning trees on earthen levees.

Table 4-4. Levee Inspection Rating Descriptions for Vegetation on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	The levee has a good grass cover with no unwanted vegetation (brush, bushes, undesirable weeds) blocking visibility or access.
Minimally Acceptable (M)	Tall grass, weeds, or brush partially block visibility of or access to the levee and/or are within 10 feet of the landside toe.
Unacceptable (U)	Tall grass, weeds, or brush completely block visibility of or access to the levee and/or are within 10 feet of the landside toe.

Source: DWR, 2010b
Note:
See Appendix A-8, Figure A-31, for schematic showing *DWR Interim Vegetation Inspection Criteria for Standard Levees*, October 2007.

Table 4-5. Levee Inspection Rating Descriptions for Trimming/Thinning Trees on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	Any trees on the levee or the 10-foot landside toe easement are trimmed to at least 5 feet above the levee slope, and spaced to allow visibility and floodfight access. Trees adjacent to the levee crown or patrol road are trimmed at least 12 feet above ground.
Minimally Acceptable (M)	Moderate density of limbs, leaves, or the trees themselves is partially obstructing visibility and floodfight access to the levee slope and/or 10 feet beyond the landside toe.
Unacceptable (U)	Significant density of limbs, leaves, or the trees themselves is completely obstructing visibility and floodfight access to the levee slope and/or 10 feet beyond the landside toe.

Source: DWR, 2010b

Note:
See Appendix A-8, Figure A-31, for schematic showing *DWR Interim Vegetation Inspection Criteria for Standard Levees*, October 2007.

To support maintaining agencies in reaching full compliance with the DWR interim vegetation inspection criteria by November 1, 2010, DWR conducted a follow-up evaluation of remaining levee vegetation problems identified in the DWR fall 2009 inspection. In July 2010, environmental scientists conducted site visits to all levee reaches rated as Unacceptable during the DWR fall 2009 inspection. The site visits documented continued improvements needed for levees to comply with the *DWR Interim Levee Vegetation Criteria* (2007).

Levee vegetation data were not considered in the assignment of the ULE and NULE overall hazard classifications and categorizations, respectively. However, levee vegetation data are included in this FCSSR because ongoing research is evaluating the potential impact of levee vegetation on levee integrity.

4.7.2 Limitations of Status Evaluations

Reported levee vegetation conditions are based on inspections and assessments relative to the *DWR Interim Levee Vegetation Criteria* (2007), and not relative to USACE vegetation standards. Differences between DWR and USACE levee vegetation criteria are significant enough that comparison of DWR and USACE criteria would likely show more SPFC levees as noncompliant. Levee status evaluations do not yet have the benefit of a complete body of research to support a meaningful correlation between levee vegetation and geotechnical hazard to levees.

4.7.3 Results of Status Evaluations

Inspection results reflect vegetation and trimming/thinning trees levee inspection ratings from the *2009 Annual Inspection Report* (DWR, 2010b), updated by data collected from DWR's additional site visits in July 2010. Unacceptable and Minimally Acceptable inspection ratings are shown in Figures 4-19 through 4-22 for the Sacramento and San Joaquin River watersheds.

Although difficult to determine from the figures because of the scale of the maps, levee reaches with Unacceptable ratings include approximately 15 total miles of levees. Levees with Unacceptable ratings had brush and weeds, trees needing trimming/thinning, and approximately 111 elderberry shrubs requiring thinning or removal. Elderberry shrubs are host plants for the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), federally listed as threatened. Most of the Unacceptable ratings for levee vegetation and trimming/thinning of trees were located on the Sacramento River south of Sacramento, and in the Sacramento-San Joaquin Delta.

Additional information on recent, ongoing, and planned levee remedial actions, and ongoing actions to improve future evaluations of levee vegetation problems is included in Appendix A, Section A-8. Also, USACE periodic inspection results for levee vegetation growth (based on USACE levee vegetation inspection criteria) in 10 USACE levee systems are included in Appendix A, Section A-1.

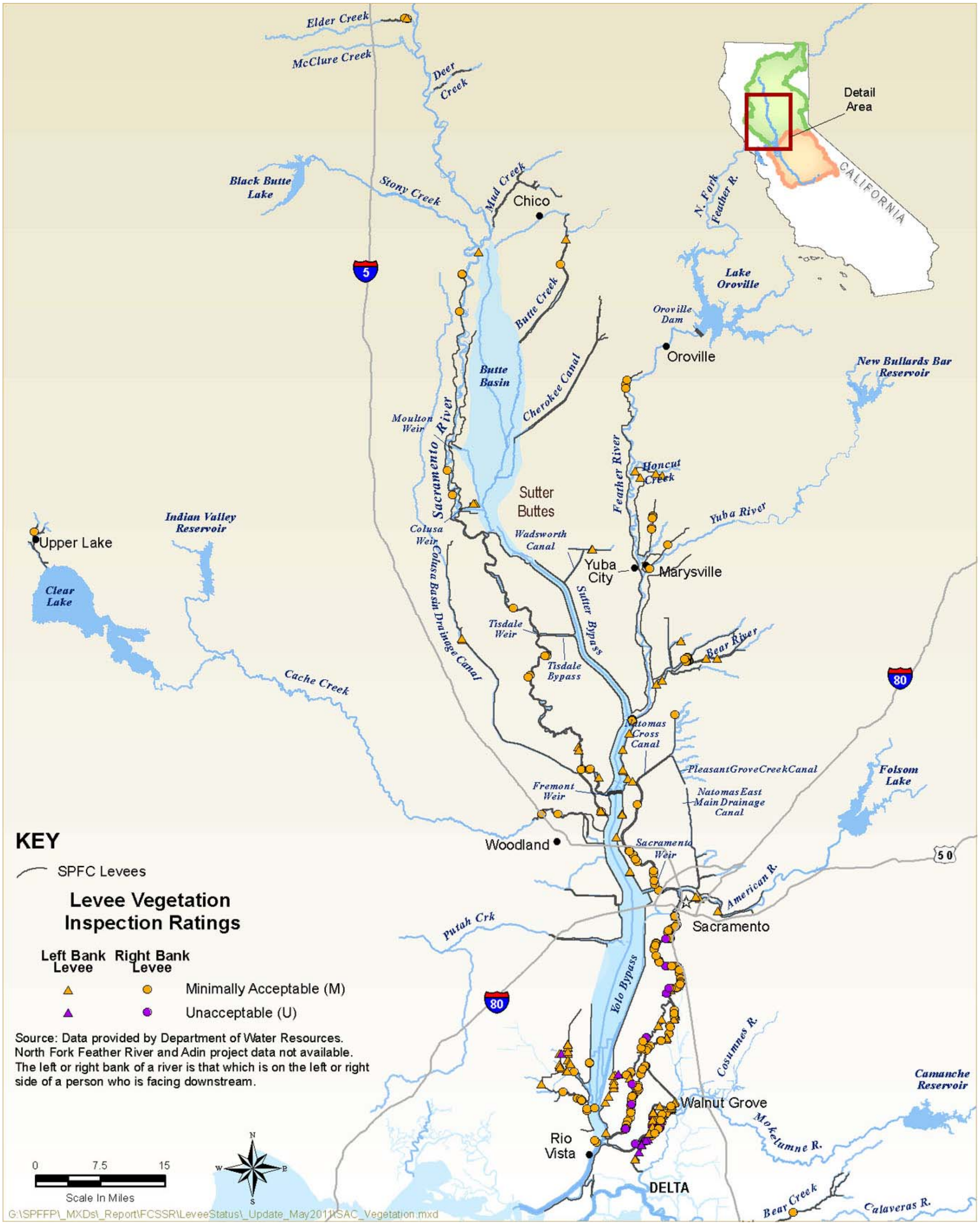


Figure 4-19. 2009 Levee Vegetation Inspection Ratings in Sacramento River Watershed

Figure 4-20. 2009 Levee Vegetation Inspection Ratings in San Joaquin River Watershed

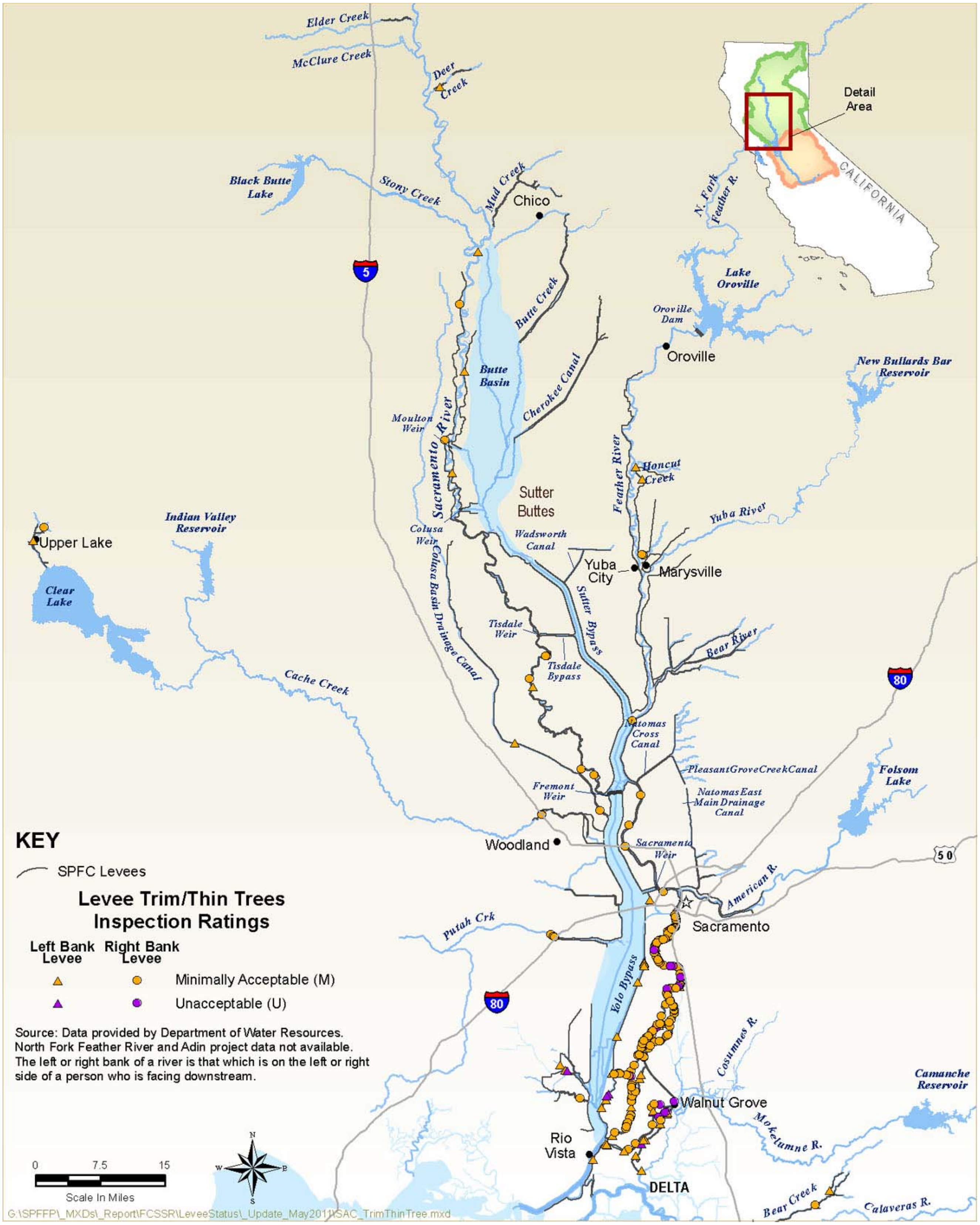


Figure 4-21. 2009 Trimming/Thinning Trees Inspection Ratings in Sacramento River Watershed

Figure 4-22. 2009 Trimming/Thinning Trees Inspection Ratings in San Joaquin River Watershed

4.8 Rodent Damage

SPFC levees may be damaged by animals creating burrows to form tunnels and galleries. These tunnels and galleries can be isolated or interconnected, depending on the animal species. The void spaces created by animal burrows can cause a preferential seepage path through a levee, promote surface and internal erosion, and reduce the strength of levee embankment and foundation materials by increasing pore water pressure. Large burrows and dens can also eventually collapse, inducing internal zones of low strength within a levee, thereby reducing its stability and internal erosion resistance. Collapse of large void spaces creates sinkholes at the surface, which could lead to levee breaches if the collapse occurs during high water (see also Section 4.5, “Settlement”).

Animal burrows can increase seepage through a levee

Burrowing animal (rodent) damage to SPFC levees can worsen because of deferred repairs or maintenance and other factors, such as land use adjacent to levees. While it is infeasible to eliminate all burrows from SPFC levees, maintaining agencies implement animal burrow control programs that reduce active burrowing and fill existing burrows. The specific type of control method used varies among maintaining agencies, and includes the following: grouting burrows, excavating and filling burrows, baiting, and others.

4.8.1 Status Evaluation Methodology

DWR conducted an Animal Burrow Hole Persistence Study on SPFC levees using data from biannual DWR inspections from 1984 to 2008 (DWR, 2009b). The metric used to assess animal activity in the study was cumulative occurrences of documented burrowing activity over time. Occurrences of documented burrowing activity include the presence of burrow holes on levee slopes or direct animal sighting. It was assumed that repeated documented animal burrows at a given location during a series of biannual inspections indicates animal activity persistence and, as a result, a higher degree of structural damage in embankments than at levee locations with lower numbers of documented burrows.

Statistical analysis was used to categorize levels of animal burrow hole persistence as the lower, middle, and upper third of the distribution (i.e., low, medium, and high persistence). Levels of persistence are described in Table 4-6. For more details on the study, refer to the *Assessment of Animal*

Burrow Hole Persistence on Project Levees Technical Memorandum (DWR, 2009b).

Table 4-6. Animal Burrow Hole Persistence Levels

Animal Burrow Hole Persistence Levels[1]	Cumulative Occurrences of Documented Burrowing Activity per Levee Unit	Total Levee Miles
No Activity[2]	0	184
Low Persistence	1 – 3	350
Medium Persistence	4 – 7	382
High Persistence	8 or higher	543
No Data[3]	No data	108

Notes:
[1] The Animal Burrow Hole Persistence Study included 42 biannual DWR inspection records spanning 21 years, from 1984 to 2008. Records for 1988, 1990, 1991, and 1993 inspections were not available (DWR, 2009b).
[2] No Activity represents levee reaches for which no occurrences of documented burrowing activity were found in inspection reports, but for which documented occurrences were found elsewhere within the same levee unit.
[3] No Data represents entire levee units for which there were no data in the inspection reports. It is unknown whether the lack of data along these levee units was an indication of absence of activity or a reflection of problems observing animal activity in these areas.

As described in Section 3.3, burrow hole persistence data were not considered in assigning ULE overall hazard classifications. However, burrow hole persistence data were considered in assigning NULE through-seepage hazard categorizations.

4.8.2 Limitations of Status Evaluations

Levee inspections only document the presence (or absence) of animal burrows and do not measure burrow hole density, hole diameter, or structural damage to levees.

To facilitate analysis, data were grouped together by reach for levees with similar burrowing activity, land use, and physical features in and around the levee. However, this grouping may not capture variability in animal burrowing activity at small scales (i.e., 1 – 3 miles). Furthermore, recent efforts of maintaining agencies may have changed conditions since the study was completed in 2009.

Some burrowing animals tend to be more damaging to levees (e.g., deeper penetrating burrows) than others; however, the type of burrowing animal in any particular area generally was not documented. The study did not address burrows and dens associated with large rodents, such as muskrats and beavers. These species usually do not burrow directly into levee slopes, but prefer to construct the entrances to their dens under water.

Records covering only 1,459 miles of approximately 1,600 total miles of SPFC levees contained information on burrowing activity. An additional 108 miles corresponded to entire levee units for which there were no data in the inspection reports ("No Data" level). It is unknown whether the lack of data along these levee units was an indication of absence of activity or a reflection of problems observing animal activity in these areas.

Animal persistence data were collected from levee inspections that are traditionally performed from a moving vehicle. For a variety of reasons, inspectors do not normally exit their vehicles to observe and document animal burrows. Visual inspection from a moving vehicle is not as effective for gathering information as foot surveys, and may lead to some underreporting of burrows. Certain maintenance measures, such as levee dragging, can also cover burrows on the surface, making underlying burrows difficult to observe during an inspection. Over time, this leads to levees that appear to lack any burrows on the surface, but instead may have internal burrows within the levee embankment.[3]

4.8.3 Results of Status Evaluations

Figures 4-23 and 4-24 show results for the DWR Animal Burrow Hole Persistence Study for the Sacramento and San Joaquin river watersheds, respectively (DWR, 2009b). More than one-third of the 1,459 miles of SPFC levees studied had high persistence (at least eight reported incidences of burrowing activity over the 21-year study span of inspection results).

Additional information on animal control inspection results, recent, ongoing, and planned levee remedial actions for rodent damage, and ongoing actions to improve future evaluations is included in Appendix A, Section A-9. Also, USACE periodic inspection results on animal control for 10 USACE levee systems are included in Appendix A, Section A-1.

[3] This observation is verified by DWR's experience in grouting rodent holes, such as on Cache Creek. In the first year of the grouting program, the grout takes were large because grout going into one burrow flowed to many other interconnected burrows. In subsequent years, grout take decreased because only the new burrows required grout.

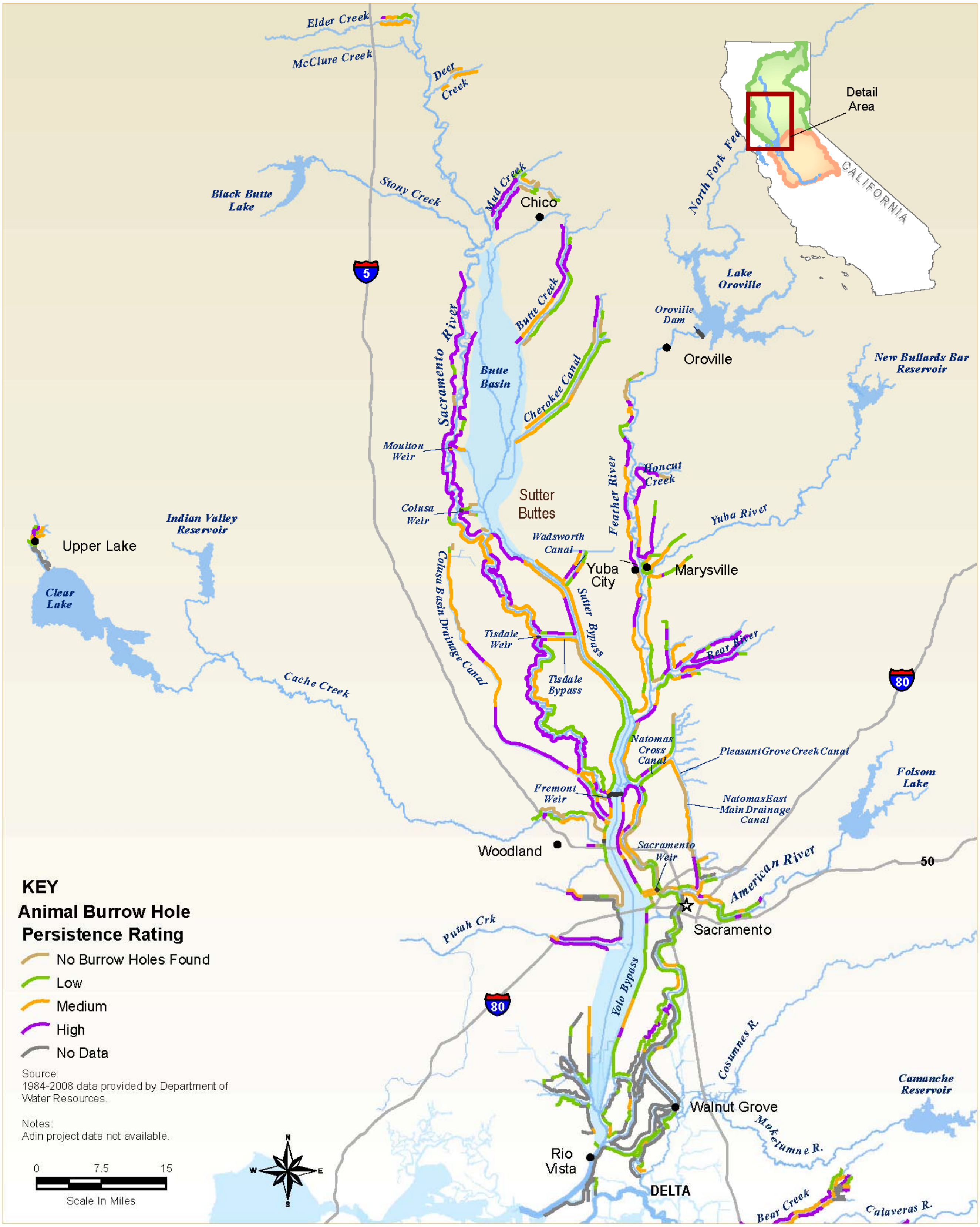


Figure 4-23. Animal Burrow Hole Persistence in Sacramento River Watershed

Figure 4-24. Animal Burrow Hole Persistence in San Joaquin River Watershed

4.9 Encroachments

Encroachments are any obstruction or physical intrusion by construction of works or devices, planting or removal of vegetation, or caused by any other means, for any purpose, into a flood control project, waterway area of the flood control project, or area covered by an adopted plan of flood control (California Code of Regulations Title 23 Chapter 1 Article 2 Section 4 (m)). Encroachments include boat docks, ramps, bridges, sand and gravel mining, placement of fill, fences, retaining walls, pump stations, residential structures, and irrigation and landscaping materials/facilities. Standard procedure is for the Board to obtain USACE approval before issuing an encroachment permit. More than 18,000 encroachment permits have been issued by the Board since its inception. A permit may be for a single encroachment or multiple encroachments. Many current encroachments are properly maintained. However, numerous permitted encroachments are not properly maintained, and numerous unpermitted encroachments exist on or within SPFC levee rights-of-way.

Encroachments can interfere with floodfighting, inspection, and maintenance

Unmaintained or unpermitted encroachments often jeopardize levee integrity and can interfere with floodfighting, inspection, and maintenance. Although adverse impacts to levees from encroachments can be associated with deferred maintenance, some encroachments posing a geotechnical hazard fall outside the jurisdiction of maintaining agencies to remediate because the encroachment may be Board-permitted or other factors may prevent maintaining agencies from taking action.

DWR is updating its *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley Version 4* (DWR, 2010d) to include encroachment criteria for urban levee design.

4.9.1 Status Evaluation Methodology

DWR visually inspects SPFC levees for encroachments at least two times per year, and reports results annually. Table 4-7 shows DWR inspection rating descriptions for encroachments on earthen levees, used for annual inspections in 2009.

Table 4-7. Levee Inspection Rating Descriptions for Encroachments on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	No trash or debris present. No excavation, structures, or other encroachments threaten levee integrity. No encroachments obstruct visibility or access to the levee or landside toe easement.
Minimally Acceptable (M)	Minimal trash or debris present. Minor excavation, structure, or other encroachments pose minor threat to levee integrity.
Unacceptable (U)	Significant trash or debris present. Major excavation, structure, or other encroachments pose major threat to levee integrity.
Partially Obstructing (PO)	An encroachment (permitted or nonpermitted) partially obstructs visibility and access to the levee and/or 10 feet beyond landside toe.
Completely Obstructing (CO)	An encroachment (permitted or nonpermitted) completely obstructs visibility and access to the levee and/or 10 feet beyond landside toe.

Source: DWR, 2010b

DWR documents and rates three types of encroachments:

- Encroachments that threaten levee integrity
- Encroachments that are inappropriately placed on a levee, such as trash, prunings, or equipment
- Encroachments that obstruct visibility and access

Encroachments that threaten levee integrity and those that are inappropriately placed on a levee are included in the overall ratings, and may need to be remediated by the maintaining agencies, if not permitted by the Board. Encroachments that obstruct visibility and access may be beyond the current authority of maintaining agencies to remediate because the encroachments may be Board-permitted, or have other associated factors that prevent maintaining agencies from taking action. DWR inspectors record the location, length, and type of encroachments that obstruct visibility and/or access. Partially Obstructing (PO) and Completely Obstructing (CO) encroachments are not included in the overall ratings (A, M, and U).

As discussed in Section 3.3, encroachment data were not considered in the assignment of ULE hazard classification or NULE hazard categorization. Detailed assessments or surveys of encroachments are beyond the scope of the DWR Levee Evaluations Program.

4.9.2 Limitations of Status Evaluations

Although efforts are underway to create a GIS database of historical encroachment permits, current inspection reporting does not distinguish between permitted or nonpermitted encroachments. It is also difficult for inspectors to determine whether observed encroachments are located within existing easement or right-of-way boundaries. A more thorough evaluation of encroachment status would include a complete inventory of permitted and nonpermitted encroachments and associated documentation, along with project-specific hydraulic modeling to assess the potential impact of encroachments on water surface elevation and levee integrity.

4.9.3 Results of Status Evaluations

The *2009 Annual Inspection Report* encroachment inspection ratings are shown in Figures 4-25 through 4-28 for the Sacramento and San Joaquin river watersheds, respectively (DWR, 2010b).

Minimally Acceptable and Unacceptable ratings are shown in Figures 4-25 and 4-26. Inspection results include 536 encroachment sites identified as minor threats to levee integrity (i.e., Minimally Acceptable) and 15 encroachment sites identified as major threats to levee integrity (i.e., Unacceptable). Encroachment sites may consist of multiple individual encroachments.[4]

Partially Obstructing and Completely Obstructing ratings are shown in Figures 4-27 and 4-28. Inspection results include 354 encroachment sites found to partially obstruct visibility and access to levees and 869 encroachment sites found to completely obstruct visibility and access.

Additional information on recent, ongoing, and planned levee remedial actions for encroachments and ongoing actions to improve future evaluations is included in Appendix A, Section A-10. Also, USACE periodic inspection results on encroachments for 10 USACE levee systems are included in Appendix A, Section A-1.

[4] Annual DWR inspections rate both individual encroachments and ranges of multiple adjacent encroachments. These ranges vary widely in length, but are rarely longer than a mile. Since ranges less than a mile long are difficult to identify at the map scale shown, all encroachment sites (both ranges and individual encroachments) are shown as points on the map.

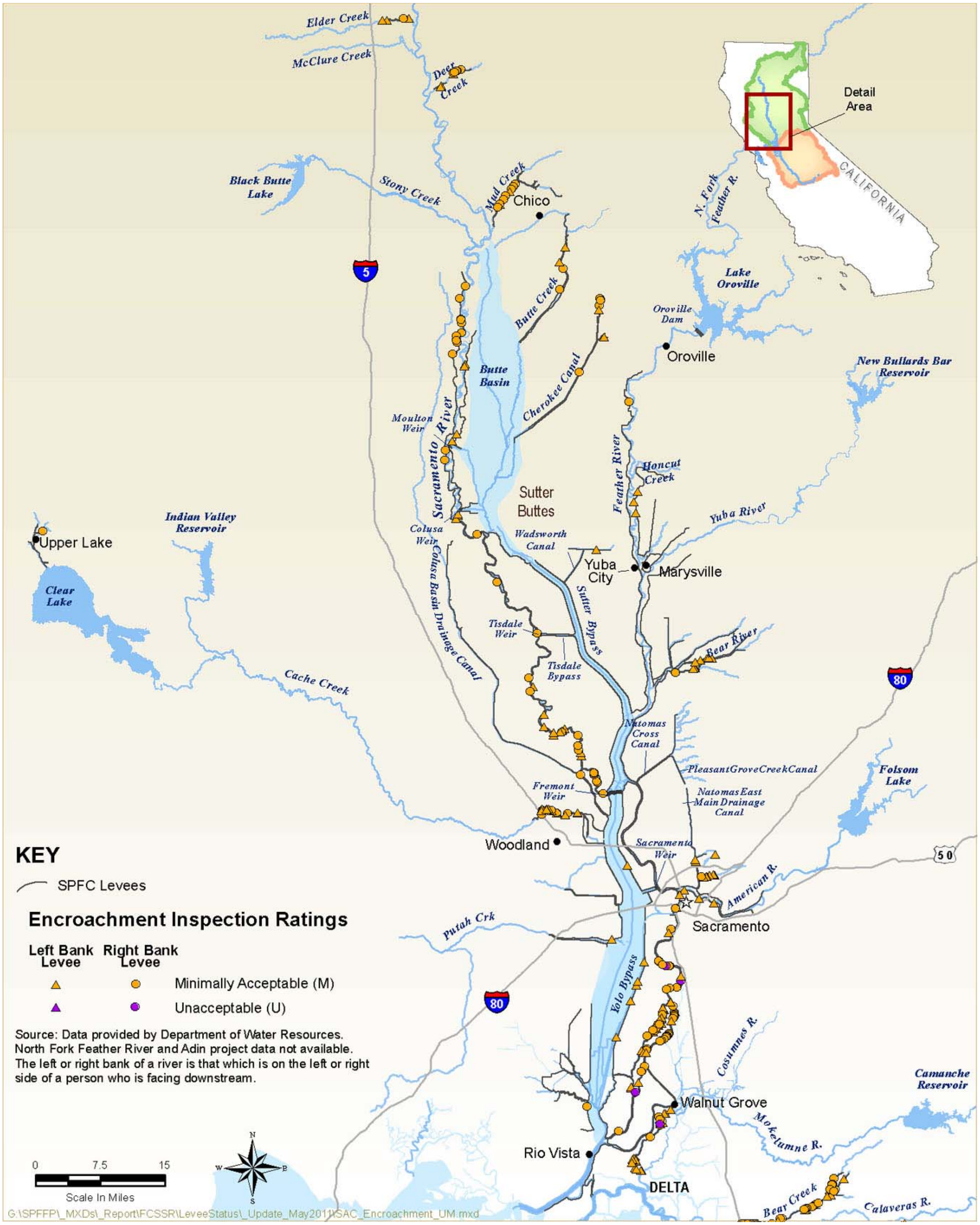


Figure 4-25. 2009 Encroachment Inspection Ratings in Sacramento River Watershed (Threats to Levee Integrity)

Figure 4-26. 2009 Encroachment Inspection Ratings in San Joaquin River Watershed (Threats to Levee Integrity)

Figure 4-27. 2009 Encroachment Inspection Ratings in Sacramento River Watershed (Obstructions to Visibility and Access)

Figure 4-28. 2009 Encroachment Inspection Ratings in San Joaquin River Watershed (Obstructions to Visibility and Access)

5.0 Channel Status

Channel conveyance capacity can be reduced by a number of factors. These factors can be the result of conditions in the channel, such as vegetation growth in the channel, sediment deposited in the channel, encroachments in the channel, bank erosion, revetments, and bank caving. Levee conditions such as lack of freeboard due to localized settlement, erosion, or original levee design can also reduce channel conveyance capacity. Consequently, identifying the causes of channel conveyance problems (and whether they are channel-related or levee-related) often requires additional site-specific investigation that is beyond the scope of this FCSSR. Furthermore, the conveyance capacity of the system is dynamic and therefore needs to be reevaluated at regular intervals.

Estimates of DWR channel conveyance capacity, as presented in this FCSSR, are not based on the same approach as USACE channel conveyance capacity estimates. DWR uses freeboard as an index point to estimate conveyance capacity, expressed as a flow value. USACE uses a risk-based or probabilistic approach to estimate conveyance capacity. While a risk-based approach provides a better indicator of flood risk, this approach has not been used to define performance expectations for SPFC channels. A risk-based approach can sometimes be impractical to use because of limited geotechnical data and dependence of the approach on the hydrological record, which changes dynamically based on new flood events.

This section summarizes channel conveyance capacity conditions, and then discusses channel vegetation and channel sedimentation as two key factors affecting channel conveyance capacity. Other factors that could reduce channel conveyance capacity (such as encroachments in the channel) were not evaluated because supporting data were not available.

5.1 Channel Conveyance Capacity

SPFC channel conveyance capacity has been estimated based on the ability of a channel to pass original design flood flows. Design flood flows (or design channel capacities) from different official sources have been sometimes inconsistent. These discrepancies have complicated the evaluation of channel conveyance capacities throughout the Sacramento and San Joaquin river watersheds.

The basis for evaluating channel conveyance capacity in the Sacramento River watershed was refined several times after the Flood Control Act of 1917. Design flows were later amended by the Flood Control Act of 1928, Senate Document Number 23, the 1953 Memorandum of Understanding between USACE and the Board (USACE and Board, 1953), and the 1957 design profile for the Sacramento River (USACE, 1957a). The profile and associated design capacities were developed based on USACE analysis of the 1937, 1951, and 1955 floods on the Sacramento River at the request of the Board.

In the San Joaquin River watershed (excluding the Mormon Slough Project), original design flows were derived from the *Report on Control of Floods, San Joaquin River and Tributaries Between Friant Dam and Merced River* (DWR, 1954) and later changed to reflect the 1955 design profile for the San Joaquin River, as shown in *Design Memorandum No. 1, San Joaquin River Levees, Lower San Joaquin River and Tributaries Project* (1955 design profile) (USACE, 1955b). For SPFC channels in the Mormon Slough Project, design capacities were based on the 1965 design profile (USACE, 1965).

All design profiles for the SPFC are included on the reference DVD of the *State Plan of Flood Control Descriptive Document* (DWR, 2010a), or can be viewed on the Board Web site (Board, 2011). For channels not delineated in the 1955, 1957, or 1965 design profiles above, design capacities were determined based on as-constructed capacities specified in appendices to O&M manuals provided by USACE.

Design channel capacities were calculated from the design profiles based on steady-state, uniform flow hydraulic computations of historical floods using data available at the time. Therefore, design channel capacities were based on a very limited hydrological record, were highly dependent on the boundary conditions assumed, and did not consider variations in flow and depth with respect to time and distance. Furthermore, the design profiles could not account for changes in vegetation and sedimentation patterns within the channels, or flood system improvements that have taken place after the historical floods used to derive the design flood flow capacities. For example, the 1955 historical flood used to determine the 1955 design profile for the San Joaquin River downstream from the Merced River confluence occurred before construction of the San Joaquin River bypass system.

Design channel capacities reported in USACE O&M manuals sometimes do not agree with channel capacities associated with design profiles. This is because USACE created some O&M manuals before the design profiles were adopted. DWR operates and maintains SPFC facilities based on design capacities calculated from the design profiles when available, rather than on design capacities included in the USACE O&M manuals (USACE, 1969). Design channel capacities from both the design profiles and O&M manuals are used as the basis for evaluation of channel conveyance capacities in this FCSSR.

5.1.1 Status Evaluation Methodology

Channel conveyance capacity conditions are evaluated in this FCSSR by comparing estimated existing capacities with design channel capacities specified in O&M manuals and design profiles provided by USACE for each SPFC channel.

Existing capacities were estimated for 1,016 miles of about 2,600 miles of SPFC channels using data from the *State Plan of Flood Control Existing Channel Capacity Assessment Technical Memorandum* (CVFED, 2009) and project-specific modeling results. Existing channel capacities were determined to be the lowest flow rate that occurs when the water surface encroaches on a levee low point (on either the left bank or right bank) minus the design freeboard height. It was assumed that when the water surface encroaches on freeboard at a single location, the capacity of the entire reach is compromised.

The 2009 State Plan of Flood Control Existing Channel Capacity Assessment was conducted by the DWR Central Valley Floodplain Evaluation and Delineation Program. The assessment of existing channel capacities was based strictly on analysis of available information. No direct geotechnical analyses, levee stability investigations, or new hydraulic modeling were conducted. Most of the existing channel capacity information was developed from channel capacity profiles prepared in support of the Comprehensive Study (USACE and DWR, 2002). When available, existing channel capacities from the *State Plan of Flood Control Existing Channel Capacity Assessment Technical Memorandum* (CVFED, 2009) were replaced with more recent project-specific modeling of individual reaches. Project-specific modeling results were provided by the DWR maintenance program or project-level hydraulic studies. The data source for each existing channel capacity is listed by reach in Appendix B, Tables B-1 and B-2.

For the FCSSR, the following criteria were used to determine whether estimated current capacities of the SPFC channels were sufficient to safely convey identified design capacities in the O&M manuals or design capacities calculated from design profiles:

- If the estimate of current capacity was greater than both the design capacity reported in the O&M manual and the design capacity based on the design profile, channel status was reported as “no obvious inadequacy.”

- If the estimate of current channel capacity was less than the design capacity reported in the O&M manual, or the design capacity based on the design profile (or both), the channel status was reported as “potential inadequacy; additional evaluation required.”

- If the estimate of current channel capacity for a reach depends on backwater flow assumptions, channel status was reported as "backwater controlled; additional evaluation required."

5.1.2 Limitations of Status Evaluations

Accuracy of the existing channel capacity estimates in this report was limited by the topographic and hydraulic modeling performed. Project-specific modeling results generally are less uncertain than systemwide modeling results. Uncertainties associated with estimating current channel capacities throughout the system include vertical datum errors, inaccurate levee crown profiles, arbitrary nature of standard freeboard values, limited calibration data, fixed-bed assumption, wind/wave effects, and unaccounted-for local hydrodynamic effects. Also, differing hydraulic modeling assumptions for boundary conditions, freeboard criteria, and top-of-levee elevations likely contribute to conflicting results among hydraulic modeling evaluations and should be resolved with additional evaluation.

Furthermore, estimates of current channel capacities throughout the system using modeling generally characterizes impedance to flow, and are not designed or intended to evaluate subtle changes in the channels as a result of vegetation, sediment deposition, and/or other obstructions in the channel.

Another uncertainty results from identifying levee low points. In many cases, low levee crown elevations for only a mile or so constrained the capacity of reaches as long as 30 miles. Project-specific modeling of individual reaches could demonstrate that the channel conveyance capacity at one location in a reach is not representative of the entire reach.

Because of these uncertainties, data included in this FCSSR cannot conclusively identify locations of channel conveyance capacity inadequacies, but instead the data identify potential inadequacies requiring additional evaluation.

5.1.3 Results of Status Evaluations

Differences between design capacities reported in O&M manuals and flows associated with the design profiles shown in Figures 5-1 and 5-2 demonstrate the need to resolve discrepancies in some locations. Potential inadequate channel conveyance capacities are shown in Figures 5-3 and 5-4.

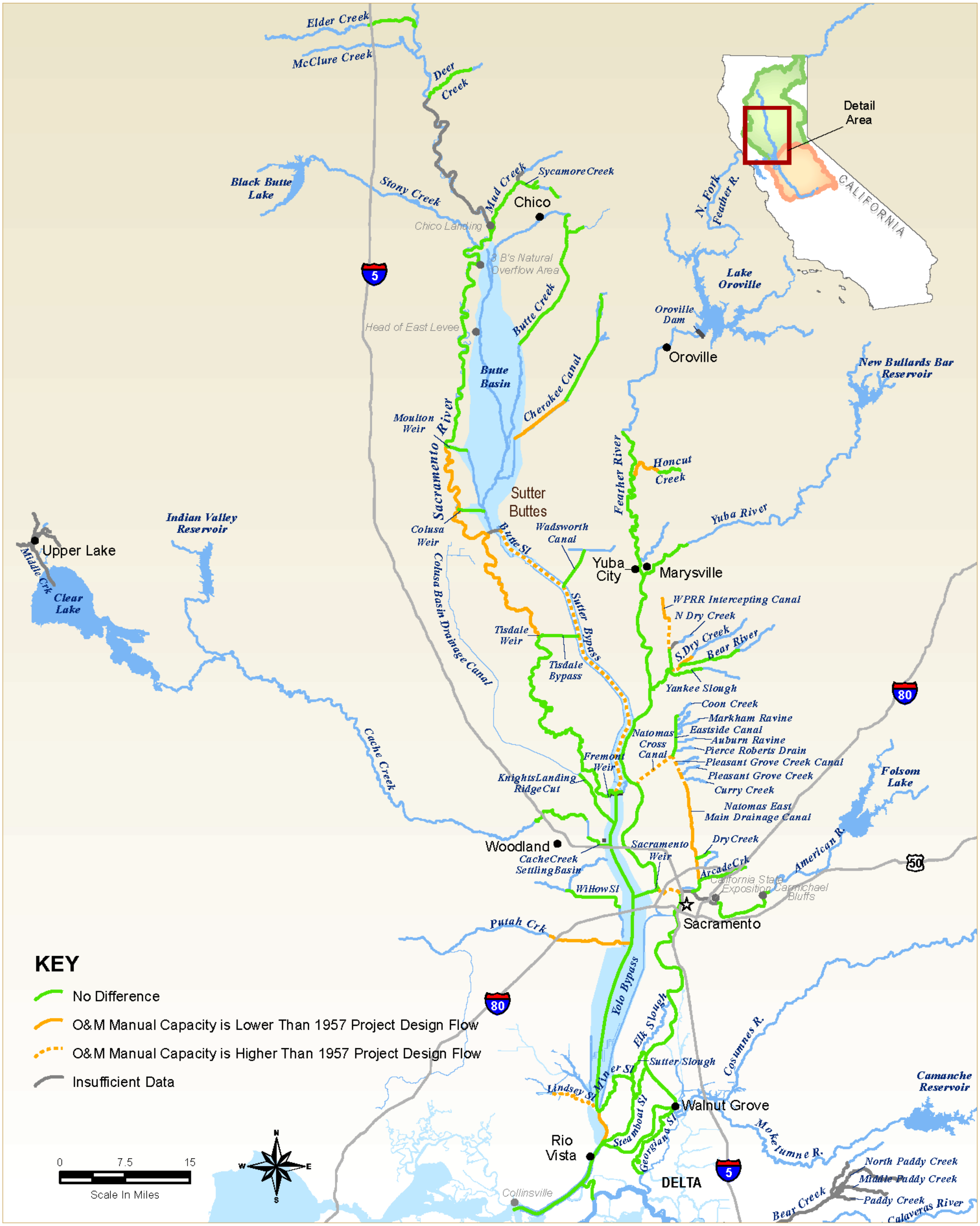


Figure 5-1. Differences Between O&M Manual Design Capacities and Design Profile Flows in Sacramento River Watershed

Figure 5-2. Differences Between O&M Manual Design Capacities and Design Profile Flows in San Joaquin River Watershed

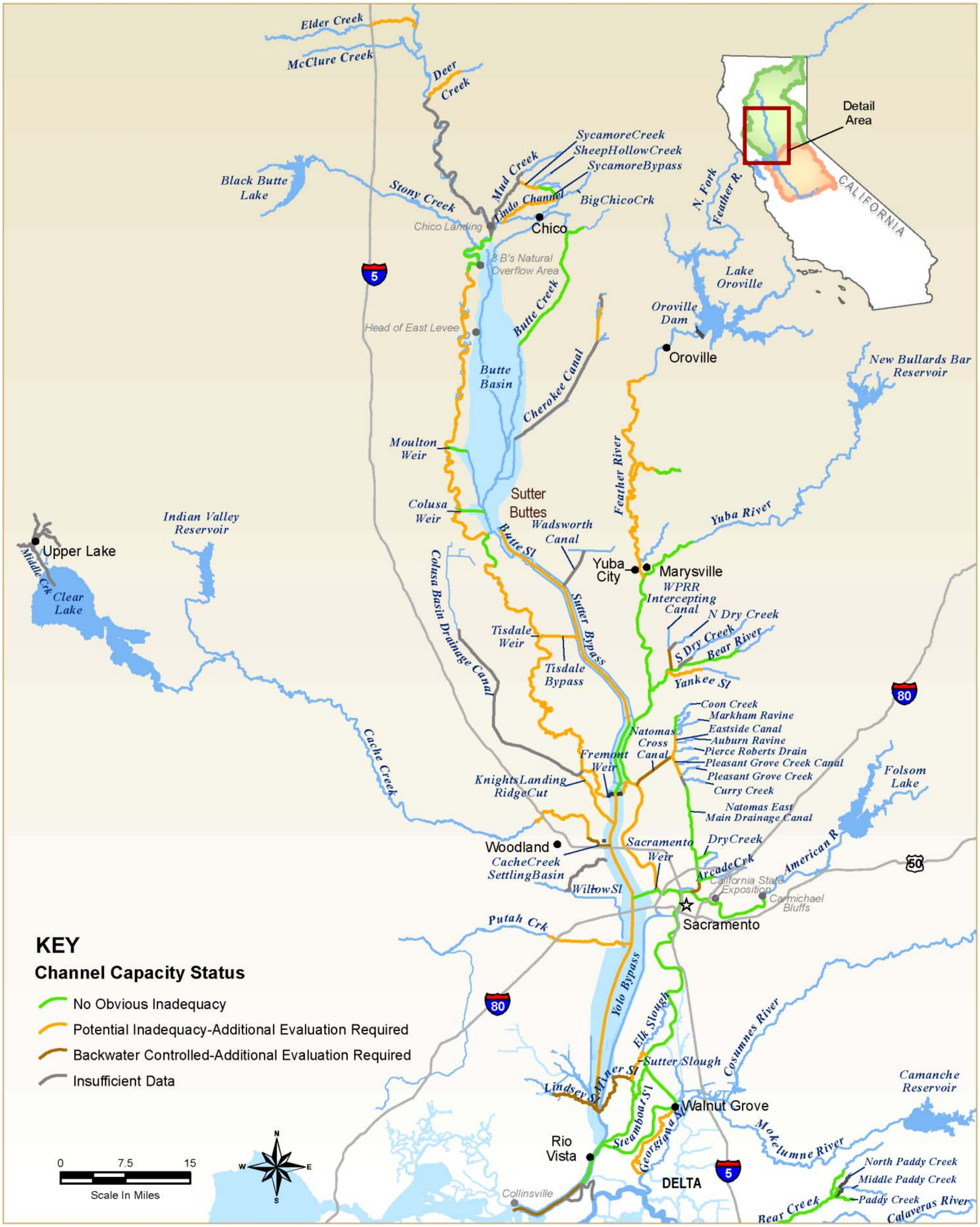


Figure 5-3. Channel Capacity Status in Sacramento River Watershed

Figure 5-4. Channel Capacity Status in San Joaquin River Watershed

For the Sacramento River watershed, approximately four-ninths of the channels show a potential capacity inadequacy and need for additional evaluation, and data are insufficient for approximately one-fifth of the channels. In general, approximately three-fifths of the channels in the San Joaquin River watershed show a potential capacity inadequacy and need for additional evaluation, and data are insufficient for one-eighth. These results will be refined as systemwide and project-specific hydraulic modeling efforts progress. Appendix B, Section B-1, contains tables of the results shown in Figures 5-3 and 5-4.

For additional information on recent, ongoing, and planned remedial actions/improvements, and ongoing actions to improve future evaluations, see Appendix B, Section B-2.

5.2 Channel Vegetation

Criteria for vegetation management in the channels have been evolving since SPFC facilities were constructed. Maintenance criteria are contained in standard and unit-specific O&M manuals provided by USACE, Title 23 of the California Code of Regulations, and Title 33 of the Code of Federal Regulations.

State and federal environmental laws have complicated efforts to maintain SPFC channels. These environmental laws include the State and federal Endangered Species Acts; federal Clean Water Act, federal Porter-Cologne Act and Migratory Bird Treaty Act; and California Fish and Game Code requirements for Stream Bed Alteration Agreements. Specifically, channel maintenance is increasingly challenging because of compliance requirements for these laws and regulations, and the length of time for obtaining approvals for maintenance.

Table 5-1 lists current standards that apply to vegetation management for channels. (Note that standards that apply to vegetation management for levees are discussed in Section 4.7.)

Table 5-1. Current Standards for Channel Vegetation Management

Source of Standard	General Description of Standard
Title 33, Federal Statutes, Part 208	Provides some flexibility in allowing vegetation in a channel as long as project works function properly and are not impaired by debris, weeds, or wild growth.
Title 23, CCR	Vegetation that impedes or misdirects floodflows is not permitted to remain within a floodway or bypass.[1]
General and unit-specific O&M manuals	Generally requires that "the channel or floodway is clear of debris, weeds and wild growth."[2] Limits vegetation in a project flood control channel to nondense brush or trees not more than 2 inches in diameter. Vegetation in channel is allowed if the design water surface profile is maintained.
USACE Sacramento District correspondence[3]	Allowable vegetation in a floodway shall not affect the capability of the project works to convey design flows within specified levels of freeboard, and shall not compromise the integrity or inspectability of the flood control project. In addition, channels shall pass design flows at stage levels at or below the 1957 design profile.[4] Projects containing significant vegetation within a channel will be considered in compliance when the sponsor shows, through hydraulic analysis, that the project is capable of conveying design flows while maintaining the specified levels of freeboard.
Clean Water Act Section 404	Vegetation management activities could require that a Clean Water Act Section 404 permit be obtained from USACE for discharge of dredged or fill material into "waters of the United States, including wetlands." Waters of the United States include traditionally navigable rivers and their tributaries, and adjacent wetlands that have a significant nexus with waters of the United States. If a Section 404 permit is required, a Clean Water Act Section 401 Water Quality Certification would also be required by the Regional Water Quality Control Board.
Federal Endangered Species Act	Vegetation management activities could potentially adversely impact fish and wildlife species and their habitat. Section 7 of the Endangered Species Act outlines procedures for federal interagency cooperation for implementing the Endangered Species Act. Section 7(a)(2) requires that federal agencies consult with USFWS and/or NMFS so that "any action authorized, funded, or carried out by such agency" does not jeopardize the existence of a listed species or adversely modify critical habitat. If there is no federal nexus, a Habitat Conservation Plan or low-threat Habitat Conservation Plan may need to be prepared and complied with.
California Endangered Species Act	Vegetation management activities could potentially adversely impact fish and wildlife species and their habitat. Pursuant to the California Endangered Species Act, a permit from the California DFG is required for projects that could result in the "take" of a plant or animal species that is State-listed as threatened or endangered, or is a candidate species. In accordance with Sections 2080 and 2081 of the California Fish and Game Code, a Consistency Determination or Incidental Take Permit could be required.
California Fish and Game Code Section 1600, Streambed Alteration Agreement	Because vegetation management activities conducted in channels could potentially change the bed, channel, or bank of a channel, and potentially adversely impact fish and wildlife species and their habitat, a California Fish and Game Code Section 1600 Streambed Alteration Agreement may be needed (DFG, 2010).
DWR Interim Levee Vegetation Inspection Criteria	Interim Levee Vegetation Inspection Criteria that also affect vegetation in channels (DWR, 2007).

Table 5-1. Current Standards for Channel Vegetation Management (contd.)

Source of Standard	General Description of Standard
Central Valley Flood System Improvement Framework—Interim Criteria for Vegetation Management	Interim Criteria for Vegetation Management (until adoption of CVFPP) (California Levees Roundtable, 2009).

Notes:
[1] Title 23, California Code of Regulations, Section 131.
[2] Standard O&M Manual for the Sacramento River Flood Control Project, revised May 1955, USACE Sacramento District. (USACE, 1955a).
[3] USACE correspondence dated August 14, 2006, regarding The Reclamation Board's request for clarification of the State's O&M responsibilities associated with federal projects for which The Reclamation Board provided assurances of cooperation.
[4] USACE *Levee and Channel Profiles, File Number 50-10-334.*

Key:
CCR = California Code of Regulations
CVFPP = Central Valley Flood Protection Plan
DFG = California Department of Fish and Game
DWR = California Department of Water Resources
NMFS = National Marine Fisheries Service
O&M = operations and maintenance
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service

5.2.1 Status Evaluation Methodology

Channel vegetation conditions are evaluated by the degree to which vegetation impedes flood flows. Vegetation management conditions were evaluated against DWR's current maintenance standards using results of annual inspections in 2009. DWR visually inspects 26 channels identified as SPFC channels at least twice a year, in addition to visually inspecting channels adjacent to SPFC levees at least twice a year at the same time the levees are inspected. Table 5-2 contains rating descriptions for channel vegetation. Each channel inspection location includes a separate upstream and downstream channel inspection rating. In this FCSSR, only the worst of the two ratings is reported for each location.

Table 5-2. Channel Inspection Rating Descriptions for Channel Vegetation

Inspection Rating	Rating Description
Acceptable (A)	Minimal, scattered obstructions or vegetation. Flow is not impeded.
Minimally Acceptable (M)	Log jams, snags, vegetation growth (such as cattails, bullrushes, bushes, or saplings), or other obstructions block approximately 25 percent of the flood control work.
Unacceptable (U)	Log jams, snags, vegetation growth (such as cattails, bullrushes, bushes, or saplings), or other obstructions block approximately 50 percent of the flood control work.

5.2.2 Limitations of Status Results

Information on channel vegetation management conditions is limited to the channels that DWR inspects (26 channels and 186 total miles) and to conditions that are visible. Channel vegetation inspections are usually performed from selected points along a channel and from the crown of a levee. Impacts of vegetation on channel conveyance can be evaluated more thoroughly using the following methods: past performance evaluation, vegetation surveying, and project-specific hydraulic modeling.

To comply with USACE guidance, DWR must demonstrate that vegetation in a channel does not impact channel conveyance capacity and does not encroach on the freeboard. Clarification is often needed on the specified levels of freeboard used to determine the extent of allowable vegetation throughout a channel. Inconsistencies on the required level of freeboard are common among SPFC channels: the freeboard cited in O&M manuals often conflicts with the freeboard specified in as-constructed plans. Determining the required levels of freeboard is therefore critical in assessing conveyance capacity, and whether vegetation or other factors are impeding proper functioning of SPFC facilities.

5.2.3 Results of Status Evaluations

Channel inspection ratings for vegetation from the *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (DWR, 2010b) are shown in Figures 5-5 and 5-6 for channels maintained by DWR and other maintaining agencies. Of the 186 miles of SPFC channels inspected by DWR, one location was rated Unacceptable (Berenda Slough, downstream from Avenue 21) and 54 locations were rated Minimally Acceptable for channel vegetation. Additional vegetation problems may be present in channels not inspected by DWR.

Areas that are undergoing active vegetation management, or in which vegetation management has been initiated or required in the Sacramento River watershed, are shown in Figure B-5 in Appendix B, Section B-2. Similar data were unavailable for the San Joaquin River watershed. For additional information on recent remedial actions/improvements, ongoing and planned remedial actions/improvements, and ongoing actions to improve future evaluations of vegetation management in channels, see Appendix B, Section B-2.

Figure 5-5. 2009 Channel Vegetation Inspection Ratings in Sacramento River Watershed

Figure 5-6. 2009 Channel Vegetation Inspection Ratings in San Joaquin River Watershed

5.3 Channel Sedimentation

Since SPFC facilities were constructed, maintenance standards have been consistent in requiring actions to address shoaling or sedimentation that reduces channel conveyance capacity or deflects flows within a channel. Channel sedimentation can occur in areas of significant flow expansion (i.e., bypass inlets), in backwater near confluences, or in some tidally influenced reaches. In addition to reducing channel conveyance capacity, channel sedimentation of natural channels can cause lateral redirection of flows, leading to bank erosion. (In cases where design channel capacity is not impaired, such flow redirection problems caused by sedimentation can be addressed by sediment redistribution within the channel, instead of more expensive sediment removal and disposal.)

Sedimentation can also induce vegetation encroachment when low-flow conditions prevent the natural removal of vegetation on bars that are formed along a channel. Several areas with known sedimentation problems, such as the Cherokee Canal and Yuba River, are associated with hydraulic mining debris from the nineteenth century. Sedimentation also often results from eroding riverbanks and levees and agricultural runoff.

Table 5-3 lists current standards that apply to sediment management for channels.

Table 5-3. Current Standards for Channel Sediment Management

Source of Standard	Description of Standard
Title 33, Federal Statutes, part 208	Sediment management is to be performed in channels so that flood conveyance capacity is maintained.
Federal Clean Water Act Section 404	Channel sedimentation management activities could require a Clean Water Act Section 404 permit to be obtained from USACE for discharge of dredged or fill material into "waters of the United States, including wetlands." Waters of the United States include traditionally navigable rivers and their tributaries and adjacent wetlands that have a significant nexus with waters of the United States. If a Section 404 permit is required, a Clean Water Act Section 401 Water Quality Certification would also be required by the Regional Water Quality Control Board.
Federal Rivers and Harbors Act	The River and Harbors Act of 1899 addresses activities that involve the construction of, among other structures, dams, bridges, and dikes across any navigable water. The act also addresses placement of obstructions to navigation outside established federal lines, as well as the excavation or deposition of material in such waters. All of these actions require permits from USACE.
Unit-specific O&M manuals	Generally, limit sedimentation in a project flood protection system so that "the capacity of the channel or floodway is not being reduced by the formation of shoals."

Table 5-3. Current Standards for Channel Sediment Management (contd.)

Source of Standard	Description of Standard
Engineer Technical Letter 1110-2-571	Provides some flexibility to sediment management if the water surface profile is maintained. The operative rule is that "capacity of the channel or floodway is not being restricted by the formation of shoals" (USACE, 2009b).
Standard O&M Manual for the Sacramento River Flood Control Project	States that "the capacity of the channel or floodway is not being reduced by the formation of shoals" and "sediment, rubbish, industrial waste or any debris plugs or other obstructions should be removed from the channel to prevent any tendency for the flows to be deflected within the channel" (USACE, 1955a)

Key:
O&M = operations and maintenance
USACE = U.S. Army Corps of Engineers

5.3.1 Status Evaluation Methodology

Sediment management conditions were evaluated against DWR's current maintenance standards using results of the *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (DWR, 2010b). Table 5-4 shows DWR inspection rating descriptions for shoaling and sedimentation in SPFC channels. Each channel inspection location includes a separate upstream and downstream channel inspection rating. In this FCSSR, only the worst of the two ratings is reported for each location.

Table 5-4. Channel Inspection Rating Descriptions for Shoaling and Sedimentation

Inspection Rating	Rating Description
Acceptable (A)	No shoaling or sedimentation present.
Minimally Acceptable (M)	Nonaquatic grasses present on shoal. No trees or brush are present on shoal, and channel flow is not impeded.
Unacceptable (U)	Shoaling is well established, and stabilized by trees, brush, or other vegetation. Shoals are diverting flow to channel bank causing bank erosion and undercutting.

5.3.2 Limitations of Status Evaluations

Information on channel sedimentation conditions is limited to the channels that DWR inspects (26 channels and 186 miles) and to conditions that are visible. Shoaling and sedimentation inspections are usually performed from selected points along a channel and from the crown of a levee. Sedimentation conditions can be evaluated more thoroughly using the following methods: observation, past performance evaluation, channel surveying, and project-specific hydraulic modeling. Using these methods, a channel is determined to be inadequate if the channel capacity is less than the design capacity. Data on lowering of channel beds, bank instability, and channel widening are not available.

5.3.3 Results of Status Evaluations

Shoaling and sedimentation channel inspection ratings from the *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (DWR, 2010b) are shown in Figures 5-7 and 5-8. Of the 186 miles of SPFC channels inspected by DWR, one location was rated Unacceptable (Berenda Slough, downstream and upstream from Avenue 21) and 23 locations were rated Minimally Acceptable for shoaling and sedimentation. Additional channel sedimentation problems may exist in areas not inspected by DWR.

Figure B-6 in Appendix B, Section B-3, shows the current status of sediment management projects in channels that DWR is responsible for maintaining in the Sacramento River watershed. Graphs embedded in Figure B-6 show annual cubic yards of sediment removed by DWR from 1983 through 2009. Data for sediment management activities in the San Joaquin River watershed are currently not available.

For additional information on recent remedial actions/improvements, ongoing and planned remedial actions/improvements, and ongoing actions to improve future evaluations of sedimentation in SPFC channels, see Appendix B, Section B-3.

Figure 5-7. 2009 Channel Shoaling/Sedimentation Inspection Ratings in Sacramento River Watershed

Figure 5-8. 2009 Channel Shoaling/Sedimentation Inspection Ratings in San Joaquin River Watershed

6.0 Flood Control Structure Status

The SPFC depends on many flood control structures built along tributaries and bypasses to redirect, restrict, or attenuate floodflows to protect lives and property, including hydraulic structures, pumping plants, and bridges. Although major flood control structures in the Sacramento and San Joaquin river watersheds are part of the SPFC, the flood management system also relies on many non-SPFC hydraulic structures, pumping plants, and bridges to convey floodwaters. Flow in the Sacramento River is reduced by floodwater spilled into bypass areas through five SPFC weirs (Moulton, Colusa, Tisdale, Fremont, and Sacramento). Because of these spills to the bypass areas, the design flow capacity of the Sacramento River generally decreases in a downstream direction except where tributary inflow increases river flow. In the upper San Joaquin River, SPFC hydraulic structures help direct flows into the Chowchilla, Eastside, and Mariposa bypasses.

Some flood control structures are multiuse and are operated during both the flood and nonflood seasons under differing parameters. A few of the structures are mainly used to manage flows during nonflood season. These flood control structures include fixed crest diversion weirs, controllable diversion structures, outfall structures, drop structures, and interior drainage pumping plants. Flood control structures also include the M&T and Goose Lake flood relief structures and bridges that are maintained by DWR to convey floodwaters in accordance with California Water Code Section 8361.

Many flood control structures in the SPFC were designed and constructed before current design criteria were adopted, and have not been upgraded to meet current inspection criteria. These structures were generally built between 1940 and 1970, with several structures constructed even earlier. A few structures were modified or improved in the intervening years, but many of the structures are near or have exceeded the end of their expected service lives. Some flood control structures are visibly aging and have significant age-related damage and other problems, in addition to being functionally obsolete (meaning that they have inadequate controls, lack redundant backup power supply, or have restricted access for maintenance).

DWR’s maintenance activities for SPFC flood control structures were the subject of an annual report in 1959, entitled *Location, Description and Inventory of Miscellaneous Project Structures, Sacramento River Flood Control Project, and American River Flood Control Project.* This report was followed shortly by a maintenance status report. DWR has since provided annual maintenance status reports on flood control structures to the Board.

DWR inspects federal project structures in both the Sacramento and San Joaquin watersheds. Several of these project structures are not part of the SPFC because documentation of State assurances of nonfederal cooperation has not been found, but these structures are included in this section to provide status information. Physical conditions of project flood control structures inspected by DWR in 2009 are summarized below, according to the following categories:

- Hydraulic structures
- Pumping plants
- Bridges

Status information for the M&T and Goose Lake flood relief structures is not included because they were not inspected in 2009.

6.1 Hydraulic Structures

SPFC hydraulic structures include weirs, drop structures, control structures, drainage structures, and outfall structures. DWR has historically conducted visual inspections and documented conditions of SPFC hydraulic structures (but not to evaluate their structural integrity). DWR inspection criteria have evolved as USACE has updated design guidance. The most significant recent change in DWR inspection criteria is the emphasis on structural integrity (overall condition of the structures) and the functionality of hydraulic structures (such as availability of redundant backup power supply).

DWR has expanded its current inspection program to evaluate overall conditions of the hydraulic structures it maintains. Because the hydraulic structures maintained by DWR are the oldest in the system and are near or have exceeded their expected service lives, DWR is now evaluating these structures to determine their future serviceability. Furthermore, DWR is working with USACE and maintaining agencies to evaluate other hydraulic structures and, if necessary, reconstruct them with USACE to meet federal standards.

6.1.1 Status Evaluation Methodology

Annual inspections for hydraulic structures form the basis for this evaluation, as presented in the DWR *2009 Inspection Report of the Central*

Valley State-Federal Flood Protection System (2010b). In addition, 2009 inspection results from the DWR Hydraulic Structures Inspection Program were incorporated into the evaluation, as appropriate (see Section 2.1 for details on the two inspection programs). Thirty-two SPFC hydraulic structures and twelve non-SPFC hydraulic structures were inspected. The hydraulic structure inspections rated conditions as Acceptable (A), Minimally Acceptable (M), or Unacceptable (U) based on the following categories: structural condition, vegetation and obstructions, encroachments, and erosion/bank caving and shoaling/sedimentation. These categories are based on the USACE *Flood Damage Reduction Segment/System Inspection Report* (2009a).

Hydraulic structure inspection ratings for structural conditions include a wide variety of inspection categories:

- Closure structures
- Concrete surfaces
- Concrete tilting/settlement
- Concrete foundations
- Culverts: inlets/outlets
- Culverts: breaks/holes/cracks
- Electric gate operators
- Flap gates
- Manual gate operators
- Metal pipes
- Monolith joints
- Other metallic items
- Revetments
- Sluice/slide gates
- Trash racks

Detailed hydraulic structure inspection rating descriptions for structural conditions can be found in the DWR *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (2010b). Tables 6-1 through 6-3 show DWR inspection rating descriptions of hydraulic structures for vegetation and obstructions conditions, encroachment conditions, and erosion/bank caving and shoaling/sedimentation conditions, respectively.

Table 6-1. Hydraulic Structure Inspection Rating Descriptions for Vegetation and Obstruction Conditions

Inspection Category	Inspection Rating	Rating Description
Vegetation and Obstructions	Acceptable (A)	Minimal, scattered obstructions or vegetation. Flow is not impeded.
	Minimally Acceptable (M)	Log jams, snags, vegetation growth (such as cattails, bullrushes, bushes, or saplings), or other obstructions block approximately 25 percent of the flood control work.
	Unacceptable (U)	Log jams, snags, vegetation growth (such as cattails, bullrushes, bushes, or saplings), or other obstructions block approximately 50 percent of the flood control work.

Table 6-2. Hydraulic Structure Inspection Rating Descriptions for Encroachment Conditions

Inspection Category	Inspection Rating	Rating Description
Encroachments	Acceptable (A)	No trash, debris, excavation, structures, or other obstructions present within the project easement area. Encroachments that do not diminish proper functioning of the project have been previously approved by the Central Valley Flood Protection Board.
	Minimally Acceptable (M)	Trash, debris, excavations, structures, other obstructions present, or inappropriate activities that will not inhibit project operations and maintenance or emergency operations. Encroachments have been approved by the Central Valley Flood Protection Board.
	Unacceptable (U)	Trash, debris, excavations, structures, other obstructions present, or inappropriate activities that will inhibit project operations and maintenance or emergency operations.

Table 6-3. Hydraulic Structure Inspection Rating Descriptions for Erosion/Bank Caving and Shoaling/Sedimentation Conditions

Inspection Category	Inspection Rating	Rating Description
Erosion/Bank Caving	Acceptable (A)	No active erosion or bank caving observed on the landward or riverward side of the levee.
	Minimally Acceptable (M)	Active erosion is occurring in some areas or has occurred on or near the levee embankment, but levee integrity is not threatened.
	Unacceptable (U)	Erosion or caving is occurring or has occurred that threatens the stability and integrity of the levee. The erosion or caving has progressed into the levee section or into the extended footprint of the levee foundation and has compromised the levee foundation stability.
Shoaling/ Sedimentation	Acceptable (A)	No shoaling or sedimentation present.
	Minimally Acceptable (M)	Nonaquatic grasses present on shoal. No trees or brush are present on shoal, and structure operation and channel flows are not impeded.
	Unacceptable (U)	Shoaling is well established, and is stabilized by trees, brush, or other vegetation. Shoals are obstructing structure operation or diverting flow to channel bank, causing bank erosion and undercutting.

6.1.2 Limitations of Status Evaluations

This evaluation covers only hydraulic structures inspected by DWR, and is limited to conditions that can be visually inspected, annually, during the summer. Most hydraulic structures inspected by DWR are part of the SPFC, but there are a few non-SPFC structures inspected as part of federal projects. Status information for other hydraulic structures in the flood management system is not included because it was not available.

6.1.3 Results of Status Evaluations

Hydraulic structure conditions observed during annual inspections in 2009 (DWR, 2010b) are presented in Figures 6-1 through 6-8 for the Sacramento and San Joaquin river watersheds. Tabular results summarizing the Minimally Acceptable and Unacceptable inspection ratings for SPFC and non-SPFC hydraulic structures are shown in Table 6-4.

Ongoing and planned remedial actions and ongoing actions to improve future evaluations are summarized in Appendix C, Section C-1.

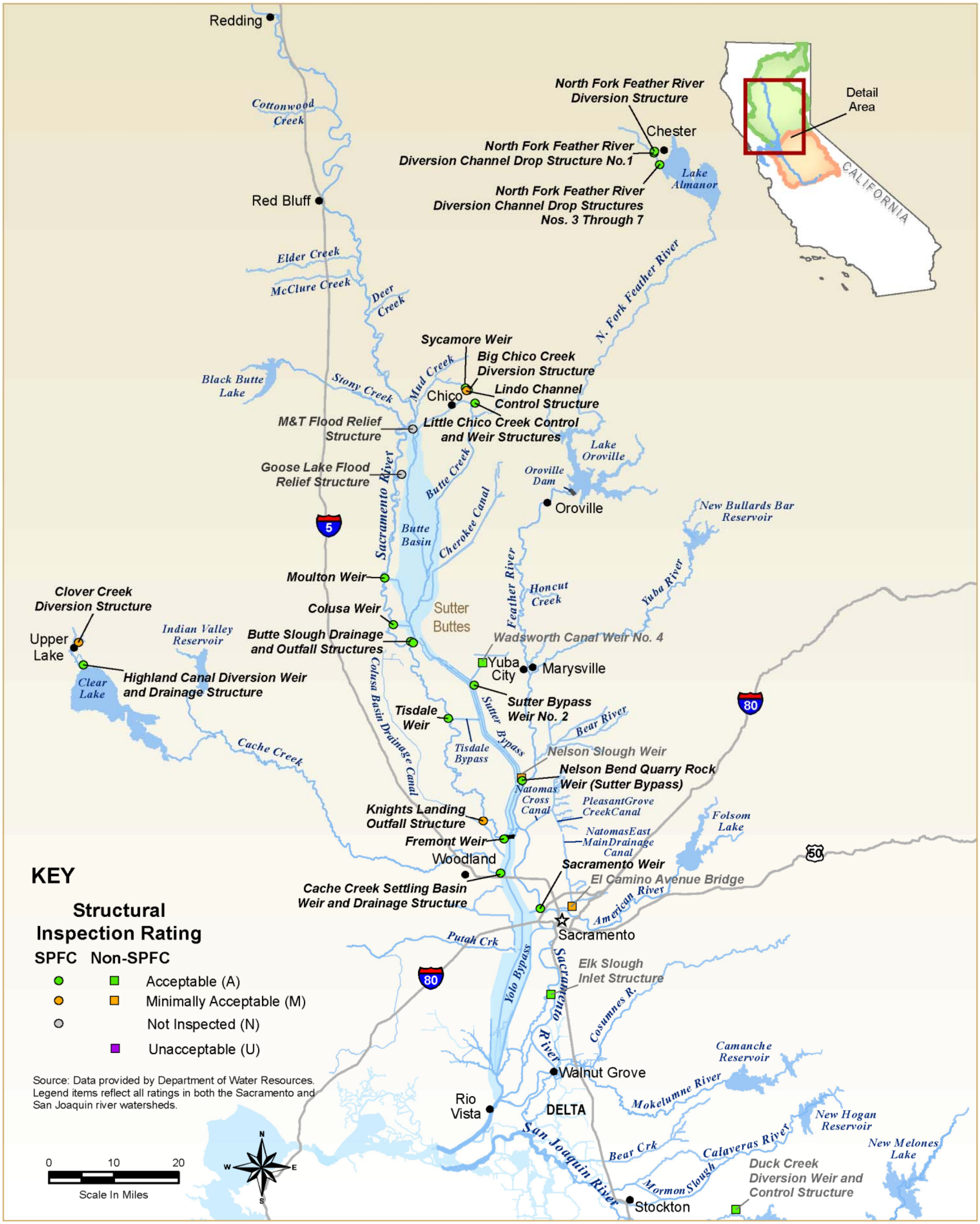


Figure 6-1. Hydraulic Structures – Structural Conditions in Sacramento River Watershed

Figure 6-2. Hydraulic Structures – Structural Conditions in San Joaquin River Watershed

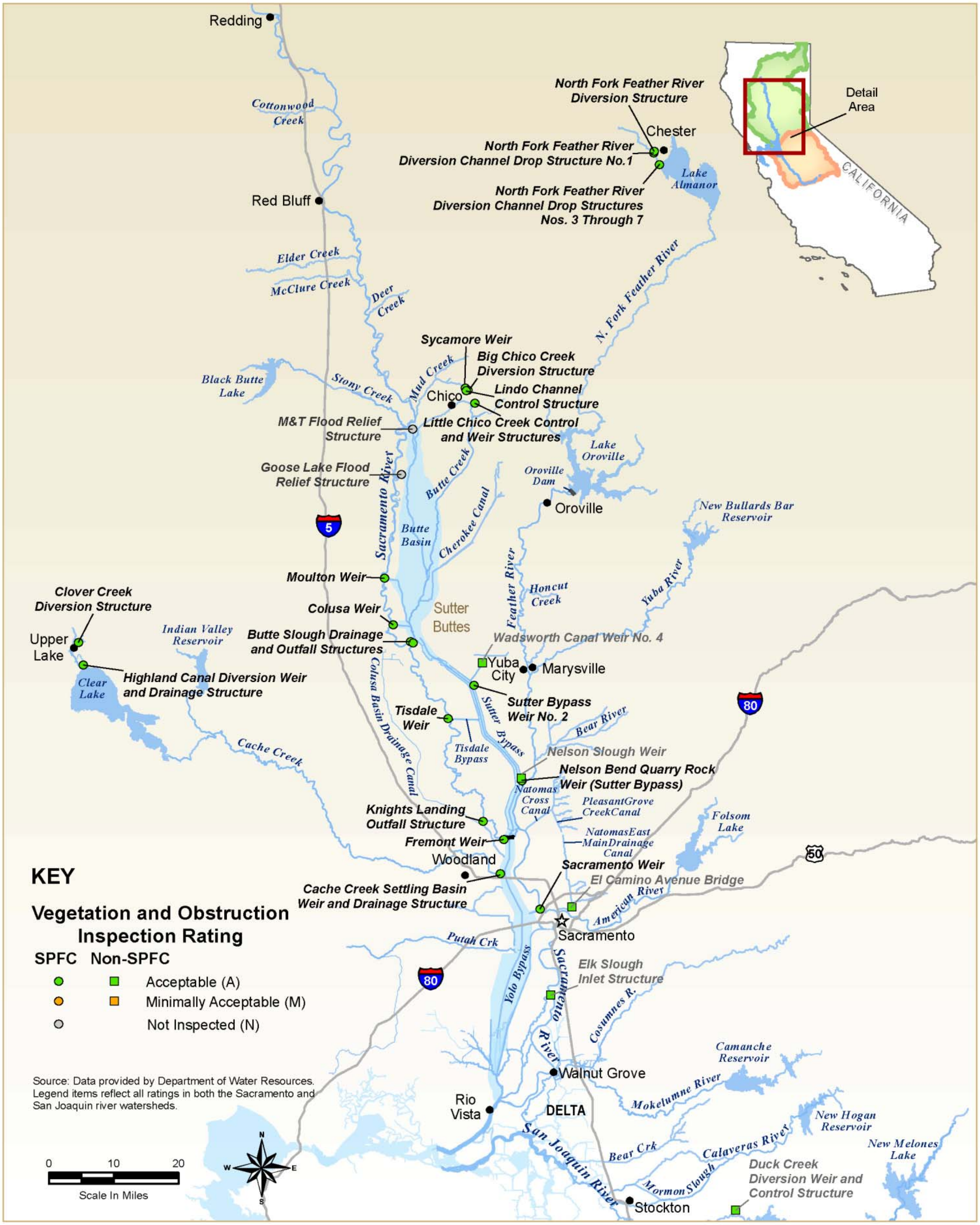


Figure 6-3. Hydraulic Structures – Vegetation and Obstruction Conditions in Sacramento River Watershed

Figure 6-4. Hydraulic Structures – Vegetation and Obstruction Conditions in San Joaquin River Watershed

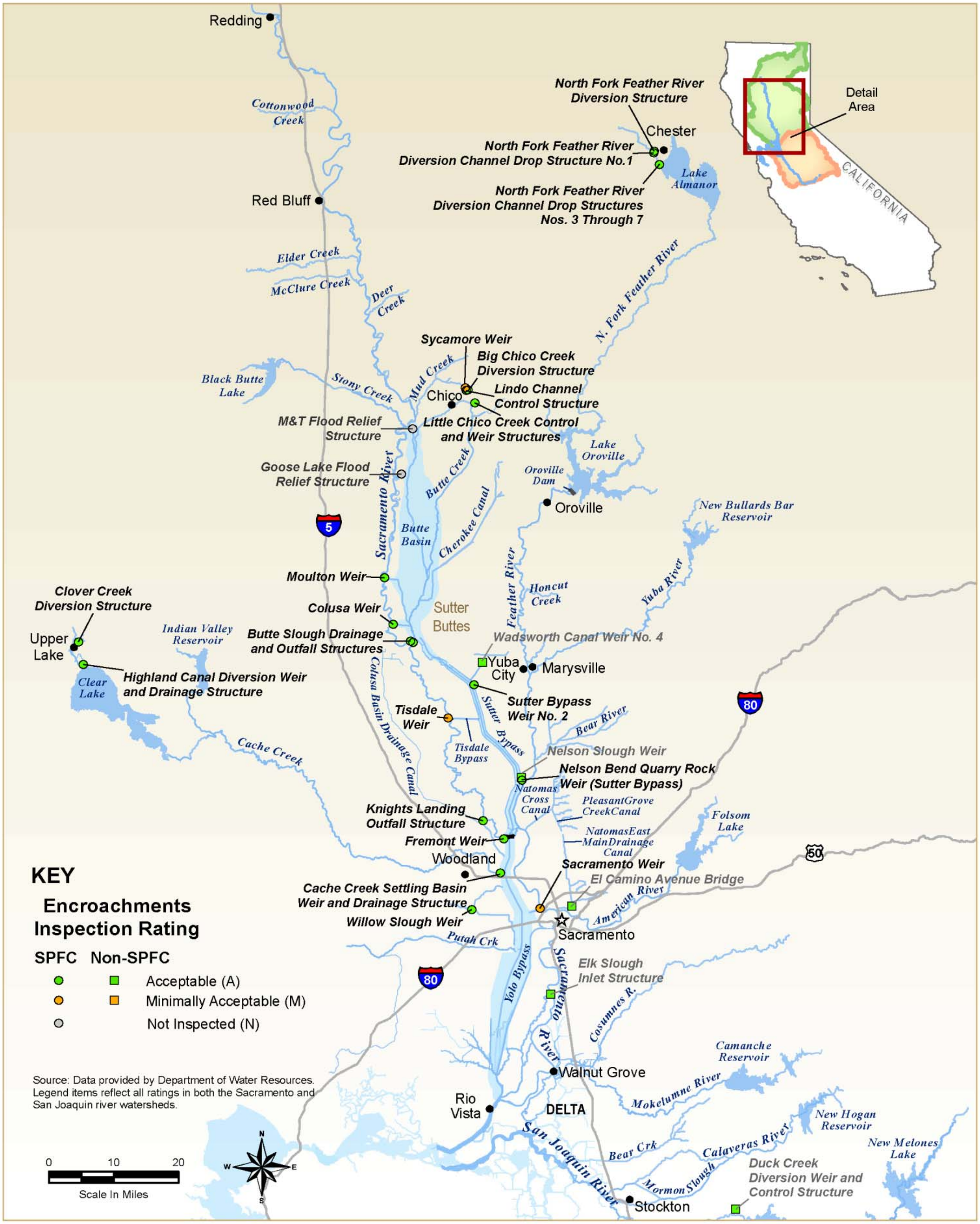


Figure 6-5. Hydraulic Structures – Encroachment Conditions in Sacramento River Watershed

Figure 6-6. Hydraulic Structures – Encroachment Conditions in San Joaquin River Watershed

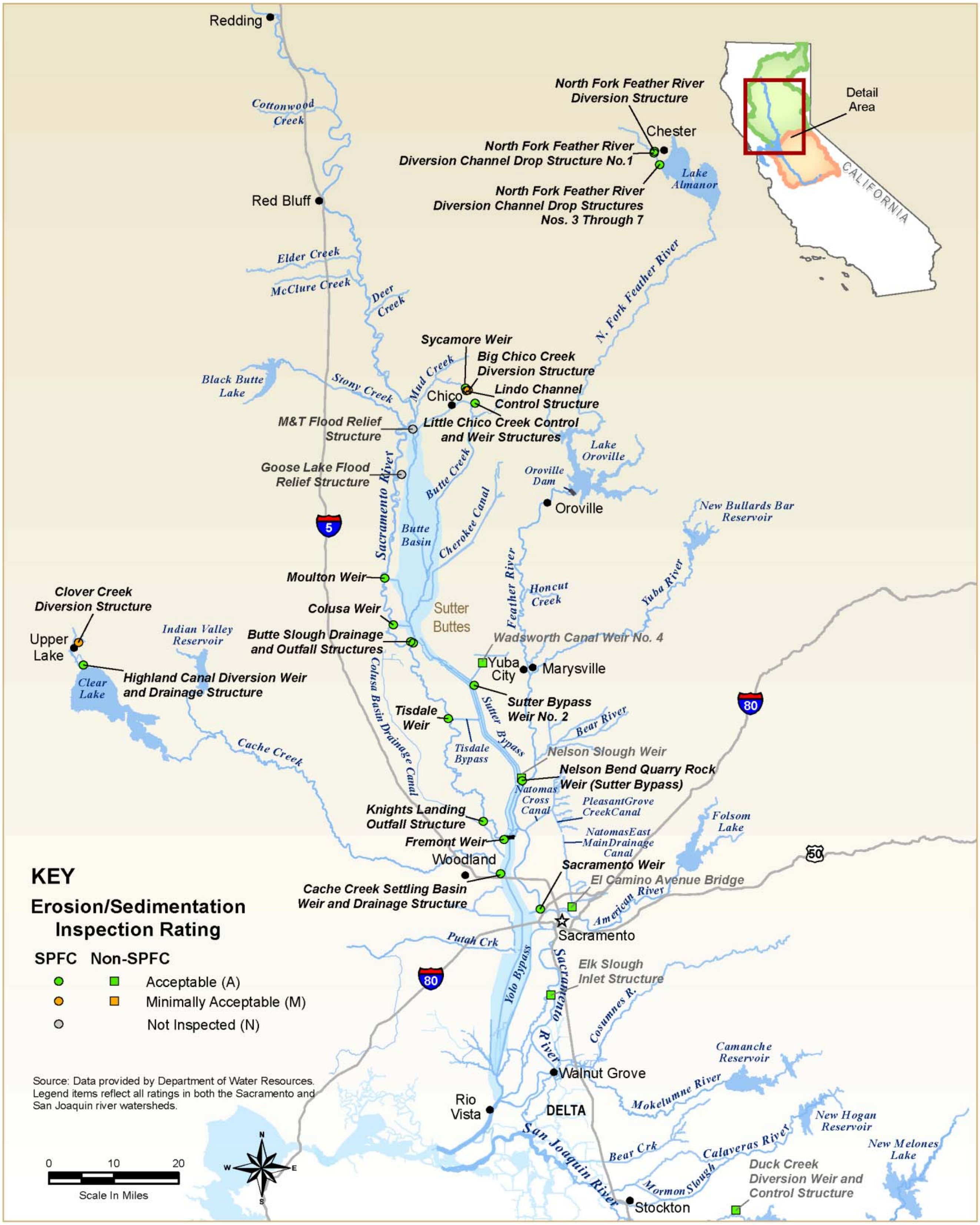


Figure 6-7. Hydraulic Structures – Erosion/Bank Caving and Shoaling/Sedimentation Conditions in Sacramento River Watershed

Figure 6-8. Hydraulic Structures – Erosion/Bank Caving and Shoaling/Sedimentation Conditions in San Joaquin River Watershed

Table 6-4. Hydraulic Structure Conditions Summary (2009)

	SPFC Hydraulic Structures[1]			Non-SPFC Hydraulic Structures[1,2]		
Inspection Category	**Unacceptable**	**Minimally Acceptable**	**Acceptable**	**Unacceptable**	**Minimally Acceptable**	**Acceptable**
Structural	0	5	27	1	5	6
Vegetation/ Obstructions	0	2	30	0	2	10
Encroachment	0	4	28	0	2	10
Erosion/Bank Caving Shoaling/ Sedimentation	0	2	30	0	1	11

Note:
[1] Information is summarized for hydraulic structures inspected by DWR in 2009, only.
[2] Non-SPFC hydraulic structures summarized are inspected by DWR as part of the federal project, but not as part of the SPFC because they lack documentation of assurances of nonfederal cooperation from the Board to USACE.
Key:
SPFC = State Plan of Flood Control

6.2 Pumping Plants

Pumping plants discharge drainage water into adjacent channels to reduce localized flooding. The evolution of criteria and DWR inspections related to pumping plants is the same as described for hydraulic structures in Section 6.1.

6.2.1 Status Evaluation Methodology

Annual inspections for pumping plants are presented in the DWR *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (2010b). Eleven SPFC pumping plants and two non-SPFC pumping plants were inspected. Pumping plants were rated as Acceptable (A), Minimally Acceptable (M), or Unacceptable (U) based on numerous inspection categories. Table 6-5 shows DWR inspection rating descriptions for pumping plants.

Detailed rating criteria for each inspection category can be found in the DWR *2009 Inspection Report of the Central Valley State-Federal Flood Protection System*, Appendix C (2010b).

Table 6-5. Pumping Plant Inspection Rating Descriptions

Inspection Rating	Rating Description
Acceptable (A)	Weighted calculation of Acceptable, including consideration of operating log, O&M manual, plant building, communications, safety, cranes, pumps, power, motors, engines, fans, gear reducers, pump control systems, sumps/wet well, trash racks, trash rakes, sluice/slide gates, electric gate operators, manual gate operators, other metallic items, flap gates, closure structures, security fencing, intake and discharge pipes, and pressurized pipes.
Minimally Acceptable (M)	Weighted calculation of Minimally Acceptable, including consideration of elements above.
Unacceptable (U)	Weighted calculation of Unacceptable, including consideration of elements above.

Key:
O&M = operations and maintenance

6.2.2 Limitations of Status Evaluations

This evaluation covers only pumping plants inspected by DWR, and is limited to conditions that were visually inspected, annually, during summer. Most pumping plants inspected by DWR are part of the SPFC, but there are two non-SPFC pumping plants inspected as part of federal projects. Status information for other pumping plants in the flood management system is not included because it was not available.

6.2.3 Results of Status Evaluations

Pumping plant conditions from annual inspections in 2009 (DWR, 2009b) are presented in Figure 6-9 for the Sacramento and San Joaquin river watersheds. Of 13 pumping plants inspected, no pumping plants were rated Unacceptable overall; six pumping plants were rated as Minimally Acceptable.

Ongoing and planned remedial actions and ongoing actions to improve future evaluations are summarized in Appendix C, Section C-2.

Figure 6-9. Pumping Plant Conditions in Sacramento and San Joaquin River Watersheds

6.3 Bridges

DWR maintains and inspects some bridges in the Sacramento Watershed in accordance with California Water Code Section 8361 (c), and does not maintain or inspect any bridges in the San Joaquin River watershed. Before 2008, DWR did not conduct a separate annual inspection for bridges, but inspected bridges as components of overall channel inspections for conveyance capacity under the DWR Annual Inspection Program. Many bridges in the SPFC were designed and built before other SPFC facilities were constructed. In most cases, conveyance capacity through bridge openings was incorporated into SPFC levee and channel design. However, in some instances, encroachment into the floodflow capacity caused by bridges was not addressed as part of the design capacity (e.g., a bridge is lower than the design stage and/or levees at the bridge abutment have insufficient freeboard or are below the design stage). Bridges constructed after other SPFC facilities were generally evaluated by USACE and the Board so that bridges would not impact flows and/or impede flood emergency and/or maintenance operations.

6.3.1 Status Evaluation Methodology

DWR evaluated the condition of bridges against current maintenance standards using the results of annual bridge inspections in 2009 through the DWR Bridge Inspection Program. Inspection criteria for DWR's inspection logs were customized to each bridge based on the material used to construct the bridge. Visual inspections were performed on each DWR-maintained bridge regarding safe passage by evaluating the following: foundation scour, abutment erosion, approach grades, and overall structural integrity. Concrete bridges were inspected for cracks, chips, spalling, joint separation, and exposed rebar. Wooden structures were inspected for deterioration, cracking, joint and fastener separation, and wear. Inspection rating descriptions for bridges are listed in Table 6-6, with inspection elements listed above categorized for bridge deck conditions, foundation conditions, approach conditions, foundation scour, and spalling concrete.

Table 6-6. Bridges Inspection Rating Descriptions

Inspection Categories	Rating and Description
Deck Conditions, Foundation Conditions, Approach Conditions, Foundation Scour, and Spalling Concrete	1. Bridge is excellent condition. No visual inadequacies noted.
	2. Bridge has areas of minor cosmetic inadequacies; however, it appears to be in good working condition.
	3. Bridge is in fair condition. The bridge has minor observable inadequacies; however, it remains in good working condition.
	4. Bridge is in need of repair. The bridge condition does not pose an immediate hazard to the public.
	5. Bridge needs immediate repairs. The bridge condition poses an immediate hazard to the public.

6.3.2 Limitations of Status Evaluations

As mentioned, DWR only maintains and inspects the bridges shown in Figure 6-10 in accordance with California Water Code Section 8361 (c). DWR does not maintain or inspect any bridges in the San Joaquin River watershed. Reported conditions are limited to items that can be visually inspected annually during summer, and does not involve additional testing by DWR. Status information for other bridges in the flood management system is not included because it was not available.

6.3.3 Results of Status Evaluations

Bridge conditions noted from the DWR Bridge Inspection Program are presented on Figure 6-10 for the Sacramento River watershed. Detailed description, of the DWR inspections can be found in the DWR *Annual Bridge Inspection Report* (2009c).

Of the 10 bridges inspected by DWR, 2 had ratings of 4 and 5 overall, and were noted as needing repairs. Since 2000, three Sutter Basin bridges (not inspected by DWR or depicted in Figure 6-10) have been replaced and turned over to Sutter County for future O&M.

Ongoing and planned remedial actions and ongoing actions to improve future evaluations are summarized in Appendix C, Section C-3.

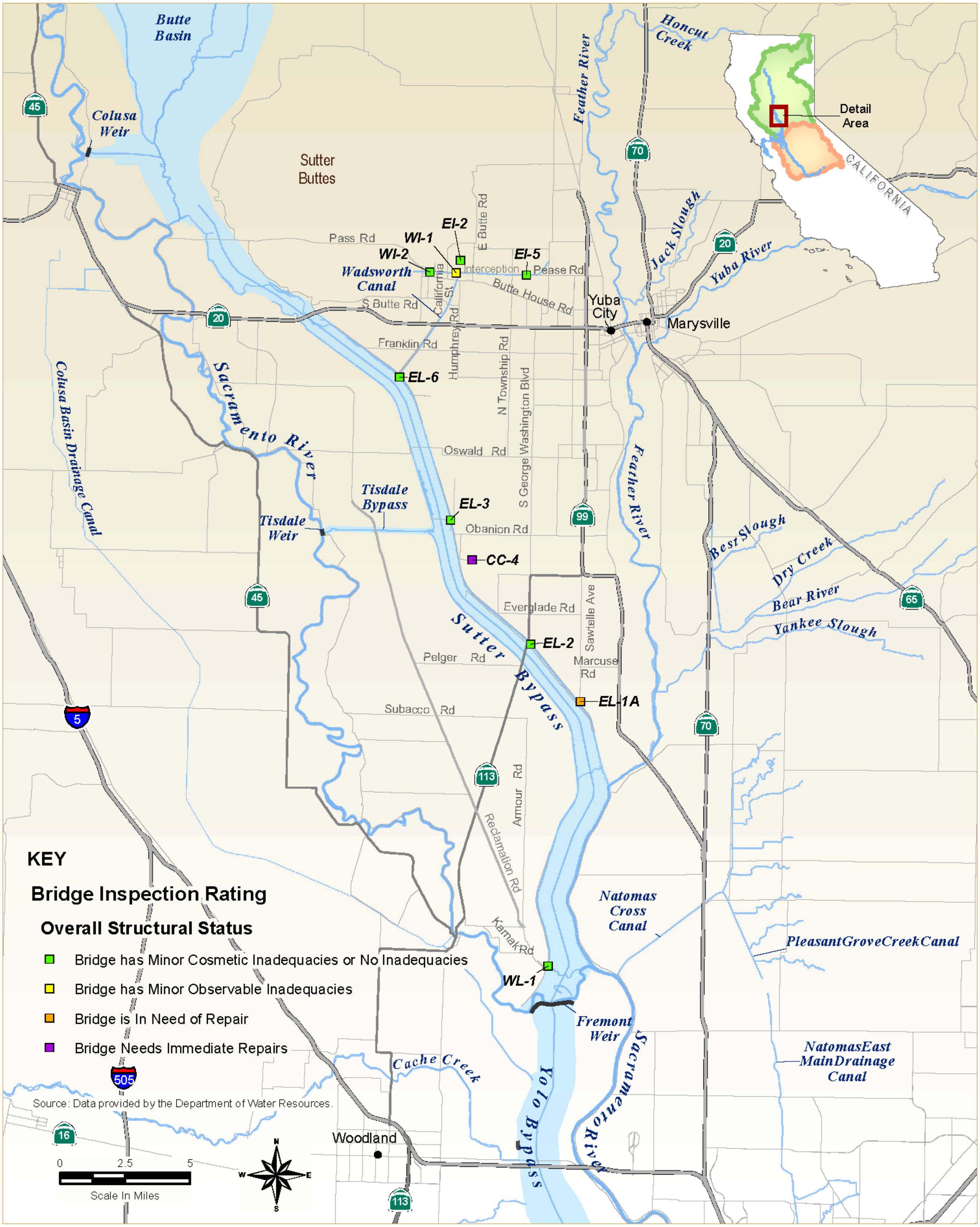


Figure 6-10. Bridge Conditions in Sacramento River Watershed

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7.0 Approach for SPFC Improvements

Sections 4.0, 5.0, and 6.0 of the FCSSR describe physical conditions of SPFC levees, channels, and flood control structures based on best available information. In some areas of the Sacramento and San Joaquin watersheds, not enough information is available at this time to determine whether SPFC facilities are performing to their expected level. While some SPFC facilities meet their intended performance standards, many do not, show visible distress, or otherwise have problems that could impair how the facilities function. These problems likely increase the chances that facilities could fail and contribute to major flooding.

DWR has plans and programs to further evaluate SPFC facility performance, identify needed flood system reconstructions and improvements, and implement reconstructions and improvements as State, federal, and local funding becomes available. These include ongoing programs under the FloodSAFE initiative and as part of long-term Central Valley Flood Protection Plan implementation. This section provides an overview of DWR's systematic approach for addressing problems with flood management facilities and for taking actions to improve performance of the SPFC.

7.1 FloodSAFE California

In January 2005, the governor drew attention to the State's flood problems, calling for improved maintenance, system rehabilitation, effective emergency response, and sustainable funding. In a white paper entitled *Flood Warnings: Responding to California's Flood Crisis* (DWR, 2005), DWR outlined flood challenges California faces and offered specific recommendations for administrative action and legislative changes.

An important result of the white paper was the creation of DWR's FloodSAFE California (FloodSAFE) in 2006, a multifaceted initiative to improve integrated flood management. Most of the funds currently available to help implement FloodSAFE are provided by Propositions 1E and 84. The vast majority of funds currently available for flood system improvements were allocated for the Central Valley and for the SPFC. Work to improve and rehabilitate SPFC flood management facilities intensified after passage of Propositions 1E and 84 in 2007, and included emergency repairs, urban levee improvements, and early implementation projects in the Central Valley.

FloodSAFE seeks to improve all aspects of integrated flood management. Because SPFC improvements will occur incrementally over decades, FloodSAFE must be flexible and program organization periodically updated based on new information and changing conditions. DWR has expanded its ongoing core programs and added new programs to cover all near-term and long-term activities needed for SPFC improvement.

7.2 Central Valley Flood Protection Plan

A critically important component of FloodSAFE work is the CVFPP. The CVFPP is the primary vehicle for addressing problems identified in this FCSSR, and further improvements to the SPFC. It is highlighted again in this section because the CVFPP addresses how to correct, improve, and manage the SPFC.DWR is required to prepare the CVFPP by January 1, 2012, for adoption by the Board by July 1, 2012. The plan will be updated every 5 years thereafter (in years ending in 7 and 2). As the first edition of this long-term planning document, the 2012 CVFPP will guide State investments for improving integrated flood management in the Sacramento-San Joaquin Valley. It is being produced in coordination with federal, regional, local, and tribal entities, and other interested parties and will guide many subsequent implementation activities.

The CVFPP represents a sustainable, integrated flood management plan that will guide State, federal, and local actions to improve flood management in this vital region of the State. To adequately address current and increasing future demands on the SPFC, significant and sustained actions are needed to improve the performance level of SPFC facilities that exist today. Implementing a program of actions to address identified problems as part of a systemwide approach to improving flood management throughout the Sacramento and San Joaquin river watersheds will take many years and significant coordination between local, State, and federal governments.

The CVFPP describes a recommended implementation approach that considers the sequential phasing of projects. Sequential phasing will allow an initial focus on the most urgent flood system needs, provide time needed to establish a firm foundation to further develop and implement actions in subsequent phases, and allow for the establishment of a sound funding strategy to pursue future additions to effective flood management in the Central Valley.

A wide range of actions will be required to develop, construct, and manage improvements to the SPFC. This work will be organized into several programs, established and led by DWR and implemented in coordination with local and federal partners. These programs are managed by DWR's existing FloodSAFE organization. Each program will be responsible for specialized implementation. Together, the programs cover all work required for implementation and management of the improved SPFC. DWR's major flood management programs are as follows:

- Flood Emergency Response Program
- Flood System Operations and Maintenance Program
- Floodplain Risk Management Program
- Flood Risk Reduction Projects Program
- Flood System Assessment, Engineering, Feasibility, and Permitting Program

The first three programs are responsible for residual risk management. The fourth program is responsible for implementing on-the-ground projects for SPFC improvement. The last program is responsible for conducting feasibility evaluations, design, engineering, and other activities necessary for implementation.

As described in Section 1.1, the *State Plan of Flood Control Descriptive Document* (DWR, 2010a) and this FCSSR are two important documents contributing to the CVFPP.

The Central Valley Integrated Flood Management Study, which is being led by USACE, is the federal complement to the CVFPP and focuses on shared opportunities to reduce flood risk in the Central Valley in an integrated water resource and flood management context. Both studies have the common goal of determining a State-federal strategy that will lead to expedient and cost-shared implementation of new and continuing projects to reduce flood risk in the Central Valley. USACE participated in CVFPP development, providing valuable input on all phases of the plan, producing joint data and technical information, and assisting in use of analytical tools. USACE is also providing technical expertise in developing flood hydrology, analyzing reservoir operations, and incorporating risk-based decision-making processes that improve system reliability.

In summary, DWR has plans and programs to further evaluate the status of facility performance, identify needed flood system improvements, and implement those improvements as State, federal, and local funding becomes available. The CVFPP, in particular, will guide improvement and management of the SPFC in the future.

8.0 Findings and Recommendations

This section summarizes major finding and recommendations of the FCSSR for use in the CVFPP.

8.1 Findings

The flood management system has provided tremendous benefits to public safety and protection of property in the Central Valley – as mentioned, the system has prevented many billions of dollars in flood damages since facilities were originally constructed. However, today, the system is being relied on to provide flood protection and other benefits at levels that were not envisioned when the system was constructed. When evaluated against modern engineering and safety criteria, some SFPC facilities face a higher chance for failure during a flood event than other facilities.

The SPFC includes approximately 1,600 miles of levees and approximately 2,600 miles of channels. DWR's Levee Evaluations Program has evaluated approximately 1,530 miles[1] of levee included in the SPFC. Of the SPFC levees evaluated by the Levee Evaluations Program, about 300 miles help protect urban areas and about 1,230 miles help protect nonurban areas. Associated with the SPFC levees are about 420 miles of non-SPFC levees (120 miles of urban and 300 miles of nonurban levees) that are instrumental to effective functioning of the SPFC. Information from the *State Plan of Flood Control Existing Channel Capacity Assessment Technical Memorandum* (CVFED, 2009), supplemented with project-specific modeling results, supported evaluation of 1,016 miles of approximately 2,600 miles of SPFC channels. The overall condition of urban levees, nonurban levees, channels, and flood control structures of the SPFC can be summarized as follows:

- **Urban levees –** Approximately half of about 300 miles[2] of SPFC urban levees evaluated do not meet current levee freeboard, stability, or seepage design criteria[3] at the design water surface elevation.

[1] An additional 13 miles of SPFC urban levees are being evaluated, and results will be included in future updates.
[2] An additional 13 miles of SPFC urban levees are being evaluated, and results will be included in future updates.
[3] The design criteria used were based on USACE 2000 *Design and Construction of Levees Engineering Manual 1110-2-1913* and DWR 2010 *Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento Valley, Version 4*.

- **Nonurban levees –** Approximately three-fifths of about 1,230 miles of SPFC nonurban levees evaluated have a high potential for failure from under-seepage, through-seepage, structural instability, and/or erosion at the assessment water surface elevation.[4] Nonurban levees were evaluated based on systematic, consistent, repeatable analyses that correlated geotechnical data with levee performance history, not relative to any current design criteria.[5]

- **SPFC channels** – Approximately half of the 1,016 miles of channels evaluated in the SPFC have a potentially inadequate capacity to convey design flows, and require additional evaluation to confirm conditions.

- **SPFC flood control structures –** None of the 32 hydraulic structures or 11 pumping plants inspected by DWR for the SPFC were rated Unacceptable during the 2009 inspections. Of the 10 SPFC bridges inspected by DWR in 2009, 2 were in need of repairs.

Many potential factors can influence levee performance – the threats these factors pose are not all equal. Table 8-1 lists factors that influence facility performance, findings related to each factor, and the relative threat posed by the factor. The relative threat posed by each factor is a subjective representation of the prevalence of the factor and the degree to which the presence of that factor would contribute to potential facility failure. Factors identified as a “high” relative threat to SPFC facilities generally are the most prevalent and/or greatly contribute to potential facility failure. Those identified as a “low” relative threat to SPFC facilities generally are the least prevalent and/or contribute less to potential facility failure. Likewise, factors identified as a "medium" relative threat to SPFC facilities are moderately prevalent and/or contribute moderately to potential facility failure. Therefore, the relative threat posed by each factor is subjective in nature and serves only to help identify and prioritize the factors most likely to contribute to SPFC facility failure. However, prioritizing relative threats affecting SPFC facilities does not necessarily translate directly into investment priorities. To decide which levels of investment are prudent for repairs or improvements, economic and life safety consequences associated with potential failure must also be considered. Potential consequences of

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[4] Where available, 1955/57 design water surface elevations were used as the assessment water surface elevation. In the absence of 1955/57 design water surface elevations, the assessment water surface elevation was based on freeboard requirements for each levee segment (i.e., generally 3 feet below the levee crest).

[5] This approach was selected because the extent of the NULE Project is significantly greater than the ULE Project, making it difficult to conduct the same level of field explorations and geotechnical data collection performed for ULE levees.

facility failure are not presented in this report; they are evaluated in the CVFPP.

Table 8-1. Summary of Flood Control System Status Report Findings

	Factors	Findings	Relative Threat Posed by Factor[1]
Levees	Overall Levee Condition (multiple factors)	• Approximately half of SPFC urban levees do not meet current levee freeboard, stability, or seepage design criteria at the design water surface elevation. • Approximately three-fifths of SPFC nonurban levees have a high potential for levee failure from under-seepage, through-seepage, structural instability, and/or erosion at the assessment water surface elevation.	N/A
	Levee Geometry Check	• Approximately one-third of SPFC urban levees deviate from current standard levee design prism criteria. • Levee geometry deviates significantly from the standard levee design prism for some nonurban SPFC levees.	Medium
	Seepage	• Approximately one-third of SPFC urban levees do not meet current seepage design criteria. • Almost half of SPFC nonurban levees have a high potential for levee failure from under-seepage. • Approximately one-quarter of SPFC nonurban levees have a high potential for levee failure from through-seepage.	High
	Structural Instability	• Approximately one-fifth of SPFC urban levees do not meet current structural stability design criteria. • Approximately one-eighth of SPFC nonurban levees evaluated in the Sacramento River watershed and 1 percent in the San Joaquin River watershed have a high potential for levee failure from structural instability.	Medium
	Erosion	• Erosion assessments for urban levees are underway, and results are not available at this time. • Almost one-seventh of SPFC nonurban levees have a high potential for levee failure from erosion.	Medium
	Settlement	• Four known localized levee locations have settlement (localized depressions) that endangers the integrity of the SPFC levees.[5]	Low
	Penetrations[2]	• More than 6,000 penetration sites are documented in SPFC levees, and many more remain undocumented.	Medium
	Levee Vegetation	• About 15 miles of SPFC levees are noncompliant with the 2007 DWR *Interim Levee Vegetation Criteria*.[3 5]	Low
	Rodent Damage	• More than one-third of the 1,459 miles of SPFC levees studied had at least eight reported occurrences of burrowing activity over a 21-year study span.	Medium
	Encroach-ments[4]	• 1,223 encroachment sites were identified as partially or completely obstructing visibility and access to the levee and/or within 10 feet of the landside toe.[5]	Medium

Table 8-1. Summary of Flood Control System Status Report Findings (contd.)

	Factors	Findings	Relative Threat Posed by Factor[1]
Channels	**Inadequate Conveyance Capacity**	• Approximately half of the 1,016 miles of SPFC channels evaluated are potentially inadequate to convey design flows, and require additional evaluation to confirm conditions. • Approximately one-quarter of channel design capacities reported in O&M manuals do not agree with flows specified in the design profiles.	Medium
Channels	**Channel Vegetation**	• Of 186 miles of SPFC channels inspected by DWR, 1 location was rated Unacceptable and 54 locations were rated Minimally Acceptable because of vegetation and obstructions.[5]	Low
Channels	**Channel Sedimentation**	• Of 186 miles of SPFC channels inspected by DWR, 1 location was rated Unacceptable and 23 locations were rated Minimally Acceptable because of shoaling/sedimentation.[5]	Low
Structures	**Inadequate Hydraulic Structures**	• Of 32 SPFC hydraulic structures inspected by DWR, no structures were rated Unacceptable because of structural, vegetation/obstruction, encroachment, or erosion/sedimentation issues.[5]	Low
Structures	**Inadequate Pumping Plants**	• Of 11 SPFC pumping plants inspected by DWR, none were rated Unacceptable.[5]	Low
Structures	**Inadequate Bridges**	• Of 10 SPFC bridges inspected by DWR, 2 were in need of repairs.[5]	Low

Note:
[1] The relative threats listed in Table 8-1 were generated based on professional experience of technical staff from DWR and partner agencies.
[2] Penetrations include man-made objects that cross through or under a levee or floodwall and have the potential to provide a preferential seepage path or hydraulic connection with the waterside. Typically, a penetration is a pipe or transportation structure, such as a roadway or rail line.
[3] This finding is based on DWR 2007 *Interim Levee Vegetation Criteria* and not on USACE levee vegetation criteria. Comparison with USACE levee vegetation criteria would show more SPFC levees as noncompliant.
[4] Encroachments are any obstruction or physical intrusion by construction of works or devices, planting or removal of vegetation, or caused by any other means, for any purpose, into a flood control project, waterway area of the flood control project, or area covered by an adopted plan of flood control (California Code of Regulations Title 23 Chapter 1 Article 2 Section 4 (m)). Encroachments include boat docks, ramps, bridges, sand and gravel mining, placement of fill, fences, retaining walls, pump stations, residential structures, and irrigation and landscaping materials/facilities.
[5] Inspection results reported are from DWR's 2009 Inspections.

Key:
DWR = California Department of Water Resources
N/A = Not applicable
O&M = operations and maintenance
SPFC = State Plan of Flood Control
USACE = U.S. Army Corps of Engineers

The findings in Table 8-1 are relative to DWR's current criteria for use in the CVFPP. In most cases, these criteria are identical, or very similar to USACE criteria. However, differences between DWR and USACE levee vegetation criteria are significant enough that comparison of levees with USACE criteria would likely show more SPFC levees as noncompliant with current USACE criteria. As noted in Section 4.7, DWR and USACE continue to work to resolve these differences.

To adequately address current and increasing future demands on the SPFC, significant and sustained actions are needed to improve the performance level of SPFC facilities that exists today. This will include continued efforts at the State, federal, regional, and local levels to assess and evaluate programs and policies affecting the SPFC and conditions of non-SPFC facilities that affect performance of the flood control system. Implementing an appropriate collection of management actions in a systemwide approach to address identified problems properly, and to improve the conditions of flood management throughout the Sacramento and San Joaquin river watersheds will take many years. It is important to recognize that improvements to the SPFC will be costly and require the active involvement of State, federal, regional, and local interests. Significant amounts of funding will be needed for future project planning, development, implementation by USACE and the State, and for O&M primarily by maintaining agencies.

Local communities (both urban and nonurban) will require significant financial and technical assistance from the State and federal governments over the next 20 to 25 years to take appropriate actions to improve the current condition of SPFC facilities. FCSSR findings provide important input on system conditions for the CVFPP. As mentioned, the CVFPP will guide future State investments through incremental projects to address identified problems in the SPFC.

8.2 Recommendations

As mentioned, California Water Code Section 9120 directs that the FCSSR is to include appropriate recommendations regarding SPFC levees and future work activities. Recommendations regarding potential modifications to the SPFC will be included in the 2012 CVFPP. Recommendations regarding future work activities considered important to support future efforts as part of the CVFPP include the following:

- Pursue Board adoption of the findings of this FCSSR, as required by California Water Code Section 9120, and support the Board in communicating FCSSR recommendations to the California Legislature.

- Per California Water Code Section 9120(a), Continue to work with State, federal, regional, and local agencies to create a broadly supported

CVFPP to guide long-term investments related to the SPFC over the next several decades.

- Build on and improve existing partnerships with federal, regional, and local agencies to develop site-specific actions for the SPFC that are consistent with the integrated, systemwide approach developed in the CVFPP.

- Continue to partner with agencies, and form new partnerships, to conduct special studies to improve understanding of the various factors that present threats to SPFC facilities. These studies include continued efforts to research the impacts of levee vegetation, assess locations and importance of levee penetrations, characterize the probability of levee failure, and other technical studies.

- Proceed with multiagency work efforts to further evaluate facility status, identify needed flood system reconstructions and improvements, and implement them, as State, federal, and local funding becomes available.

- Continue to improve data sharing and accessibility of annual inspection results for partner agencies and the public.

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10.0 Acronyms and Abbreviations

Board	Central Valley Flood Protection Board
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPP	Central Valley Flood Protection Plan
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EC	Engineering Circular
EM	Engineering Manual
FCSSR	Flood Control System Status Report
FEMA	Federal Emergency Management Agency
FloodSAFE	FloodSAFE California
FMO	DWR Flood Maintenance Office
GIS	geographic information system
LiDAR	light detection and ranging
NULE	Non-Urban Levee Evaluations
O&M	operations and maintenance
SPFC	State Plan of Flood Control
State	State of California
ULE	Urban Levee Evaluations
USACE	U.S. Army Corps of Engineers

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

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Flood Control System Status Report Appendix A – Levee Status

December 2011

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Appendix A – Levee Status

Appendix A provides additional supporting information on levee physical conditions. The levee status overview includes data that reflect the impacts of multiple levee status factors on levee conditions. These data include information from U.S. Army Corps of Engineers (USACE) Periodic Inspection results, historical levee breaches and overtopping locations, and a summary of Early Implementation Program projects, Central Valley Flood Protection Board (Board) projects, and other modifications to SPFC facilities. Sections A-2 through A-10 of Appendix A are organized by levee status factors, and correspond to the subsections in Section 4 of the Flood Control System Status Report (FCSSR) main document. Additional inspection and/or evaluation data, recent, ongoing, and planned remedial actions/improvements, and ongoing actions to improve future evaluations are described for each levee status factor.

A-1 Levee Status Overview

This section presents USACE Periodic Inspection results, contains data on historical levee breaches and levee overtopping locations, Early Implementation Program and USACE/Board projects, and other modifications to State Plan of Flood Control (SPFC) facilities.

USACE Periodic Inspection Report Cards

USACE Periodic Inspections are conducted to verify proper operations and maintenance (O&M); evaluate operational adequacy and structural stability; identify features to monitor over time; and improve communication regarding overall facility condition and safety. USACE conducts its Periodic Inspections to rate flood damage reduction systems. A flood damage reduction system is a complete and independent unit made up of one or more flood damage reduction segments that collectively provide flood damage reduction to a defined area. Failure of one segment within a system constitutes failure of the entire system. The following 10 USACE systems were inspected between December 2009 and February 2010.

- City of Marysville, Units 1, 2, and 3 System
- City of Marysville, Unit 3 Northeast Extension System

- American River Flood Control District – Dry Creek Right Bank, Unit 8 System
- American River Flood Control District – Dry Creek, Natomas East Main Drainage Canal, and Arcade Creek System
- American River Flood Control District – American River Right Bank, Natomas East Main Drainage Canal System
- Reclamation District 1000 – Natomas System
- Feather River Right Bank – Sutter Bypass East Bank Levee System
- Maintenance Area 9 – City of Sacramento, American River Left Bank System
- Reclamation District 404 and Duck Creek Right Bank – Boggs Tract System
- Reclamation Districts 17, 2094, 2096, 2075, and 2064 – San Joaquin River East Levee System

Report cards serve as a findings summary of USACE Periodic Inspections. Tables A-1 through A-10 display Periodic Inspection Report Cards for each system.

Table A-1. City of Marysville – Units 1, 2, 3 System Report Card

City of Marysville - Units 1, 2, 3 Unacceptable-Inactive	Unit 1 Jack Slough	Unit 2 Feather River	Unit 3 Yuba River
Operations and Maintenance Manuals	M	M	M
Emergency Supplies and Equipment	A	A	A
Flood Preparedness and Training	M	M	M
Unwanted Vegetation Growth	U	U	U
Sod Cover	A	A	A
Encroachments	U	U	U
Closure Structures	A	A	A
Slope Stability	U	A	M
Erosion/Bank Caving	M	M	M
Settlement	A	A	A
Depressions/Rutting	U	A	A
Cracking	U	A	A
Animal Control	M	M	M
Culverts/Discharge Pipes	NA	NA	NA
Riprap Revetments & Bank Protection	NA	NA	M
Revetments other than Riprap	NA	NA	NA
Underseepage Relief Wells/Toe Drainage Systems	NA	NA	NA
Seepage	A	A	A

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

Legend

A	Acceptable
M	Minimally Acceptable
U	Unacceptable
N/A	Not Applicable

July 6, 2010

Table A-2. City of Marysville – Unit 3 Northeast Extension Report Card

City of Marysville Unit 3, NE Extension Unacceptable-Inactive	Unit 3, NE Extension
Operations and Maintenance Manuals	M
Emergency Supplies and Equipment	A
Flood Preparedness and Training	M
Unwanted Vegetation Growth	U
Sod Cover	A
Encroachments	U
Closure Structures	NA
Slope Stability	A
Erosion/Bank Caving	M
Settlement	A
Depressions/Rutting	A
Cracking	A
Animal Control	M
Culverts/Discharge Pipes	NA
Riprap Revetments & Bank Protection	NA
Revetments other than Riprap	NA
Underseepage Relief Wells/Toe Drainage Systems	NA
Seepage	A

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend
- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Table A-3. American River Flood Control District – Dry Creek Right Bank, Unit 8 System Report Card

American River FCD - Dry Creek Right Bank, Unit 8 Minimally Acceptable-Active	Dry Creek Right Bank, Unit 8
Operations and Maintenance Manuals	M
Emergency Supplies and Equipment	A
Flood Preparedness and Training	A
Unwanted Vegetation Growth	A
Sod Cover	A
Encroachments	U
Closure Structures	A
Slope Stability	A
Erosion/Bank Caving	A
Settlement	A
Depressions/Rutting	M
Cracking	A
Animal Control	M
Culverts/Discharge Pipes	N/A
Riprap Revetments & Bank Protection	A
Revetments other than Riprap	A
Underseepage Relief Wells/Toe Drainage Systems	A
Seepage	A

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend
- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Table A-4. American River Flood Control District – Dry Creek, Natomas East Main Drainage Canal, Arcade Creek System Report Card

American River FCD - Dry Creek, NEMDC, Arcade Creek Minimally Acceptable-Active	Dry Creek Left Bank Unit 6	NEMDC Unit 2 North	Arcade Creek right bank Unit 7						
Operations and Maintenance Manuals	M	M	M						
Emergency Supplies and Equipment	A	A	A						
Flood Preparedness and Training	A	A	A						
Unwanted Vegetation Growth	U	U	U						
Sod Cover	A	M	A						
Encroachments	U	U	U						
Closure Structures	A	N/A	A						
Slope Stability	A	A	A						
Erosion/Bank Caving	A	M	A						
Settlement	A	A	A						
Depressions/Rutting	A	A	A						
Cracking	A	A	A						
Animal Control	M	M	M						
Culverts/Discharge Pipes	N/A	N/A	N/A						
Riprap Revetments & Bank Protection	A	N/A	N/A						
Revetments other than Riprap	A	N/A	N/A						
Underseepage Relief Wells/Toe Drainage Systems	N/A	N/A	N/A						
Seepage	A	A	A						

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend
- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Table A-5. American River Flood Control District – American River Right Bank – Natomas East Main Drainage Canal System Report Card

American River Right Bank, NEMDC Minimally Acceptable-Active	Unit 1, Arcade Creek Left Bank	Unit 2, South NMDEC below Arcade Creek	Unit 3, SRFCP	Unit 3, American River Right Bank - MA 10 and 11					
Operations and Maintenance Manuals	M	M	M	M					
Emergency Supplies and Equipment	A	A	A	A					
Flood Preparedness and Training	A	A	A	A					
Unwanted Vegetation Growth	U	M	U	U					
Sod Cover	A	M	A	A					
Encroachments	U	U	U	U					
Closure Structures	A	N/A	A	N/A					
Slope Stability	A	M	A	A					
Erosion/Bank Caving	M	A	A	A					
Settlement	A	A	A	A					
Depressions/Rutting	A	A	A	A					
Cracking	A	A	A	A					
Animal Control	M	M	M	M					
Culverts/Discharge Pipes	N/A	N/A	N/A	U					
Riprap Revetments & Bank Protection	A	N/A	N/A	N/A					
Revetments other than Riprap	A	N/A	N/A	N/A					
Underseepage Relief Wells/Toe Drainage Systems	A	N/A	N/A	N/A					
Seepage	A	A	A	A					

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend
- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Table A-6. Reclamation District 1000 – Natomas System Report Card

RD 1000 - Natomas Unacceptable-Active	Unit 1, Sacramento River	Unit 2, American River	Unit 3 South, NEMDC	Unit 3 North, Cross Canal inflow	Unit 4, Natomas Cross Canal			
Operations and Maintenance Manuals	M	M	M	M	M			
Emergency Supplies and Equipment	A	A	A	A	A			
Flood Preparedness and Training	A	A	A	A	A			
Unwanted Vegetation Growth	U	U	U	U	U			
Sod Cover	A	A	A	A	A			
Encroachments	U	U	U	U	U			
Closure Structures	NA	NA	NA	NA	NA			
Slope Stability	M	A	M	A	M			
Erosion/Bank Caving	U	M	M	U	U			
Settlement	M	A	A	A	A			
Depressions/Rutting	A	A	M	M	A			
Cracking	M	A	M	A	A			
Animal Control	M	A	M	M	M			
Culverts/Discharge Pipes	NA	NA	NA	NA	NA			
Riprap Revetments & Bank Protection	M	NA	M	M	A			
Revetments other than Riprap	NA	NA	NA	NA	NA			
Underseepage Relief Wells/Toe Drainage Systems	NA	NA	NA	NA	NA			
Seepage	A	A	A	A	A			

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend
- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Table A-7. Feather River Right Bank – Sutter Bypass East Bank Levee System Report Card

Feather River Right Bank – Sutter Bypass East Bank Levee System Unacceptable-Inactive	Feather River – Hamilton West Levee – South of Afterbay Outflow Dam	Maintenance Area 07	Reclamation District 777 Live Oak – Maintenance Area 16	Levee District 9 – Sutter County	Levee District 1 – Sutter County	Maintenance Area 03	Sutter Bypass – East Levee – South of Wadsworth Canal	Wadsworth Canal – Unit 1, Left Bank	Interceptor Canal – Unit 1, East Canal
Operations and Maintenance Manuals	M	M	M	M	M	M	M	M	M
Emergency Supplies and Equipment	A	A	A	M	A	A	A	A	A
Flood Preparedness and Training	A	A	A	M	A	A	A	A	A
Unwanted Vegetation Growth	U	U	U	U	U	U	U	U	U
Sod Cover	N/A	M	M	M	M	M	M	M	A
Encroachments	U	U	U	U	U	U	U	U	U
Closure Structures	U	N/A	N/A	A	A	N/A	N/A	A	N/A
Slope Stability	M	U	A	U	M	M	M	A	M
Erosion/Bank Caving	A	U	U	U	U	U	U	U	U
Settlement	A	A	A	A	A	A	A	A	A
Depressions/Rutting	U	U	M	U	M	M	U	M	U
Cracking	A	A	A	A	A	A	A	A	A
Animal Control	A	M	M	M	M	M	M	M	M
Culverts/Discharge Pipes	N/A	N/A	N/A	N/A	N/A	N/A	U	N/A	N/A
Riprap Revetments & Bank Protection	N/A	M	N/A	N/A	M	M	M	N/A	N/A
Revetments other than Riprap	A	N/A	N/A	U	M	N/A	M	N/A	N/A
Underseepage Relief Wells/Toe Drainage Systems	N/A	N/A	N/A	N/A	U	N/A	N/A	N/A	N/A
Seepage	A	A	A	A	A	A	A	A	A

Segment & System Ratings/PL 84-99 Eligibility
- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend
- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Table A-8. Maintenance Area 09 – City of Sacramento, American River Left Bank Levee System Report Card

MA 09 - City of Sacramento, American River Left Bank Levee System Unacceptable-Active	ARFCD - Unit 4, American River Left Bank	ARFCD - Unit 5, Sacramento River	City of Sacramento	MA 09 - Sutterville Rd to Freeport	MA 09 - Freeport to Hood	MA 09 - Hood to Snodgrass Slough
Operations and Maintenance Manuals	M	M	M	M	A	A
Emergency Supplies and Equipment	A	A	A	A	A	A
Flood Preparedness and Training	A	A	A	A	A	A
Unwanted Vegetation Growth	U	U	U	U	U	U
Sod Cover	A	A	M	M	M	A
Encroachments	U	U	U	U	U	U
Closure Structures	N/A	N/A	N/A	N/A	N/A	N/A
Slope Stability	M	A	M	M	M	M
Erosion/Bank Caving	M	M	M	M	M	M
Settlement	A	A	A	A	A	A
Depressions/Rutting	M	A	A	M	A	A
Cracking	A	A	A	A	A	A
Animal Control	M	M	M	M	M	M
Culverts/Discharge Pipes	N/A	N/A	N/A	N/A	N/A	N/A
Riprap Revetments & Bank Protection	M	M	M	M	M	A
Revetments other than Riprap	N/A	N/A	M	M	N/A	N/A
Underseepage Relief Wells/Toe Drainage Systems	N/A	N/A	N/A	N/A	N/A	N/A
Seepage	A	A	A	A	U	A
Flood Wall	U	N/A	U	A	N/A	N/A

Segment & System Ratings/PL 84-99 Eligibility
Likely Prevents Performance In Next Flood Event
Serious deficiency noted in past inspections has not been corrected within the established timeframe
Likely Prevents Performance In Next Flood Event (Framework)
Not Likely to Prevent Performance In Next Flood Event
Not Likely to Prevent Performance In Next Flood Event (Framework)
The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

Legend
A Acceptable
M Minimally Acceptable
U Unacceptable
N/A Not Applicable

July 6, 2010

Table A-9. Reclamation District 404 and Duck Creek Right Bank – Boggs Tract System Report Card

RD 404 and Duck Creek right bank - Boggs Tract Unacceptable-Inactive	RD 404 - Unit 1 San Juaquin River Right Bank	RD 404 - Unit 2, French Camp Walker Slough	Duck Creek - Walker Slough right bank
Operations and Maintenance Manuals	M	M	M
Emergency Supplies and Equipment	M	M	M
Flood Preparedness and Training	M	M	M
Unwanted Vegetation Growth	U	U	U
Sod Cover	N/A	N/A	N/A
Encroachments	U	U	U
Closure Structures	N/A	N/A	N/A
Slope Stability	U	U	M
Erosion/Bank Caving	U	U	M
Settlement	U	A	A
Depressions/Rutting	M	U	A
Cracking	A	A	A
Animal Control	U	U	M
Culverts/Discharge Pipes	N/A	N/A	N/A
Riprap Revetments & Bank Protection	U	N/A	M
Revetments other than Riprap	N/A	N/A	N/A
Underseepage Relief Wells/Toe Drainage Systems	N/A	N/A	N/A
Seepage	A	M	A

Segment & System Ratings/PL 84-99 Eligibility
Likely Prevents Performance In Next Flood Event
Serious deficiency noted in past inspections has not been corrected within the established timeframe
Likely Prevents Performance In Next Flood Event (Framework)
Not Likely to Prevent Performance In Next Flood Event
Not Likely to Prevent Performance In Next Flood Event (Framework)
The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

Legend
A Acceptable
M Minimally Acceptable
U Unacceptable
N/A Not Applicable

July 6, 2010

Table A-10. Reclamation Districts 0017, 2094, 2075, 2064 San Joaquin River East System Report Card

RD 0017, 2094, 2096, 2075, 2064 - SJ River East Unacceptable-Inactive	RD 0017 Unit 1	RD 0017 Unit 2	RD 2096	RD 2094 Unit 1	RD 2094 Unit 2	RD 2075	RD 2064 Unit 1	RD 2064 Unit 2
Operations and Maintenance Manuals	A	A	M	A	A	M	M	M
Emergency Supplies and Equipment	A	A	A	A	A	M	M	M
Flood Preparedness and Training	A	A	M	M	M	M	M	M
Unwanted Vegetation Growth	U	U	U	U	U	U	U	U
Sod Cover	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Encroachments	U	U	U	M	M	U	U	U
Closure Structures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Slope Stability	A	M	A	A	A	A	A	M
Erosion/Bank Caving	M	U	A	A	A	M	M	U
Settlement	M	M	M	M	M	M	M	M
Depressions/Rutting	M	U	A	A	A	U	U	U
Cracking	A	A	A	A	A	A	A	A
Animal Control	M	M	M	A	A	M	M	M
Culverts/Discharge Pipes	N/A	N/A	U	N/A	N/A	N/A	N/A	N/A
Riprap Revetments & Bank Protection	N/A	A	N/A	N/A	N/A	A	A	N/A
Revetments other than Riprap	N/A	M	M	A	N/A	N/A	A	M
Underseepage Relief Wells/Toe Drainage Systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Seepage	M	A	A	A	A	A	A	A
Pump Station	N/A	N/A	U	N/A	N/A	N/A	N/A	N/A

Segment & System Ratings/PL 84-99 Eligibility

- Likely Prevents Performance In Next Flood Event
- Serious deficiency noted in past inspections has not been corrected within the established timeframe
- Likely Prevents Performance In Next Flood Event (Framework)
- Not Likely to Prevent Performance In Next Flood Event
- Not Likely to Prevent Performance In Next Flood Event (Framework)

Legend

- A Acceptable
- M Minimally Acceptable
- U Unacceptable
- N/A Not Applicable

The lowest rating is used to determine the overall segment & system ratings and PL 84-99 Rehabilitation Eligibility

July 6, 2010

Historical Levee Breaches and Overtopping

The California Department of Water Resources (DWR) Levee Evaluations Program collected and cataloged historical levee performance data pertinent to levee assessments in a document database. Data sources include existing levee-related data available from DWR and USACE, levee records available from State agencies, the California Levee Database, levee data obtained from local agencies, and interviews with representatives from local agencies, landowners, and DWR personnel. Data were collected on historical evidence of breaching and overtopping. For additional details on this data collection effort with respect to the Non-Urban Levee Evaluations (NULE) Project, see the *Geotechnical Assessment Report for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and 2011b). The results of this data collection effort under the Urban Levee Evaluations (ULE) Project will be reported in Geotechnical Evaluation Reports being prepared for each individual study area. Figures A-1 and A-2 show historical levee breaches and failures in the Sacramento and San Joaquin river watersheds, respectively. Figures A-3 and A-4 show historical levee overtopping events in the Sacramento and San Joaquin river watersheds, respectively.

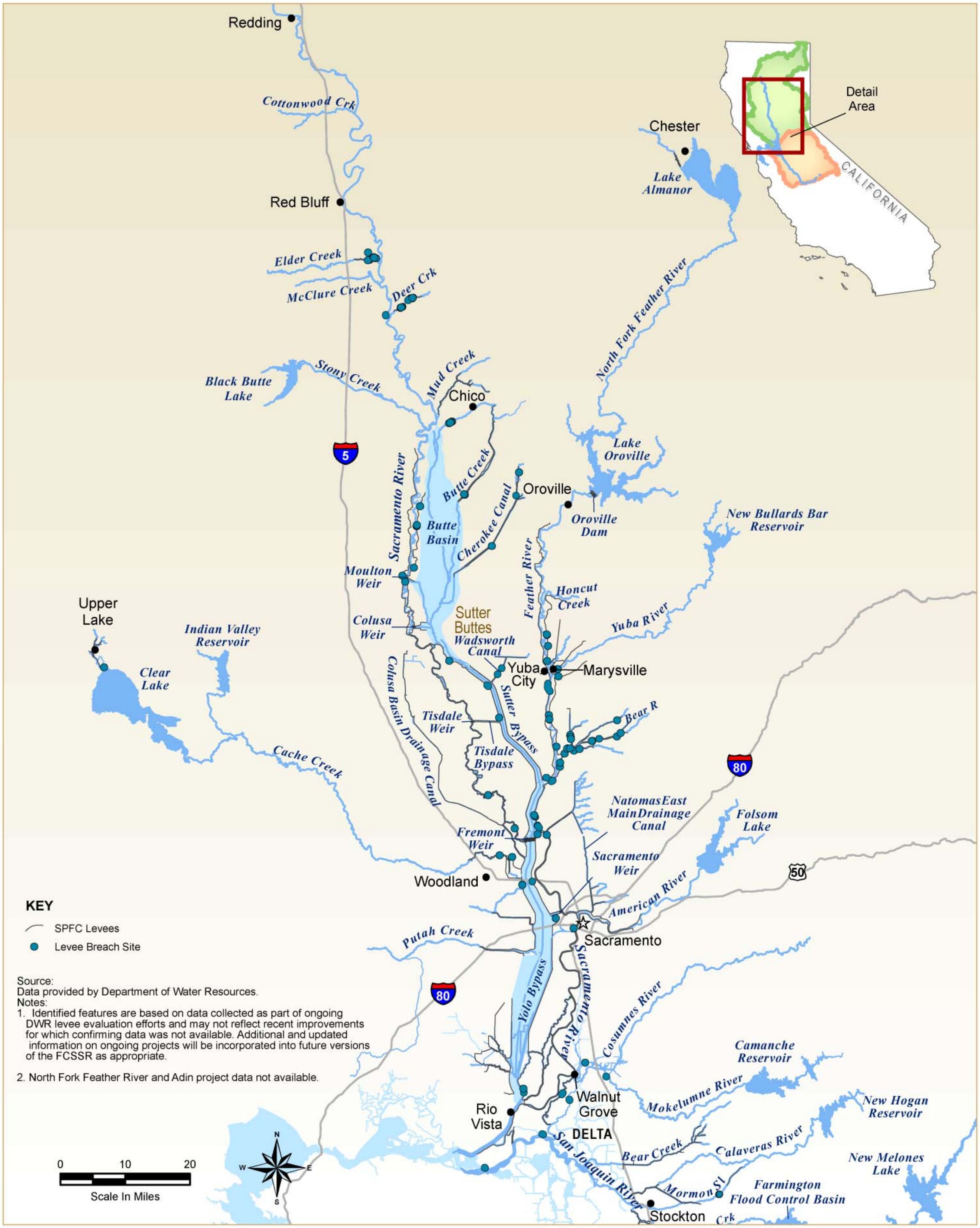

Figure A-1. Historical Levee Breaches in Sacramento River Watershed

Figure A-2. Historical Levee Breaches in San Joaquin River Watershed

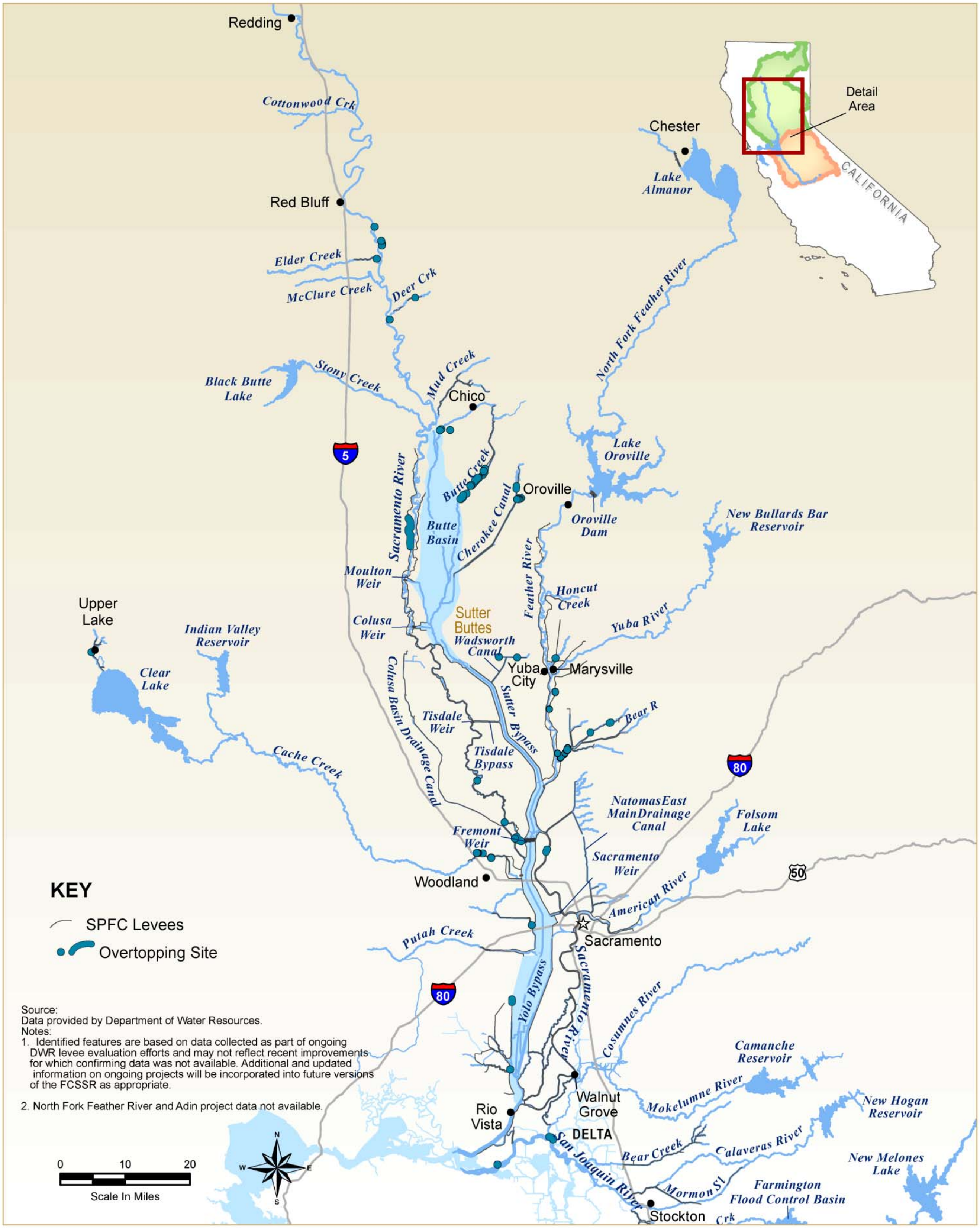

Figure A-3. Historical Levee Overtopping in Sacramento River Watershed

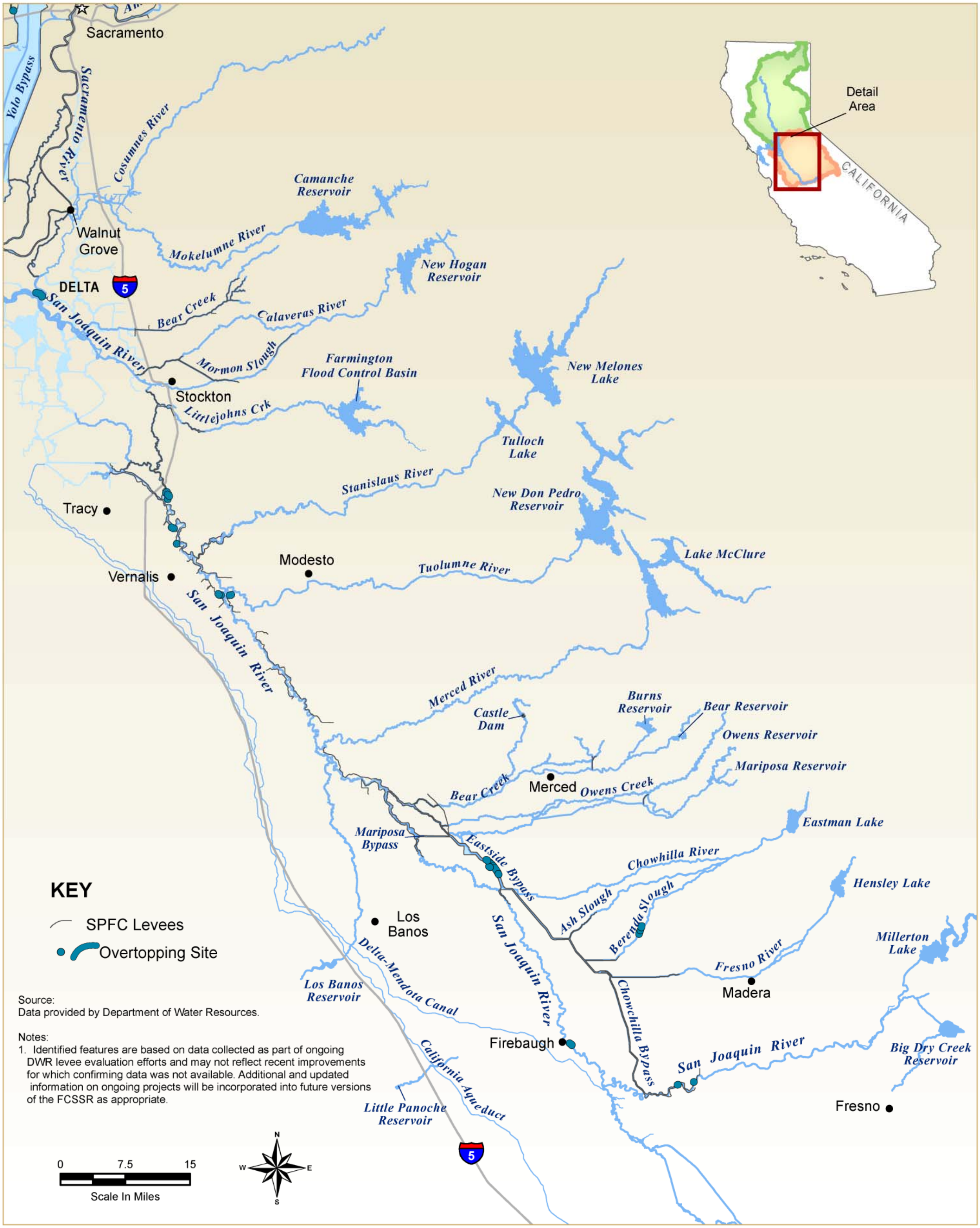

Figure A-4. Historical Levee Overtopping in San Joaquin River Watershed

Summary of Recent Remedial Actions/Improvements

USACE, the Board, and local agencies continue to implement site-specific projects as they become ready for construction. The Early Implementation Program and USACE/Board projects are not part of the SPFC, but may become part of the SPFC after completion of the processes outlined in the *SPFC Descriptive Document*, Sections 7.6 and 7.7 (DWR, 2010a). Locations of current Early Implementation Program and USACE/Board projects are shown in Figure A-5. Further description is included in the *SPFC Descriptive Document* (DWR, 2010a). Finally, other modifications to SPFC facilities have been completed by federal and local entities, but are not currently part of the SPFC because they lack State assurances of nonfederal cooperation to the federal government and/or State authorization.

Early Implementation Program

From bond funds made available by Propositions 1E and 84, DWR has developed the Early Implementation Program to help local agencies to implement their projects in advance of adoption of the Central Valley Flood Protection Plan (CVFPP). Early Implementation Program projects have an identified benefit for proceeding before adoption of the 2012 CVFPP, especially if the Early Implementation Program project provides for increased level of protection for urban areas in deep floodplains. None of these projects have received Congressional authorization yet. A brief description of each project and its current status as of May 2011 is provided in Table A-11.

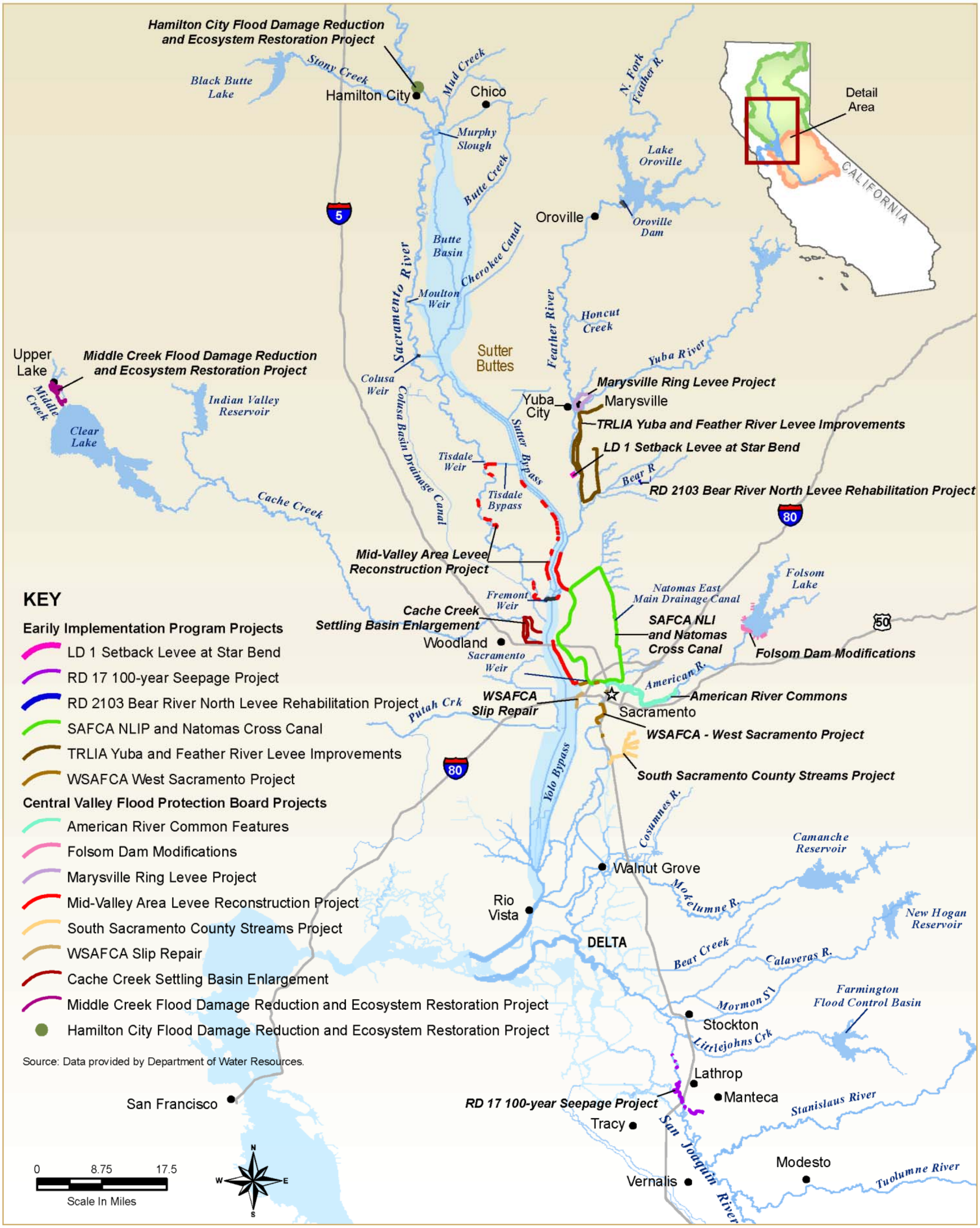

Figure A-5. Early Implementation Program and USACE/Board Projects in Sacramento and San Joaquin River Watersheds

Table A-11. Early Implementation Program Project Summary

Project Name	Project Description	Project Status (May 2011)
LD 1 Setback Levee at Star Bend (Feather River)	Setback levee with a cutoff wall and levee strengthening the existing levee system for the surrounding urban area.	Closeout phase
RD 17 100-Year Levee Seepage Area Project	Construction of cutoff walls, levee strengthening, seepage berms and setback levees to the existing system for the surrounding urban areas of South Stockton, Lathrop, and Manteca.	Construction phase
RD 2103 Bear River North Levee Rehabilitation Project	Construction of cutoff walls where under-seepage gradients on the landside toe exceed USACE criteria.	Closeout phase
SAFCA Natomas Levee Improvement Program (RD 1000)	Construction of cutoff walls and levee strengthening and reshaping features of the existing levee system surrounding the Natomas Basin.	Construction phase
TRLIA (RD 784) Feather River Levee Improvement Project	Construction of levee repairs and setback levees.	Closeout phase
TRLIA (RD 784) Upper Yuba Levee Improvement Project	Construction of levee repairs and setback levees.	Construction phase
WSAFCA West Sacramento Levee Improvement Project	Construction of levee improvements to achieve a 200-year level of protection.	Design phase

Key:
LD = levee district
RD = reclamation district
SAFCA = Sacramento Area Flood Control Agency
TRLIA = Three Rivers Levee Improvement Authority
USACE = U.S. Army Corps of Engineers
WSAFCA = West Sacramento Area Flood Control Agency

USACE/Board Projects

USACE, in partnership with the Board, is currently designing and constructing several projects that will improve the flood management system in the Sacramento and San Joaquin river watersheds. These projects reduce the occurrence and consequences of flooding. All USACE/Board projects have received Congressional authorization and have Board assurances of nonfederal cooperation contained in a project agreement. A listing and brief description of USACE/Board projects that are in design, construction, or closeout phases and their current status as of May 2011, is provided in Table A-12. In addition to the projects listed in Table A-12, several feasibility-level investigations are ongoing within the Sacramento and San Joaquin river watersheds. As these investigations proceed toward specific projects and detailed design, construction, or closeout phases they will be included in future updates to the FCSSR.

Table A-12. USACE/Board Project Summary

Project Name	Project Description	Project Status (May 2011)
American River Watershed, Common Features Project	Raise and widen levees and close gaps in slurry walls to prevent flooding in the Sacramento area.	Construction and closeout phases
American River Watershed, Folsom Dam Joint Federal Project	Raise the dikes around Folsom Reservoir by 3.5 feet to increase surcharge flood storage.	Partially complete design phase
Hamilton City Flood Damage Reduction and Ecosystem Restoration Project	6.8-mile-long setback levee alignment that will increase the level of flood protection at Hamilton City and restore approximately 1,480 acres along the Sacramento River.	Design phase
Yuba River Basin Project, Marysville Ring Levee Element	Construction of cutoff walls and levee strengthening and reshaping features for the existing levee system surrounding the Marysville urban area.	Design phase
Middle Creek Flood Damage Reduction and Ecosystem Restoration Project	Construction of flow-regulation structures to restore vegetation and wetlands.	Design phase
South Sacramento County Streams Group Project	Construct channel improvements, floodwalls, levee raising, levees, seepage cutoff walls, and bridge retrofits.	Construction phase
West Sacramento Project (Slip Repair)	Levee raising, levee offsets, and slurry wall construction.	Construction phase
Cache Creek Settling Basin Enlargement	Enlargement of settling basin facilities.	Closeout phase
Sacramento River Bank Protection Project Phase II [1]	Bank protection at identified sites of the Sacramento River Flood Control Project.	Design, construction, and closeout phases for different sites

Note:
[1] Because these sites are scattered throughout the Sacramento River watershed and GIS information was not available, the sites are not included on Figure A-5.

Key:
USACE – U.S. Army Corps of Engineers

Modifications to SPFC Facilities

In addition to the Early Implementation Program and USACE/Board projects, modifications to SPFC facilities influence SPFC status, but some are not part of the SPFC because they lack State of California (State) assurances of cooperation to the federal government and/or are not yet authorized by the Board for acceptance into the SPFC. Some modifications will not be authorized by the Board for acceptance into the SPFC, such as a gap in the Yolo Bypass east levee created by construction of the Sacramento Deep Water Ship Channel. The function of the previous levee was superseded by the Sacramento Deep Water Ship Channel federal navigation levee, but the navigation levee is not part of the SPFC. Other modifications to SPFC facilities were completed without State assurances of cooperation to the federal government and have not been authorized by the Board for acceptance into the SPFC, but may be authorized in the future. These modifications include the San Joaquin Area Flood Control Agency Flood Protection Restoration Project and the South Olivehurst Detention Basin Project improvements. While these and other modifications may not meet the legislative definition of the SPFC, they provide an important collective contribution to improve the function and status of SPFC facilities.

Ongoing Actions to Improve Future Evaluations

Levee analyses conducted through the DWR Levee Evaluations Program consider both past and future (projected) performance of levees as they relate to levee geometry, seepage, stability, erosion, and settlement. To perform a detailed evaluation of the levee system’s current condition, a wide range of critical levee properties is being studied, including the following:

- Geomorphology
- Historical events
- Levee topography
- Levee materials and construction
- Subsurface conditions
- Erosion conditions

Traditional and Other Methods

Much of the evaluation of the levees and their foundations is done by relatively straightforward geotechnical exploration methods (e.g., drilling) to collect soil samples, which are then analyzed to assess subsurface conditions. Cone penetrometer testing is also used to determine the composition and properties of subsurface soils. Looking closely at subsurface soil conditions—such as moisture, density, soil grain size distribution, and shear strength—helps identify potential problems or weaknesses in levees. In addition to the basic geotechnical evaluation program of drilling and boring to collect levee soil samples, other proven methods and innovative technologies are being used to develop a comprehensive understanding of the levees' existing subsurface conditions, and identify which areas are most in need of critical improvements or repairs.

Light Detection and Ranging Surveys

Light Detection and Ranging (LiDAR) technology deployed in low-flying helicopters has been used to electronically gather data about the topography and configuration of flood control levees. Results aid evaluation of levee geometry, stability, erosion, and settlement of the surveyed levees.

Bathymetric Surveys

The above-water topographic data collected during LiDAR surveys have been supplemented with bathymetric surveys. Underwater bathymetric surveys produce detailed topographic data of a riverbed and riverbanks that essentially form the base of the levee systems. The collected data provide an image of the levees' underwater structure that cannot be obtained by conventional land topographic methods. The results aid evaluation of levee geometry and erosion.

Surficial Geomorphic Mapping

A comprehensive surficial geomorphic map of project areas, based on field reconnaissance and review of vintage aerial photos and topographic maps, geologic maps, and satellite imagery, is also being prepared. Results of this effort will lead to a better understanding of the materials directly beneath existing levees and of geomorphic processes, such as erosion and deposition that are responsible for those materials. The collected data will aid evaluation of erosion, seepage, and structural instability.

Electromagnetic Surveys

Levee subsurface conditions are being evaluated by conducting geophysical electromagnetic surveys. The electromagnetic technology senses variations in the ground's electrical conductivity to depths of more than 100 feet underground. The goal is to map important changes in soil types and ground conditions, identifying zones where permeable soils are present or excessive water penetration is taking place. The results aid in evaluation of levee seepage, structural instability, erosion, and settlement.

A-2 Levee Geometry Check

This section describes ULE and NULE freeboard check results, recent remedial actions/improvements (including locations of levee raises, widening, and levee reconstructions), current and ongoing remedial actions/improvements, and ongoing actions to improve future evaluations of levee geometry.

Freeboard Check Results

Lack of levee freeboard can be caused by a variety of factors, such as settlement and inadequate maintenance. A freeboard check was conducted as part of the ULE and NULE projects. For the Sacramento River watershed, the freeboard check consisted of a comparison of the levee crest elevation, as provided by the levee crest survey data from the California Levee Database, to requirements of the *1953 Memorandum of Understanding* (USACE and Reclamation Board, 1953). The *1953 Memorandum of Understanding* generally requires a minimum of 3 feet of freeboard above the 1955/1957 design water surface elevation for riverine levees and 6 feet of freeboard above the 1955/1957 design water surface elevation for bypass levees.

For the San Joaquin River watershed, the freeboard check consisted of a comparison of the levee crest elevation with the design water surface elevation. Freeboard requirements were indicated from available design data. If a levee segment lacked a verifiable design water surface elevation but a 1 percent chance event (100-year) water surface elevation was available, it was used to assess freeboard. Such conditions were specific to the Calaveras and Bear Creek systems in San Joaquin County. Where neither a design nor 1 percent chance event water surface elevation were available, the freeboard check could not be performed.

Urban Levee Evaluations Project

ULE Project evaluations included assessing each ULE levee segment and assigning each segment to one of the following classifications:

- **Meets Criteria (M) –** Levees in this classification meet or exceed criteria.
- **Marginal (MG) –** Levees in this classification are marginal in meeting criteria.
- **Does Not Meet Criteria (DNM) –** Levees in this classification do not meet criteria. These are the levees that require the most immediate attention for repair or replacement.
- **Lacking Sufficient Data (LD) –** Levees in this classification lack sufficient data to allow placement into one of the above three classifications.

ULE freeboard check results are shown on Figure A-6. Levees that do not meet freeboard criteria include portions of the Pleasant Grove Creek Canal and Natomas East Main Drainage Canal, the south bank of the Yuba River east of Marysville, the Davis/Woodland area and along Upper Bear Creek.

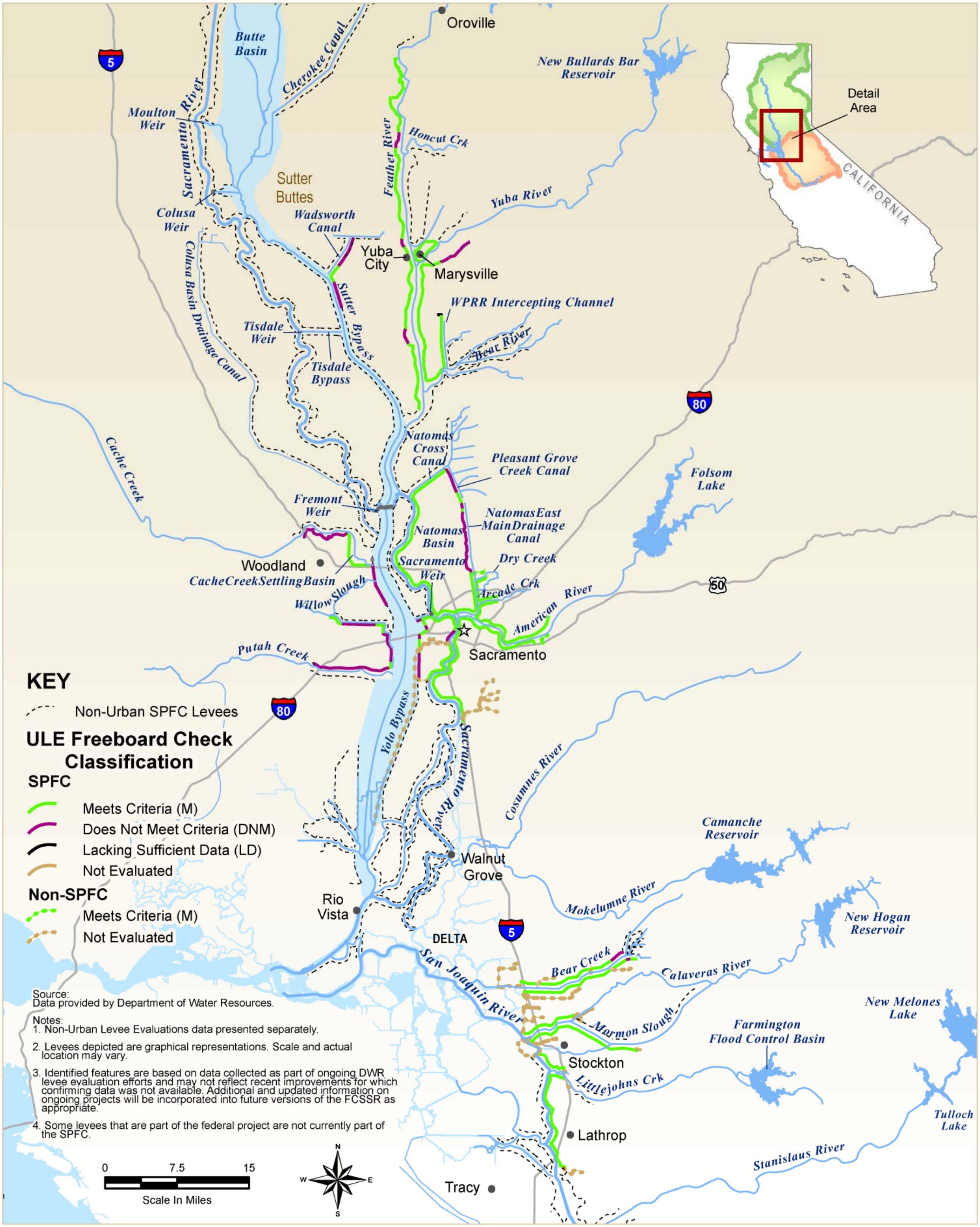

Figure A-6. ULE Freeboard Check Results

Non-Urban Levee Evaluations Project

Figures A-7 and A-8 show a pass or fail result for NULE levee segments in both the Sacramento and San Joaquin river watersheds regarding whether they meet freeboard requirements. Freeboard results show that portions of both banks of the Sutter Bypass, both banks of the Yolo Bypass, Butte Creek, Colusa Basin Drainage Canal, and the Bear River do not meet freeboard criteria. Compliance with freeboard criteria is variable in other areas within the Sacramento River watershed. In the San Joaquin River watershed, levee reaches along the lower Stanislaus River, lower Tuolomne River, San Joaquin River downstream of Merced River, upper Bear Creek and Paddy Creek do not meet freeboard criteria.

For additional details on the NULE freeboard check methodology and results, see the *Geotechnical Assessment Report for the North NULE Study Area and South NULE Study Area* (DWR, 2011a and 2011b).

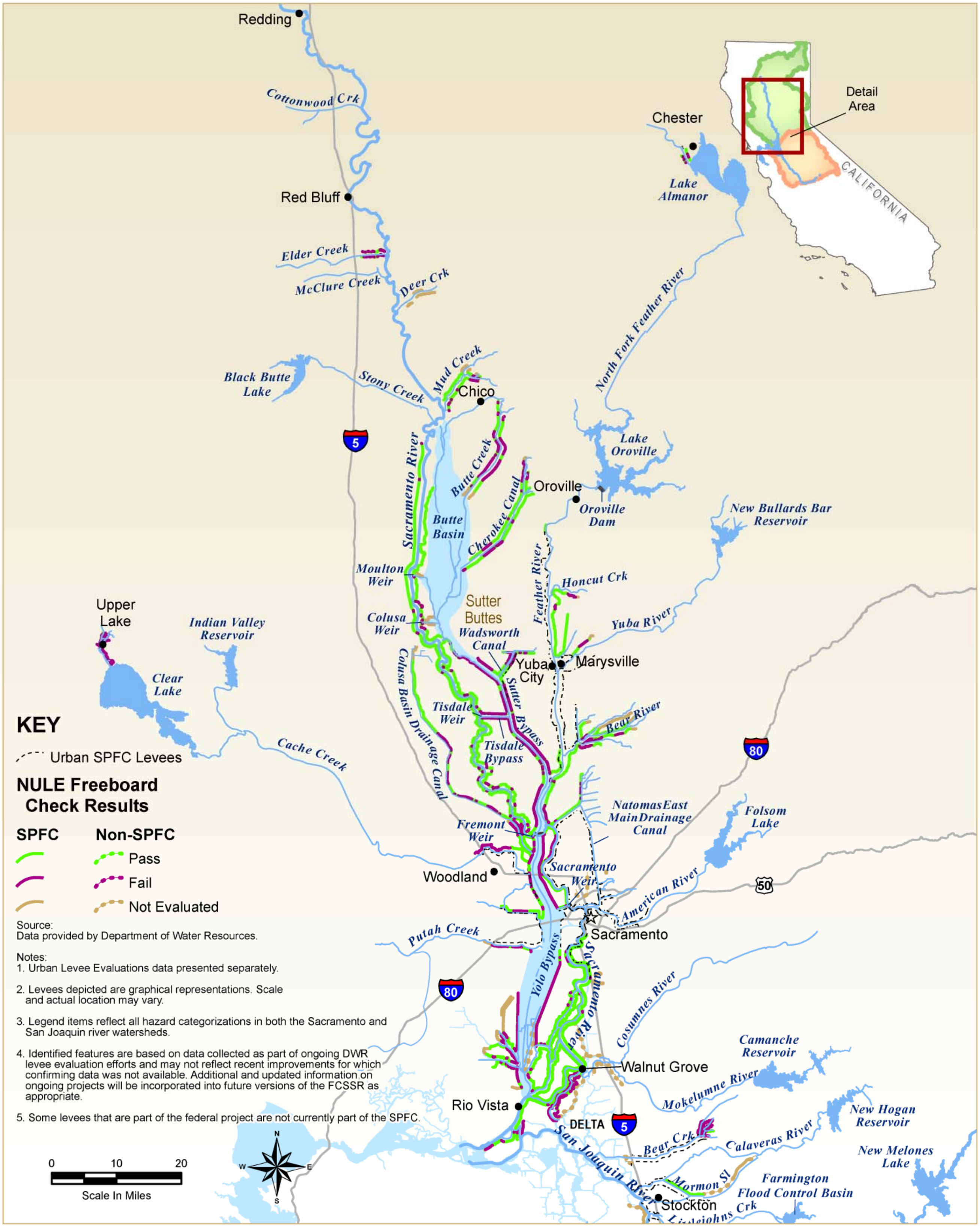

Figure A-7. NULE Freeboard Check Results in Sacramento River Watershed

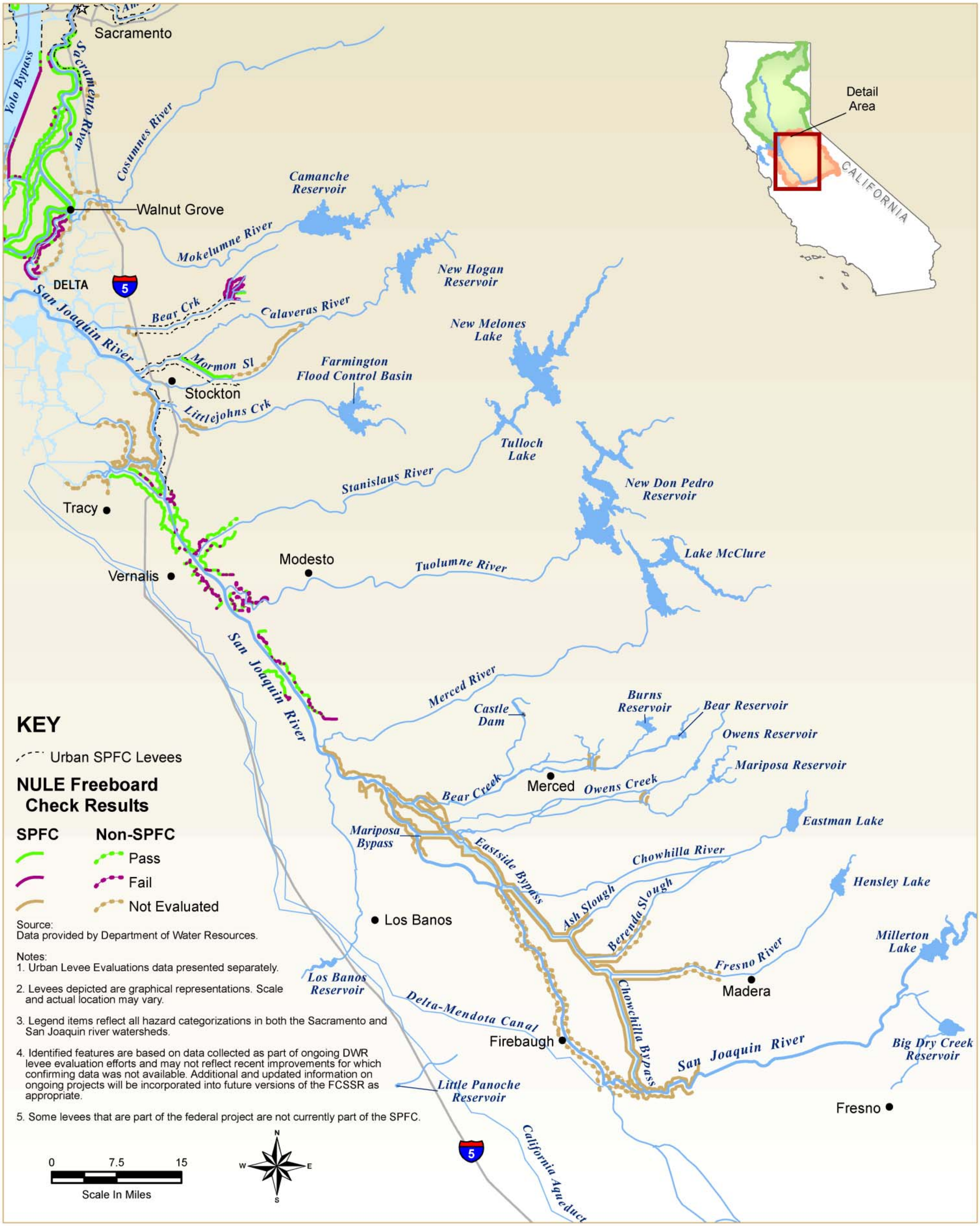

Figure A-8. NULE Freeboard Check Results in San Joaquin River Watershed

Summary of Recent Remedial Actions/Improvements

DWR's Levee Evaluations Program collected and cataloged recent levee raises, levee widening, and levee reconstructions. Figures A-9 and A-10 show locations of these documented reconstructions and improvements for the Sacramento River and San Joaquin River watersheds, respectively.

Summary of Ongoing and Planned Remedial Actions/Improvements

Several of the Early Implementation Program and USACE/Board projects discussed in Section A-1 include levee reconstructions and improvements that address inadequate levee geometry.

Ongoing Actions to Improve Future Evaluations

DWR continues to collect levee information using traditional and innovative methods, including LiDAR and bathymetric surveys (see Section A-1).

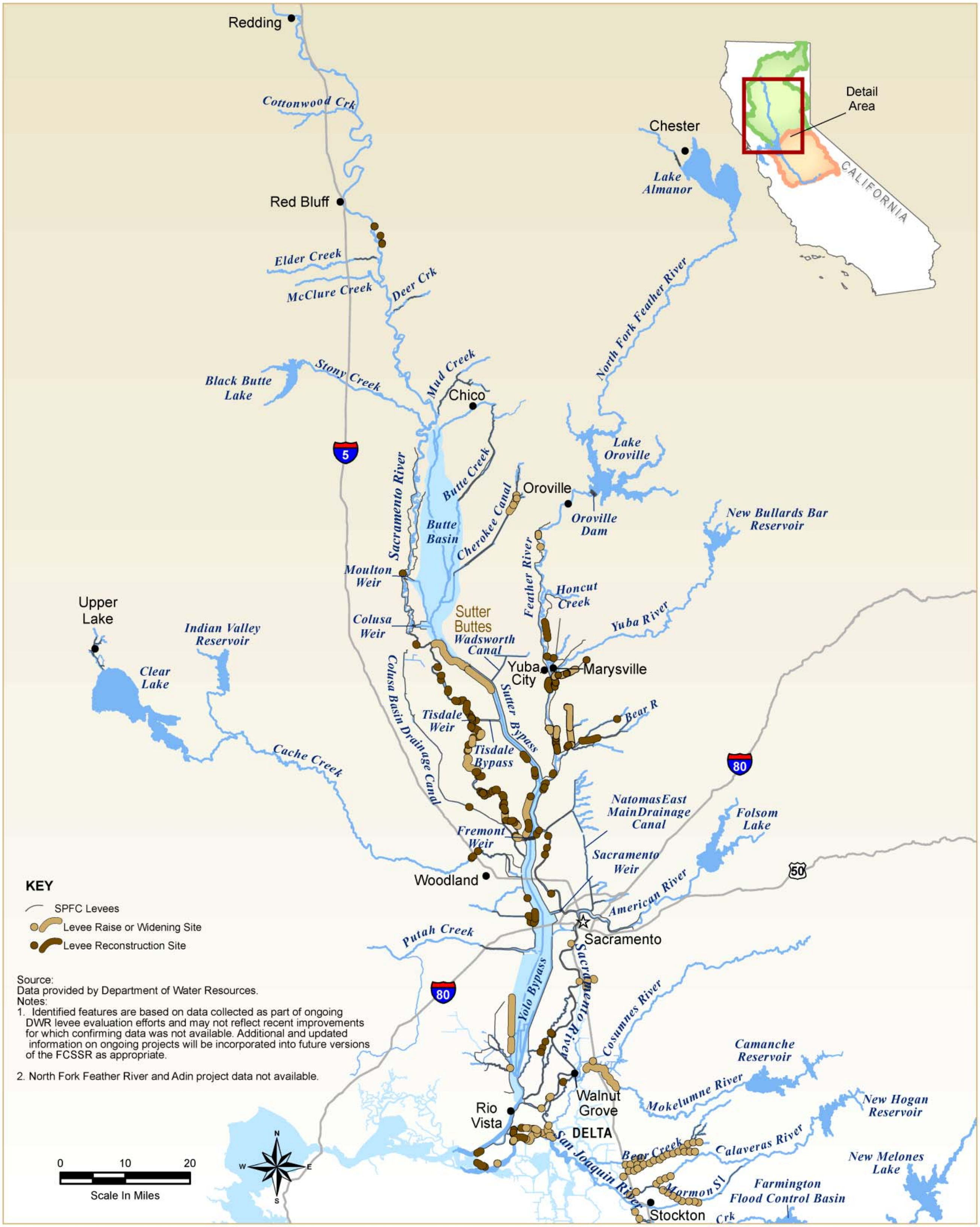

Figure A-9. Levee Raises, Levee Widenings, and Levee Reconstructions in Sacramento River Watershed

Figure A-10. Levee Raises, Levee Widenings, and Levee Reconstructions in San Joaquin River Watershed

A-3 Seepage

This section includes DWR annual inspection results for seepage, and locations of historical seepage occurrences documented by the ULE and NULE projects. Recent, current, and ongoing remedial actions/improvements including locations of seepage remediation projects documented by the ULE and NULE projects, and seepage-related levee reconstructions and improvements planned and conducted by DWR, are described. A description of ongoing actions to improve future evaluations is also included.

Results of Inspections

DWR visually inspects SPFC levees for seepage/sand boils at least twice a year, and reports results annually. Table A-13 shows the DWR inspection rating descriptions for seepage/sand boils on earthen levees.

Table A-13. Levee Inspection Rating Descriptions for Seepage/Sand Boils on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	No seepage, saturated areas, or sand boils occurring at the time of the inspection.
Unacceptable (U)	Seepage and/or sand boils were observed that could threaten the integrity of the project. Regardless of size, any sand boils observed during low water conditions could threaten project integrity when the water is high, and are considered unacceptable.

The biannual inspections that DWR conducts are performed during the spring and fall of each year, and do not necessarily coincide with the flood season. Therefore, routine DWR inspections are less likely to reveal instances of seepage because inspections are usually performed when water is below the toe of levees. Furthermore, the extent of seepage and whether the seepage condition is in a steady or changing state are difficult to determine from visual inspections. Limited knowledge of subsurface conditions also makes it difficult to identify seepage problems.

Because 2009 was a relatively dry year and there were no high-water events, no occurrences of seepage/sand boils were observed or documented in the *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (DWR, 2010b).

Historical Seepage Occurrences

The ULE and NULE projects collected and cataloged historical occurrences of levee seepage and completed or planned repairs or improvements. Figures A-11 and A-12 show historical seepage occurrences collected by the ULE and NULE projects in the Sacramento and San Joaquin river watersheds, respectively. In the Sacramento River watershed, historical seepage occurrences were located throughout the system and were particularly prevalent along the Sutter Bypass and Sacramento River south of Sacramento. In the San Joaquin River watershed, most historical seepage occurrences were along the San Joaquin River and Eastside Bypass.

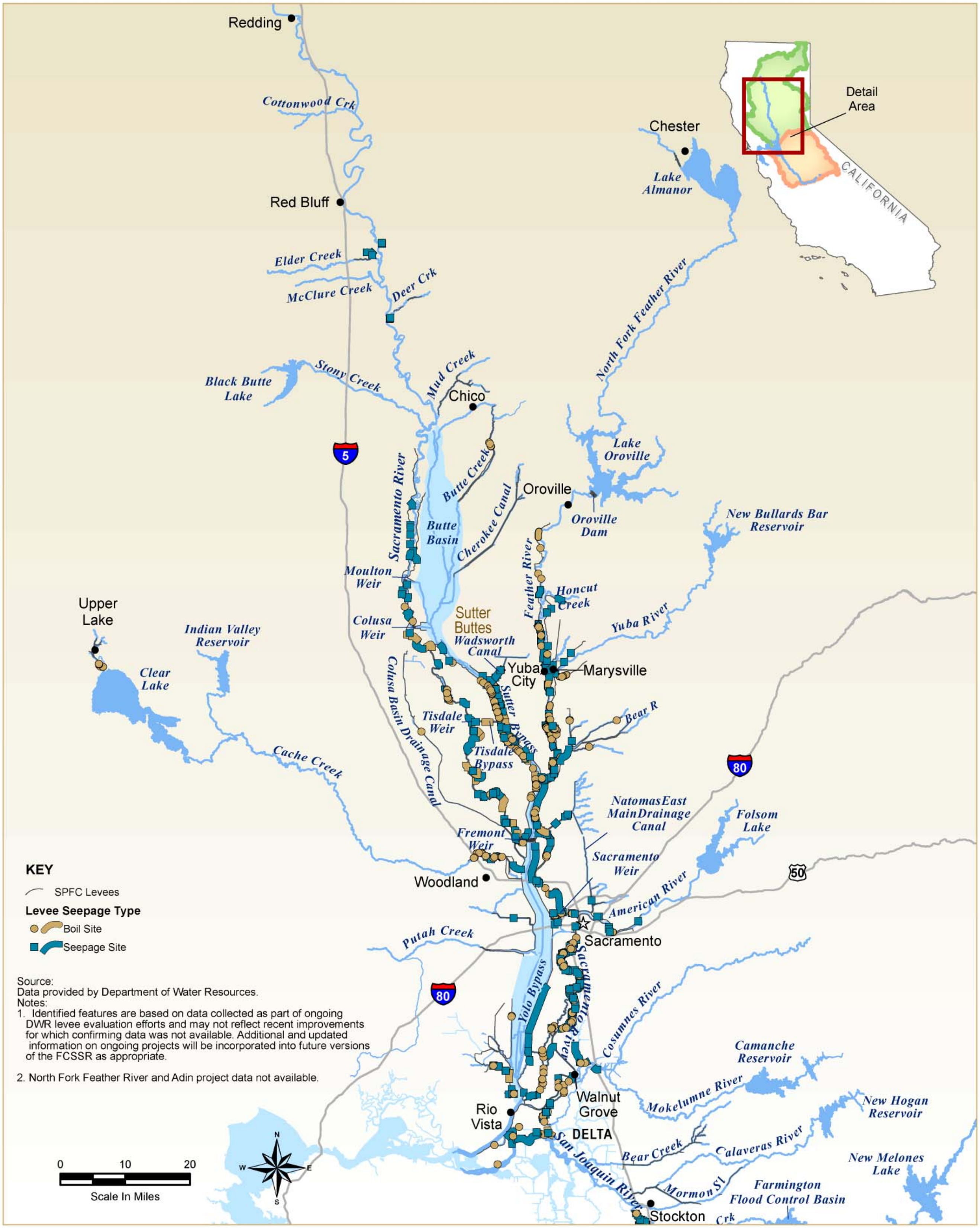

Figure A-11. Historical Seepage Occurrences in Sacramento River Watershed

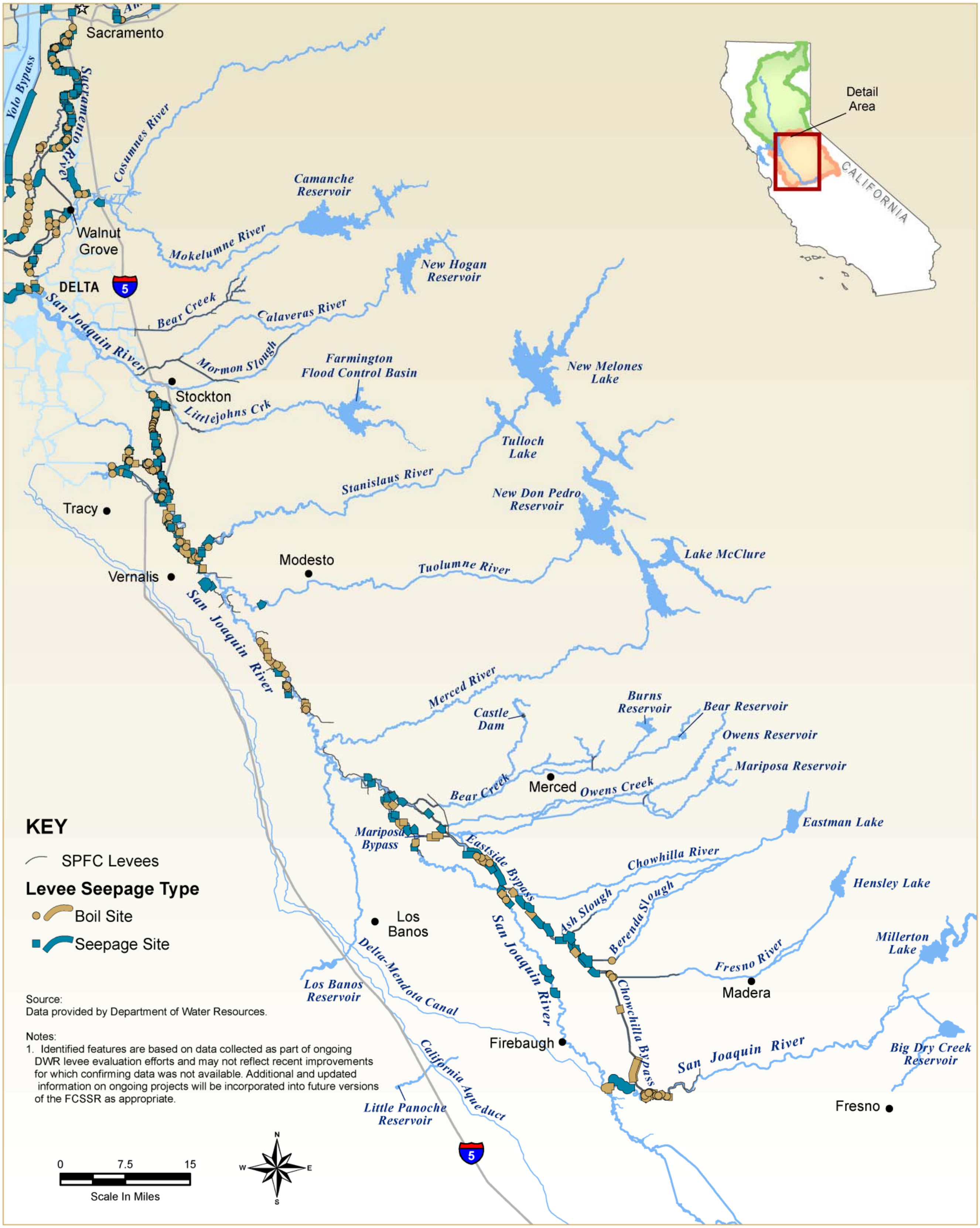

Figure A-12. Historical Seepage Occurrences in San Joaquin River Watershed

Summary of Recent Remedial Actions

Seepage remediation projects have been constructed throughout the Sacramento and San Joaquin river watersheds to address identified seepage problems. The ULE and NULE projects collected and cataloged data on the locations of a wide range of seepage remediation actions. Figures A-13 and A-14 show seepage remediation efforts in the Sacramento River and San Joaquin River watersheds, respectively. Seepage remediation has occurred throughout the Sacramento River watershed and is particularly concentrated in the Sutter Bypass, lower Feather River, west side of Natomas, American River, Sacramento River south of Sacramento, and Yolo Bypass near Woodland. In the San Joaquin River watershed, seepage remediation is the most concentrated on the lower San Joaquin River north of Stanislaus River and the upper San Joaquin River near the Chowchilla Bypass.

Summary of Ongoing and Planned Remedial Actions/Improvements

Seepage and boils are identified and monitored by maintaining agencies to initiate floodfighting and levee reconstruction and/or improvements. DWR's Levee Repairs Program is described below, and many of the Early Implementation Program and USACE/Board projects identified in Section A-1 will preserve and enhance the integrity of SPFC levees with regard to seepage.

DWR Levee Repairs Program

DWR's Levee Repairs Program repairs critically and not critically damaged levees. The projects are implemented through collaboration with the resource agencies, USACE, and local agencies. The Levee Stability Program and Public Law 84-99 Rehabilitation Assistance Program address seepage problems.

USACE's Levee Stability Program was authorized by the Water Resources Development Act of 2007. Levee Stability Program sites are selected by DWR's Levee Evaluations Program. As of December 2010, four seepage sites were recommended for remediation, but additional sites are anticipated as the Levee Evaluations Program continues.

The Flood Control and Coastal Emergency Act (Public Law 84-99) provides the federal government authority for emergency management activities. Under Public Law 84-99, USACE is authorized to undertake rehabilitation of flood control works threatened or destroyed by floods. USACE decides which sites qualify for assistance under the Public Law 84-99 program. After the 2005 – 2006 storms, 20 seepage sites were determined to be eligible for Public Law 84-99 assistance by USACE. Since then, all of these sites have been rehabilitated.

Planned and completed seepage remediation sites from the Levee Stability Program and Public Law 84-99 program are shown in Figures A-15 and A-16 for the Sacramento River watershed and San Joaquin River watershed, respectively.

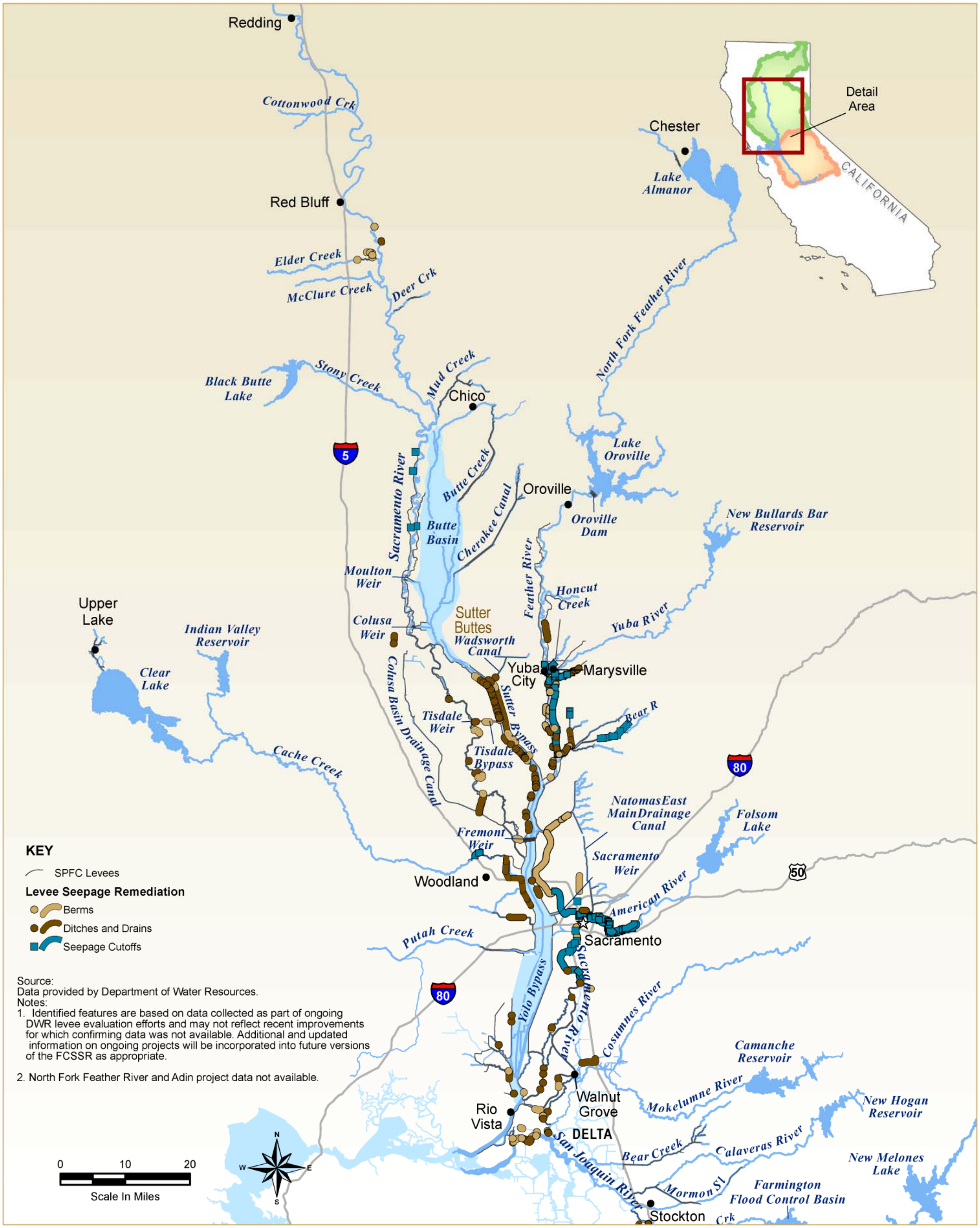

Figure A-13. Seepage Remediation in Sacramento River Watershed

Figure A-14. Seepage Remediation in San Joaquin River Watershed

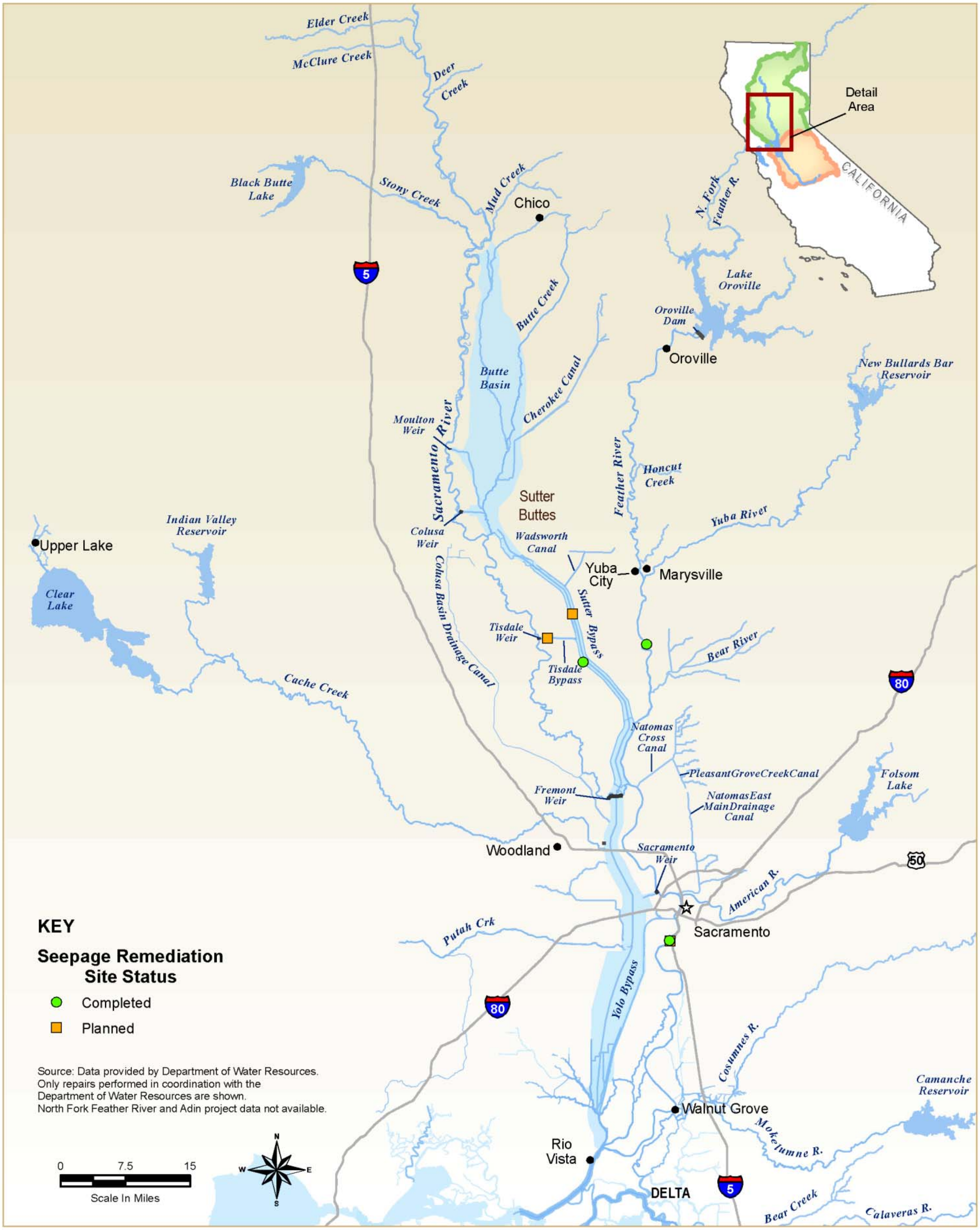

Figure A-15. Planned and Completed Seepage Remediation Sites from DWR Levee Stability Program and Public Law 84-99 Program in Sacramento River Watershed

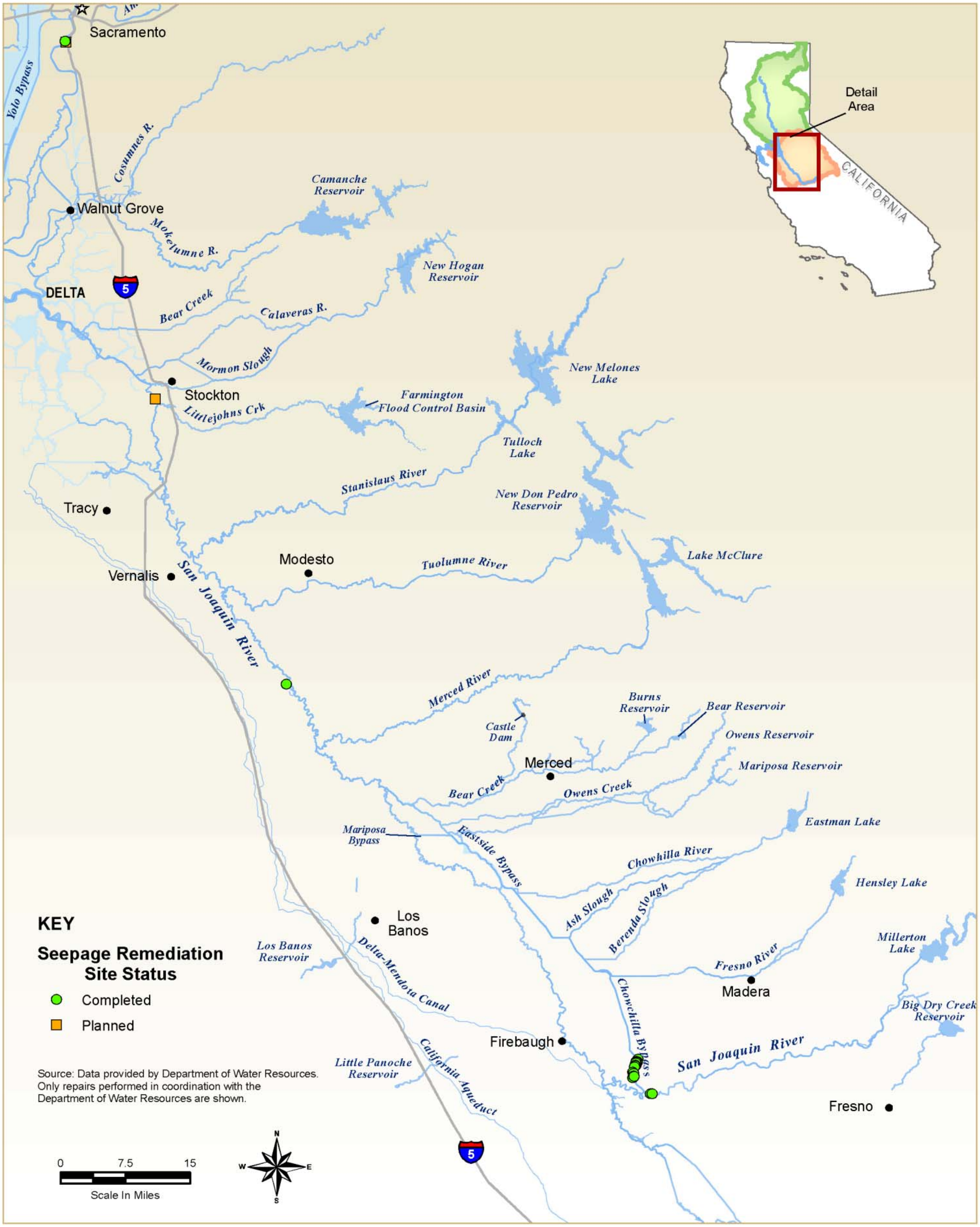

Figure A-16. Planned and Completed Seepage Remediation Sites from DWR Levee Stability Program and Public Law 84-99 Program in San Joaquin River Watershed

Ongoing Actions to Improve Future Evaluations

DWR continues to collect levee information using traditional and new innovative methods, including electromagnetic surveys. DWR is also in the early planning stages of conducting a levee monitoring pilot study that would evaluate the effectiveness and usefulness of direct, real-time measurements of seepage rates through and under levees during high-water events. The study would involve installing sealed piezometers and river stage gages at preselected critical locations within the Sacramento and San Joaquin river watersheds.

A-4 Structural Instability

This section includes results of the DWR annual inspections for slope stability and historical levee slope instability ccurrences. Recent, ongoing, and planned remedial actions and improvements, and ongoing actions to improve future evaluations for structural instability are also included.

Results of Inspections

As mentioned, DWR visually inspects SPFC levees at least twice a year, and reports results annually. Information is collected during the inspections on the performance of the levee embankment as it relates to slope stability. Table A-14 shows the DWR inspection rating descriptions for slope stability on earthen levees.

Table A-14. Levee Inspection Rating Descriptions for Slope Stability on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	No slides present.
Minimally Acceptable (M)	Minor superficial sliding that with deferred repairs will not pose an immediate threat to flood control works integrity.
Unacceptable (U)	Evidence of deep-seated sliding that threatens flood control works integrity. Repairs are required to reestablish flood control works integrity.

Visual inspections provide limited information on levee conditions related to slope stability. A typical levee inspection occurs from the crown of the levee. Thick vegetation and wide berms can obstruct an inspector's view of slides. Limited knowledge of subsurface conditions also makes it difficult to identify some slope stability problems.

Slope stability levee inspection ratings from the *2009 Inspection Report of the Central Valley State-Federal Flood Protection System* (DWR, 2010b) are shown on Figures A-17 and A-18. Two sites with Unacceptable ratings for slope stability are located in the Delta. In the Sacramento River watershed has no Unacceptable ratings, but several sites, in various locations, have Minimally Acceptable ratings. In the San Joaquin River, Minimally Acceptable ratings are located on the lower San Joaquin River, Bear Creek, Mormon Slough, and Littlejohns Creek.

Figure A-17. 2009 Slope Stability Inspection Ratings in Sacramento River Watershed

Figure A-18. 2009 Slope Stability Inspection Ratings in San Joaquin River Watershed

Historical Levee Slope Instability Occurrences

The ULE and NULE projects collected and cataloged information on historical occurrences of levee slope instability. Figures A-19 and A-20 show historical slope instability occurrences collected from the ULE and NULE projects for the Sacramento and San Joaquin river watersheds, respectively. In the Sacramento River watershed, historical levee slope instability occurrences were located most frequently in the lower Sacramento River watershed south of the Fremont Weir. Slope instability was most prevalent on the Sacramento River south of Sacramento and in the north Delta. In the San Joaquin River watershed, historical levee slope instability occurrences were prevalent through the watershed.

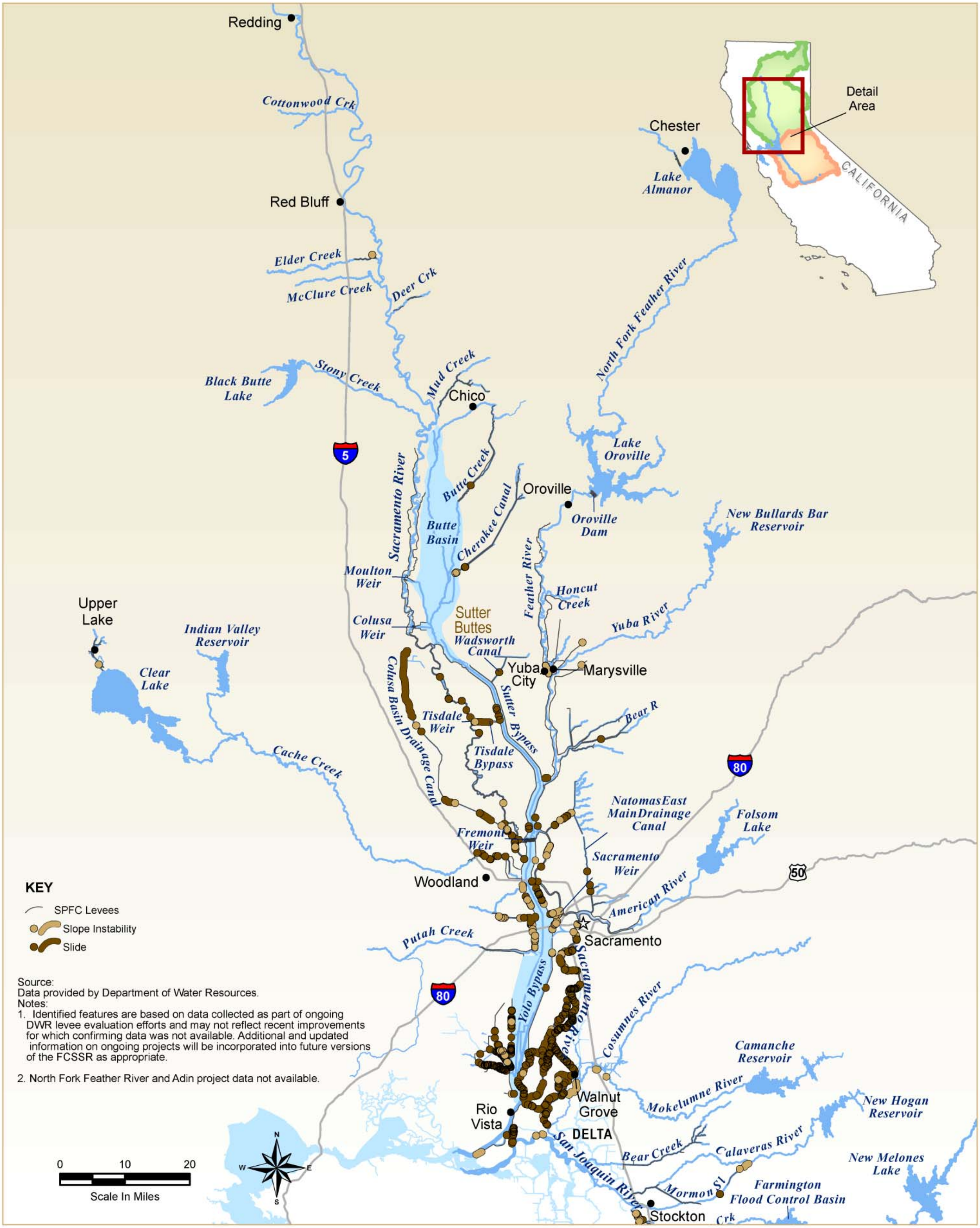

Figure A-19. Historical Slope Instability Occurrences in Sacramento River Watershed

Figure A-20. Historical Slope Instability Occurrences in San Joaquin River Watershed

Summary of Recent Remedial Actions

Stability berms, revetment, and riprap have been installed through DWR's Levee Repairs Program after slope instability was reported. Problems were generally identified from inspections or as part of levee reconstruction projects that restore levees to current design criteria. Revetments and riprap sites for the Sacramento and San Joaquin river watersheds are shown in Section A-5, Erosion.

Summary of Ongoing and Planned Remedial Actions/Improvements

Many slope stability problems are the result of inadequate levee geometry, erosion, or seepage problems. Several of the Early Implementation Program and USACE/Board projects shown in Section A-1 include levee improvements that address levee structural instability. DWR's Levee Repairs Program, described in Section A-2, also addresses structural instability.

Ongoing Actions to Improve Future Evaluations

DWR continues to collect levee information using traditional and new, innovative methods, including LiDAR, surficial geomorphic mapping, and electromagnetic surveys.

A-5 Erosion

This section includes results of DWR inspections and surveys for erosion and historical erosion occurrences. Recent, ongoing, and planned remedial actions and improvements, including revetment and riprap locations and erosion-related levee work planned and conducted by DWR, are included. Ongoing actions to improve future evaluations for erosion are also included.

Results of Inspections

Sites with erosion problems were identified through the following data sources:

- Levee Inspection Reporting (DWR, 2010b)
- San Joaquin River Flood Control System Erosion Surveys (DWR, 2010c)
- Sacramento River Bank Protection Project Erosion Surveys (USACE, 2010)

Levee Inspection Reporting

As mentioned, DWR visually inspects SPFC levees for erosion problems at least twice a year, and reports results annually. Table A-15 shows the DWR inspection rating descriptions for erosion/bank caving on earthen levees.

Table A-15. Levee Inspection Rating Descriptions for Erosion/Bank Caving on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	No active erosion or bank caving observed on the landward or on the riverward side of the levee.
Minimally Acceptable (M)	There are areas where active erosion is occurring or has occurred on or near the levee embankment, but levee integrity is not threatened.
Unacceptable (U)	Erosion or caving is occurring or has occurred that threatens the stability and integrity of the levee. The erosion or caving has progressed into the levee section or into the extended footprint of the levee foundation and has compromised the levee foundation stability.

San Joaquin River Flood Control System Waterside Erosion Surveys

In 2006, DWR began an erosion survey program for the San Joaquin River Flood Control System to assist in documenting and monitoring erosion sites. The most recent report, *2009 Supplemental Erosion Survey of the San Joaquin River Flood Control System* (DWR, 2010c), includes an inventory of levee erosion sites on the San Joaquin River Flood Control System. Surveys are conducted annually, between July and October. Land-based surveys are conducted by inspecting the waterside levee and berm from the levee crown. In navigable waterways where the view of the waterside levee is obstructed, a boat is used to conduct the survey.

Erosion sites were ranked using criteria partly based on the *2007 Field Reconnaissance Report of Bank Erosion Sites and Site Priority Ranking* (USACE, 2007), and the *Erosion Screening Process Report* (DWR, 2009a). The criteria have been partially modified to suit the type of data collected for the San Joaquin River system. An overall rating was assigned to each site based on a normalized total weighted score of erosion criteria (berm width, vegetation cover, burrow holes, levee slope, soil type, site relative to bend, radius of curvature, length of erosion, scarp height, and location of erosion). Table A-16 shows the DWR inspection rating descriptions for the surveys.

Table A-16. San Joaquin River Flood Control System Erosion Surveys Rating Descriptions for Erosion/Bank Caving on Earthen Levees

Inspection Rating	Rating Description
Minimally Acceptable (M)	A site that receives a normalized score equal to or less than the average is rated M. The site should be monitored and assessed annually for erosion activity, as it may become a serious inadequacy in the next flood event.
Unacceptable (U)	A site that receives a normalized score greater than the average is rated as U. The site may require corrective action soon, because it may become a serious inadequacy that can fail in the next flood event.

Sacramento River Bank Protection Project Erosion Surveys

Sacramento River Bank Protection Project erosion surveys are described in Section 2.1.3, Joint USACE and DWR Inspections.

DWR Levee Mile Reports incorporate data from all three inspections and present them according to the rating descriptions for erosion/bank caving on earthen levees, as shown in Table A-15. Data from the *2009 DWR Levee Mile Reports* are shown on Figures A-21 and A-22. Minimally Acceptable and Unacceptable ratings for erosion are located sporadically throughout the Sacramento River watershed. The north Delta and lower Sacramento River south of Sacramento have a relatively high concentration of erosion sites. Most of the erosion sites in the San Joaquin River watershed are along the lower San Joaquin River north of the Stanislaus River and Mormon Slough.

Limitations of Inspection Results

Visual inspections provide limited information on levee conditions related to erosion. A typical levee inspection occurs from the crown of the levee, but erosion on the slope and beyond is sometimes not visible from this vantage point. In addition, thick vegetation and wide berms can also obstruct an inspector’s view of an erosion site. Erosion surveys conducted by boat can improve on these limitations, but both the levee inspections and erosion surveys are limited to what is visible above the waterline from the top of the levee.

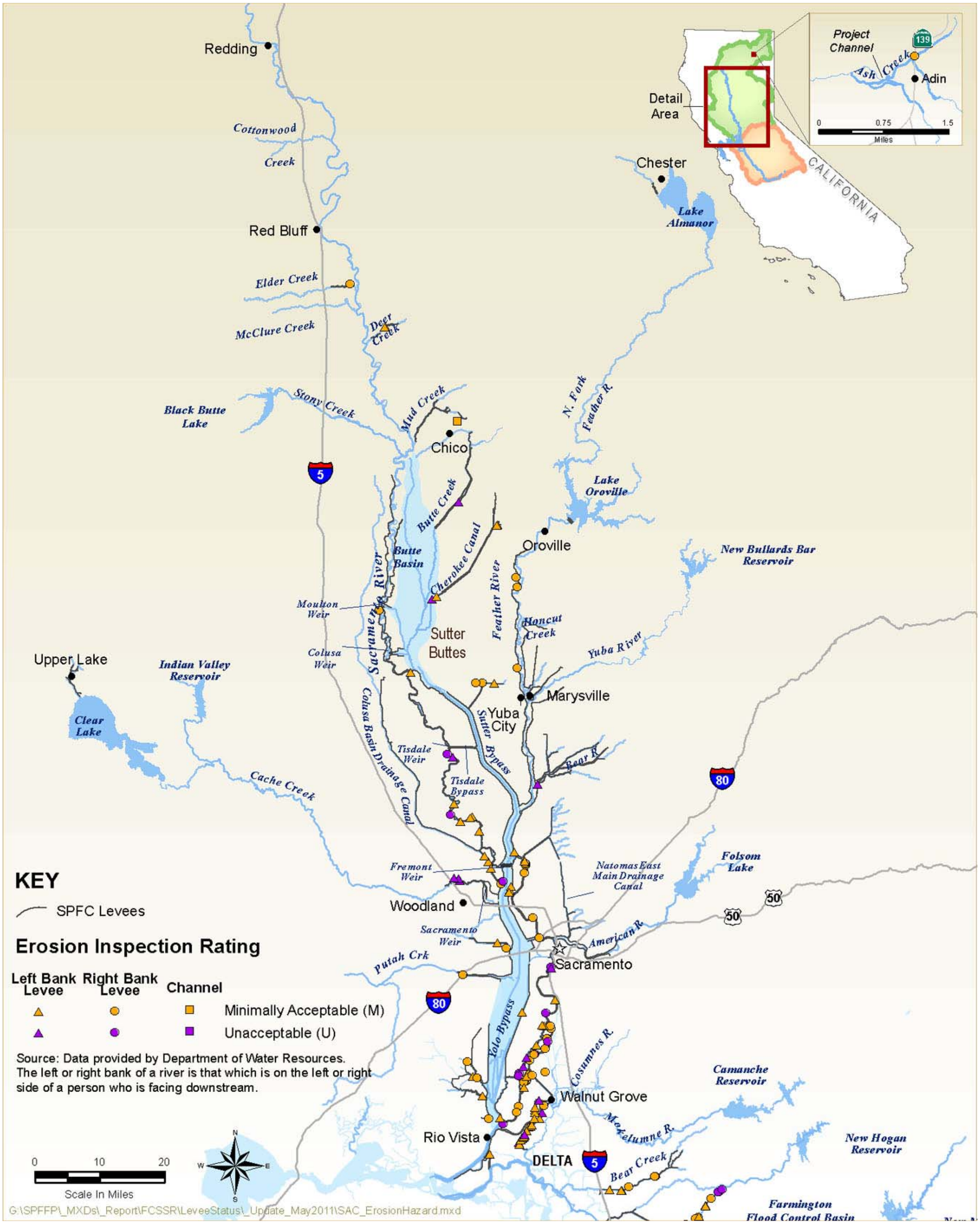

Figure A-21. 2009 Erosion Inspection Ratings in Sacramento River Watershed

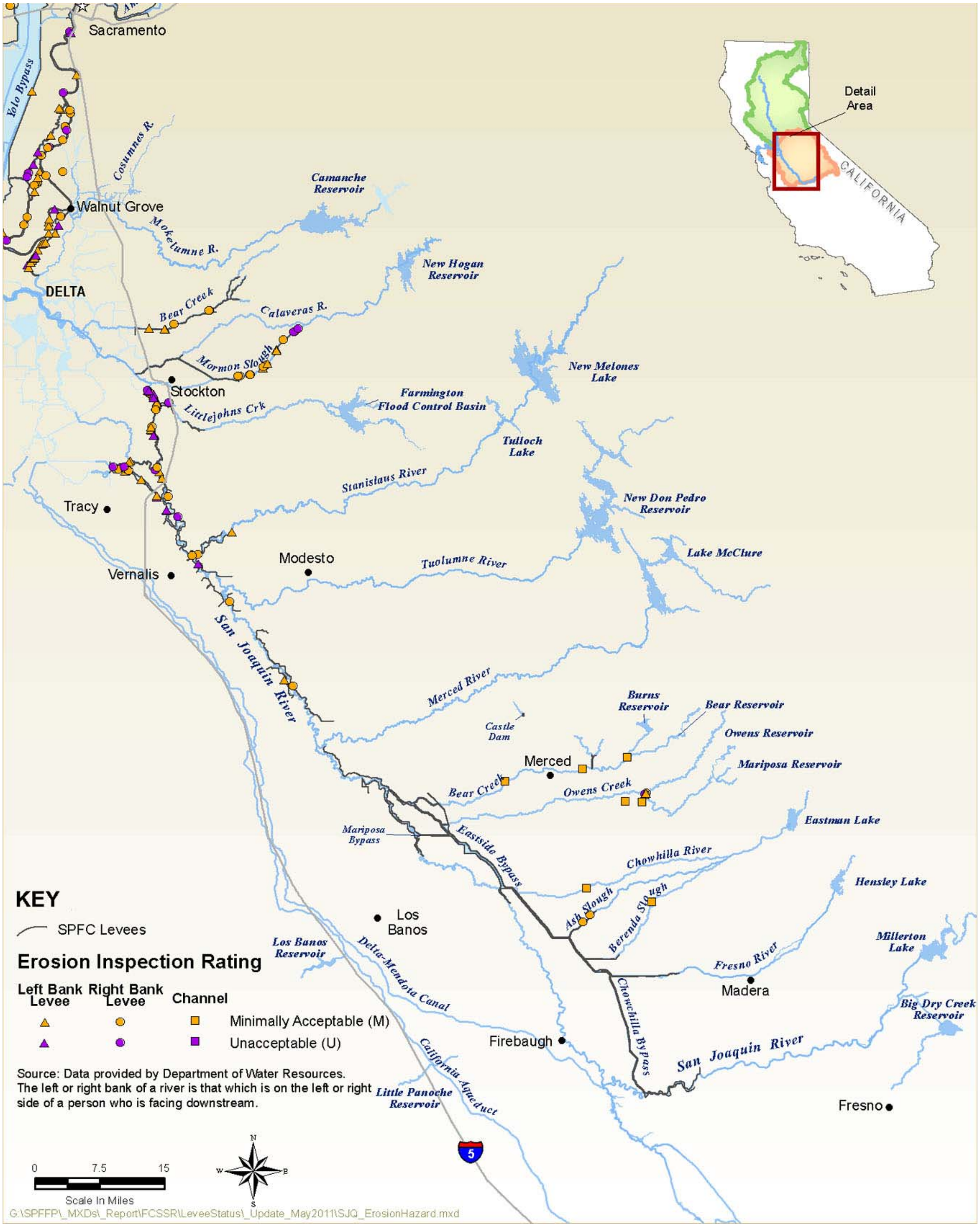

Figure A-22. 2009 Erosion Inspection Ratings in San Joaquin River Watershed

Historical Erosion Occurrences

The ULE and NULE projects collected and cataloged information on historical occurrences of levee erosion and completed or planned repairs or improvements. Figures A-23 and A-24 show historical erosion occurrences for the Sacramento and San Joaquin river watersheds, respectively. Historical erosion occurrences were located throughout almost all SPFC levees of the Sacramento and San Joaquin river watersheds.

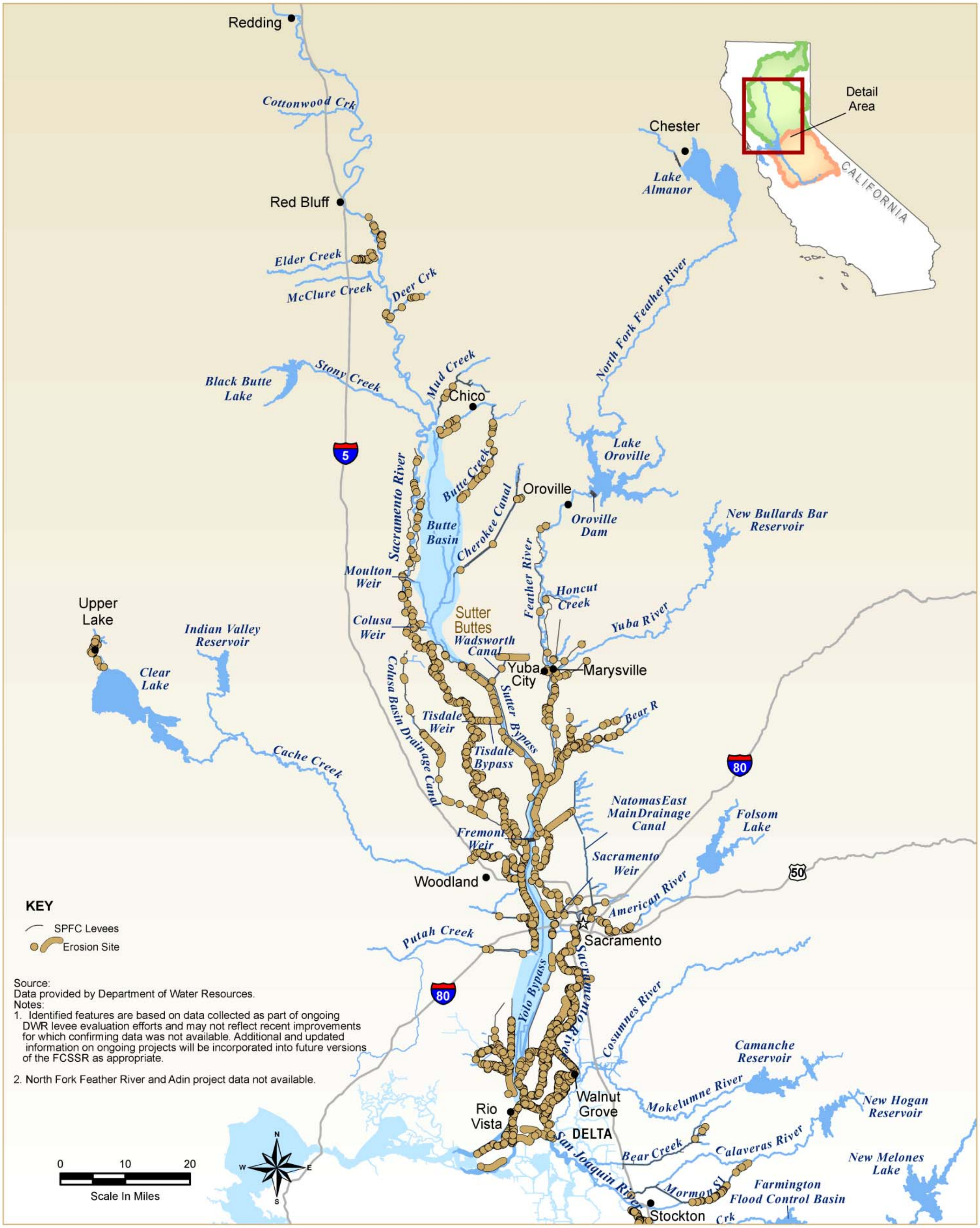

Figure A-23. Historical Erosion Occurrences in Sacramento River Watershed

Figure A-24. Historical Erosion Occurrences in San Joaquin River Watershed

Summary of Recent Remedial Actions

Revetment and riprap have been installed through DWR’s Levee Repairs Program after erosion was reported from inspections to restore levees to meet current design criteria.

Information on observed revetment and riprap sites was collected and cataloged as part of the data collection efforts for the ULE and NULE projects, as described in this section. Figures A-25 and A-26 show observed revetment and riprap sites for the Sacramento and San Joaquin river watersheds, respectively. Revetment and riprap have been placed throughout the Sacramento and San Joaquin river watersheds.

Summary of Ongoing and Planned Remedial Actions/Improvements

Erosion is identified and monitored by maintaining agencies to help identify locations that require remediation. DWR’s Levee Repairs Program is described below, and many of the Early Implementation Program and USACE/Board projects identified in Section A-1 will preserve the integrity of SPFC levees with regard to erosion.

DWR Levee Repairs Program

As mentioned, DWR’s Levee Repairs Program addresses critically and not critically damaged levees, leveraging existing programs and authorizations. The following projects/programs address erosion problems:

- Sacramento River Bank Protection Project
- Sacramento-San Joaquin Erosion Repair Project
- Levee Stability Program
- Public Law 84-99 Rehabilitation Assistance Program

The Sacramento River Bank Protection Project is a federally authorized project with cost sharing between USACE and the Board for SPFC levees that are at risk of an erosion failure during floods and/or normal flow conditions. Waterside erosion surveys of the Sacramento River system conducted every year provide an inventory of erosion sites. As of December 2010, 83 erosion sites had been repaired and 173 were planned for repair (USACE, 2010).

The Sacramento-San Joaquin Erosion Repair Project is funded by DWR and local agencies for remediation of erosion sites across the Central Valley. The Sacramento-San Joaquin Erosion Repair Project will be used to repair erosion sites when the Sacramento River Bank Protection Project authorization ends. As of December 2010, eight erosion sites had been completed and seven were planned for completion.

As mentioned, the Levee Stability Program is a federal program authorized by the Water Resources Development Act of 2007. Levee Stability Program sites are selected by the DWR Levee Evaluations Program. As of December 2010, two erosion sites had been recommended for repair, but additional sites are anticipated as the DWR Levee Evaluations Program continues.

As mentioned, the Flood Control and Coastal Emergency Act (Public Law 84-99) provides the federal government with authority for emergency management activities. After the 2005 – 2006 storms, 173 erosion sites were determined to be eligible for Public Law 84-99 assistance by USACE, all of which have been constructed.

Planned and completed erosion sites from the Sacramento River Bank Protection Project, Sacramento-San Joaquin Erosion Repair Project, the Levee Stability Program, and Public Law 84-99 projects are shown in Figures A-27 and A-28 for the Sacramento and San Joaquin river watersheds, respectively.

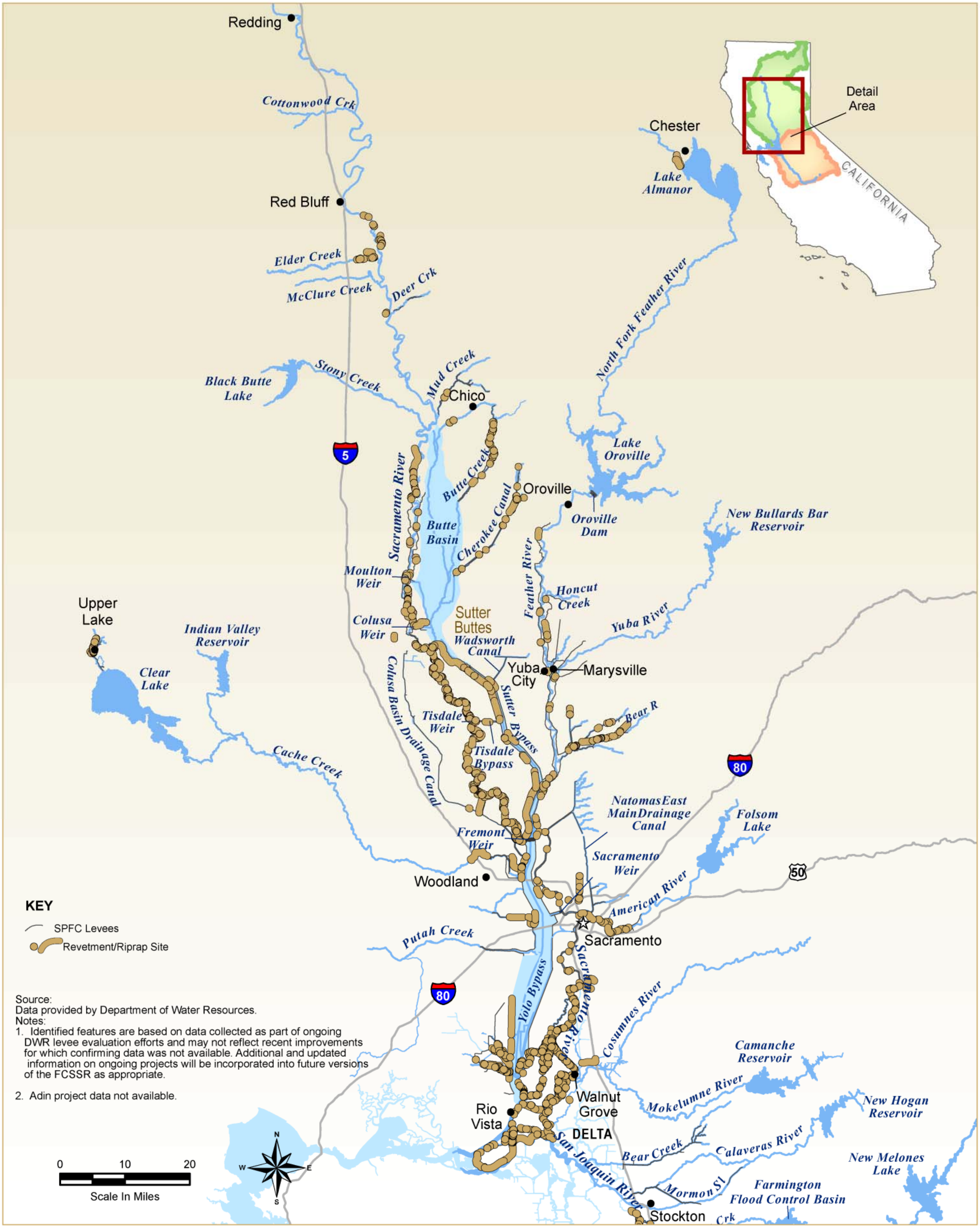

Figure A-25. Levee Revetment Sites in Sacramento River Watershed

Figure A-26. Levee Revetment Sites in San Joaquin River Watershed

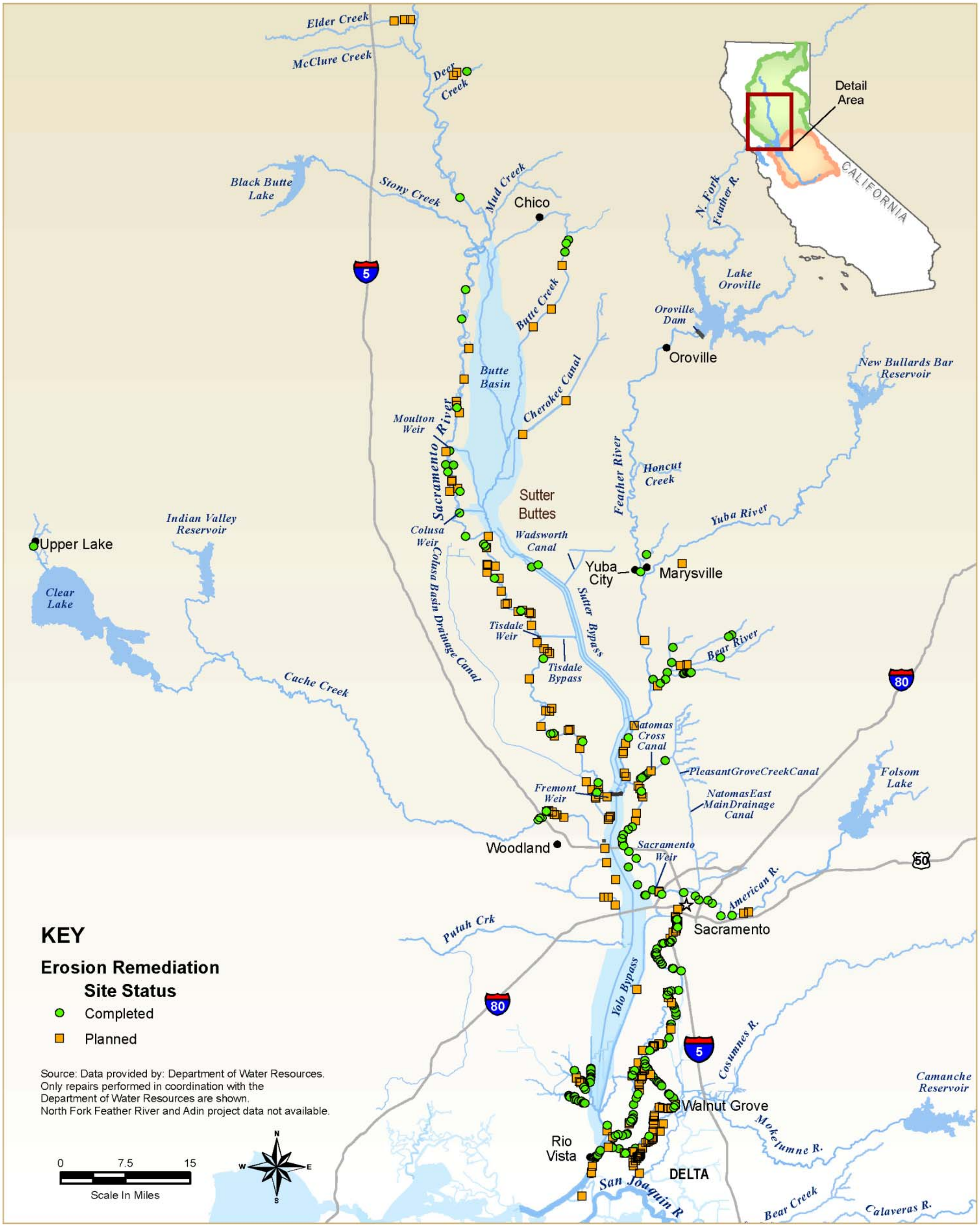

Figure A-27. Planned and Completed Erosion Repair Sites in Sacramento River Watershed

Figure A-28. Planned and Completed Erosion Repair Sites in San Joaquin River Watershed

Ongoing Actions to Improve Future Evaluations

DWR continues to collect levee information using traditional and new, innovative methods, including LiDAR, bathymetric surveys, and geomorphic mapping (see Section A-1). Bathymetric data are especially important in revealing underwater erosion of riverbanks that was previously unknown from waterside erosion surveys.

In addition, a U.S. Geological Survey Sacramento River Bank Protection Project Sedimentation Study is currently underway to evaluate sediment transport and bank stability within the Sacramento River Flood Control System. The study area extends along the Sacramento River from River Mile (RM) 46 at Freeport upstream to RM 144 at Colusa. The study consists of two phases. Phase 1 was completed in March 2009 and included collection and review of available data related to sediment transport and geomorphic trends within the study area. Phase 2 of the study will address the following objectives:

- Evaluate both long-term and flood event aggradation and degradation potential for Sacramento River system bed profiles.
- Evaluate the potential for aggradation at weirs that might affect flow distribution into bypasses.
- Assess the distribution of spawning gravels within the Sacramento River Flood Control Project today and 50 years in the future.
- Evaluate the potential reduction in riparian habitat and floodplain (potential loss of remaining overbank or “berm”) over the next 50 years.
- Assess implications of a sediment transport regime on long-term levee repair requirements for the Sacramento River Flood Control System.

Specific Phase 2 study tasks include sediment sampling, bank stability analysis, sediment transport modeling, and updates to HEC-RAS hydraulic modeling software to improve sediment transport calculation capabilities.

A-6 Settlement

This section includes locations of observed sinkhole and subsidence occurrences and a description of recent, ongoing, and planned remedial actions and improvements, and ongoing actions to improve future evaluations.

Historical Sinkhole and Subsidence Occurrences

The ULE and NULE projects collected and cataloged information on historical occurrences of levee settlement and on completed or planned levee construction or improvements. Figures A-29 and A-30 show historical sinkhole and subsidence occurrences in the Sacramento and San Joaquin river watersheds, respectively. Most of the observed subsidence occurrences in the Sacramento River watershed are located along the Colusa Basin Drainage Canal and Yolo Bypass. Sinkholes are located sporadically across the Sacramento River watershed. In the San Joaquin River watershed, observed subsidence occurrences are located on the Eastside Bypass between Chowchilla River and Owens Creek and observed sinkholes are located on the Chowchilla Bypass.

Summary of Recent Remedial Actions

DWR's Levee Repairs Program and recent other projects have remediated locations where settlement problems have been reported from inspection and evaluation activities.

Summary of Ongoing and Planned Remedial Actions/Improvements

Sinkholes and subsidence are identified and monitored by maintaining agencies to help identify locations that would require repairs or a construction project for remediation. Settlement problems are addressed through DWR's Levee Repairs Program and through other projects being implemented to address subsidence. DWR's Levee Repairs Program is described in Section A-3, and many of the Early Implementation Program and USACE/Board projects identified in Section A-1 will preserve and enhance the integrity of SPFC levees with regard to settlement.

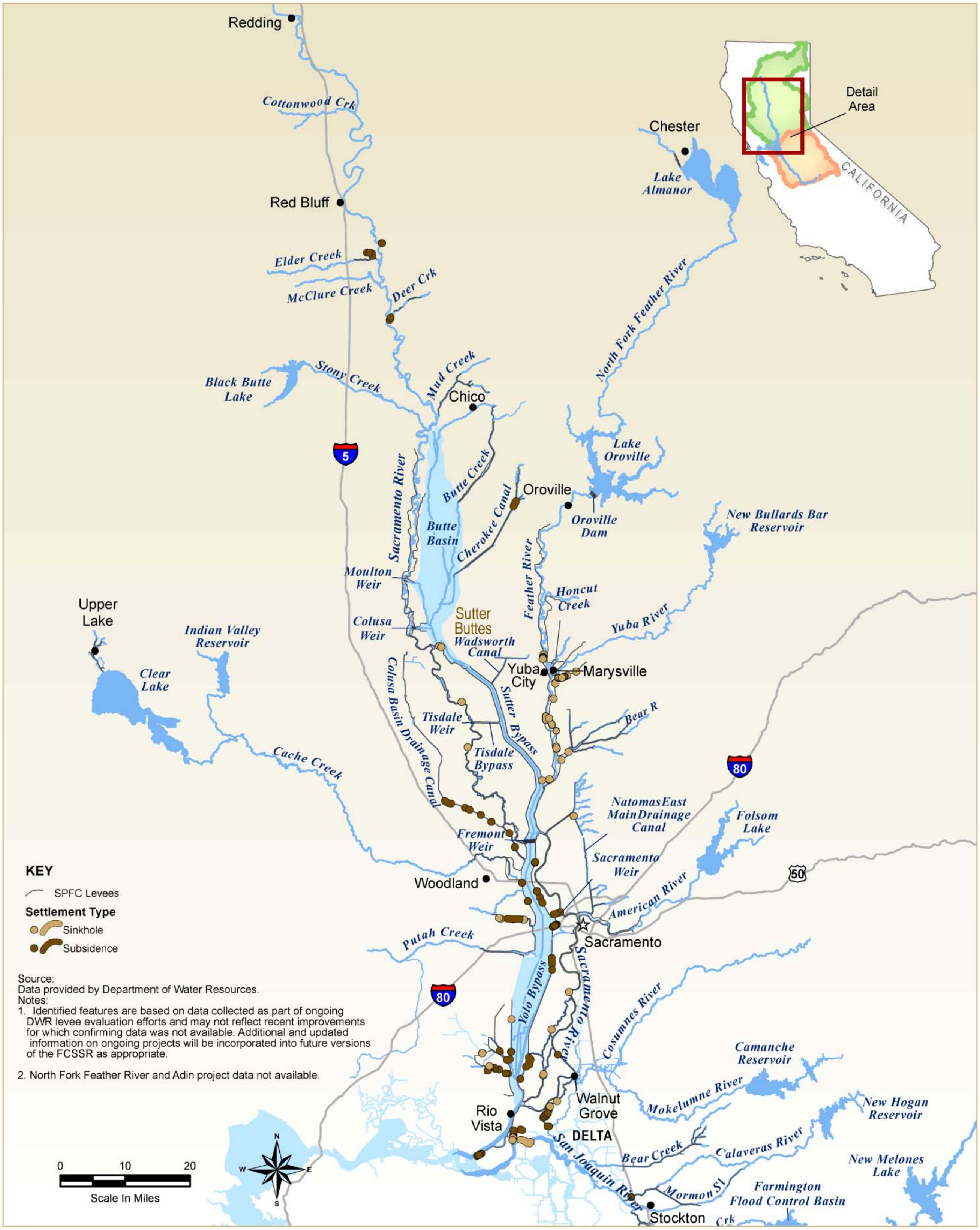

Figure A-29. Historical Sinkholes and Subsidence Distresses in Sacramento River Watershed

Figure A-30. Historical Sinkholes and Subsidence Distresses in San Joaquin River Watershed

Ongoing Actions to Improve Future Evaluations

DWR continues to collect levee information using traditional and innovative methods, including LiDAR and geomorphic mapping (see Section A-1).

A-7 Penetrations

This section includes a brief description of recent, ongoing, and planned remedial actions, and ongoing actions to improve future evaluations regarding penetrations.

Summary of Recent Remedial Actions

In 2009, six penetration failures were initially reported by either the owner or observed by the maintaining agency. DWR conducted follow-up inspections and expeditiously repaired or replaced the pipes. A description and location of these penetrations is included in Table A-17.

Table A-17. Penetrations Repaired or Replaced by DWR in 2009

Penetration Description	Location
Leak in 14-inch-diameter pipe eroded soil and created a sinkhole approximately 6 inches in diameter, located 10 feet from waterside toe of the levee.	Calaveras River
Subsidence at paved levee crown due to collapse of a 12-inch-diameter pipe, located 3 feet below levee crown.	Sacramento River
Leaky 24-inch-diameter corrugated metal pipe created a 10-foot-diameter cavity in the interior of the clayey levee. A sinkhole, 3 feet in diameter appeared on the patrol road.	Sacramento River
Corroded 12-inch-diameter drainage pipeline (located roughly 3 feet below the crown) washed out a 10-foot-diameter, 6-foot-deep hole of the landside levee slope and crown. Severe erosion at the pipe location on the waterside of the levee was evident.	San Joaquin River
Severe leak in a 6-inch-diameter irrigation pipe caused distress on the sandy levee embankment. Pipe located about 3.5 feet below the landside toe.	Sacramento River
Leaky irrigation pipe crossing the levee damaged levee waterside slope. The damage extends for a length of about 15 feet extending almost the entire waterside slope.	Putah Creek

Most penetrations through SPFC levees are maintained by entities other than DWR. Information is not available to identify the number of pipes that may have failed or have been repaired or replaced by entities other than DWR.

Summary of Ongoing and Planned Remedial Actions

DWR is continuing to inspect, identify, repair, and/or replace penetrations that could compromise the structural integrity of a levee. It is difficult to determine when remedial action is needed because internal erosion caused by penetrations often remains hidden until a surface expression occurs.

Ongoing Actions to Improve Future Evaluations

Ongoing actions to improve future evaluations of penetrations include the DWR utility crossing survey program. The goal of the program is to develop a systemwide, searchable database of all existing utility crossings. The program will develop field survey protocols and a rating system or criteria to incorporate utility crossings into current inspection ratings through a pilot project. The program will then define the frequency and schedule for completing surveys systemwide.

A-8 Levee Vegetation

This section includes the DWR *Interim Vegetation Inspection Criteria for Standard Levees* (DWR, 2007), and a description of recent, ongoing and planned remedial actions, and ongoing, actions to improve future evaluations.

DWR Interim Vegetation Inspection Criteria for Standard Levees

The DWR *Interim Vegetation Inspection Criteria for Standard Levees* (DWR, 2007) are shown on Figure A-31.

Summary of Recent Remedial Actions

Levee vegetation maintenance activities conducted by DWR and maintaining agencies include removing vegetation and downed trees that could obstruct the natural flow of water, and controlling weeds, grasses, emergent vegetation, and woody vegetation on levees. DWR's maintenance yards routinely identify and remove trees considered to have the potential to fall and undermine levees. Other specific routine maintenance activities include removing debris, spraying herbicides, mowing and burning vegetation on slopes, and dragging levee slopes.

Summary of Ongoing and Planned Remedial Actions

New levee sections being constructed as part of current Early Implementation Program and USACE/Board projects (Section A-1) will be in compliance with USACE levee vegetation criteria. DWR and the Board require maintaining agencies responsible for maintenance of SPFC levees to be in compliance with DWR interim vegetation criteria. Progress in implementing interim vegetation requirements will be reviewed by USACE, the Board, and DWR to assess progress in complying with milestones (California Levee Roundtable, 2009). Maintaining agencies are required to develop a plan to resolve vegetation problems. Finally, DWR's maintenance yards and other maintaining agencies will continue to routinely perform annual maintenance to remediate identified problems, such as identifying and removing trees considered to have the potential to fall and undermine levees.

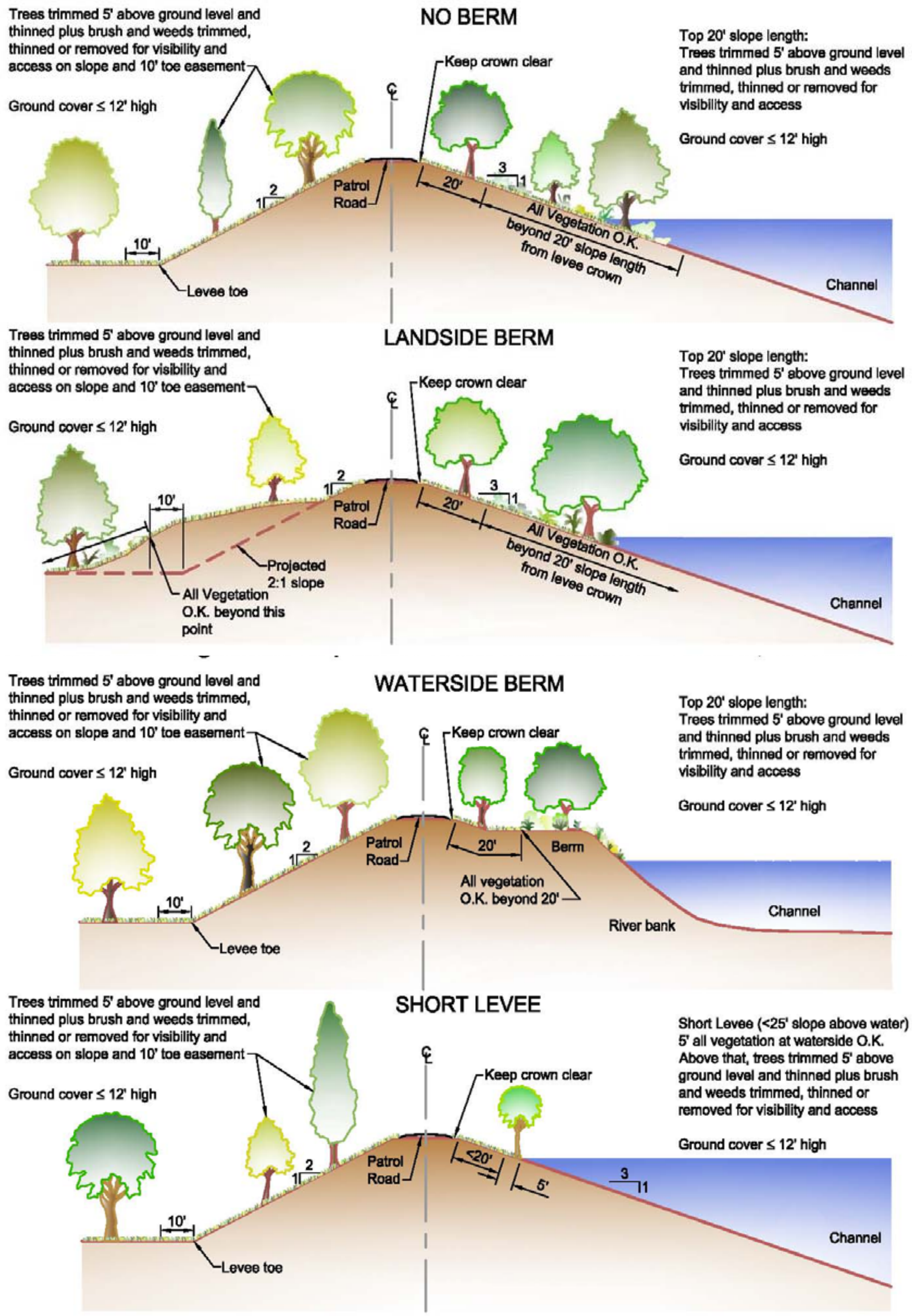

Figure A-31. DWR Interim Vegetation Inspection Criteria for Standard Levees, October 2007

Ongoing Actions to Improve Future Evaluations

Differences between USACE and DWR levee vegetation criteria are significant enough that comparison of levees with USACE criteria would likely show more SPFC levees as noncompliant with current USACE criteria. DWR and USACE continue to work to resolve these differences.

DWR may implement additional changes to its inspection program as existing USACE policies are refined over time, and as other levee management issues arise. The California Levee Vegetation Research Program is being conducted by DWR in partnership with the Sacramento Area Flood Control Agency, Board, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, California Department of Fish and Game, and local agencies that are members of the California Central Valley Flood Control Association. The partnership conducts research that will determine the extent to which woody vegetation, such as trees, may affect the safety of levees in the Central Valley. The research is being conducted in parallel with a complementary national research program underway by USACE.

A-9 Rodent Damage

This section includes the results of DWR annual inspections for animal control, and a description of recent, ongoing, and planned remedial actions, and ongoing actions to improve future evaluations.

Results of Inspections

DWR visually inspects SPFC levees for burrowing rodent damage at least twice a year, and reports results annually. Table A-18 shows the DWR inspection rating descriptions for animal control of burrowing rodents.

Table A-18. Levee Inspection Rating Descriptions for Animal Control on Earthen Levees

Inspection Rating	Rating Descriptions
Acceptable (A)	Continuous animal burrow control program in place that includes elimination of active burrowing and filling in and compacting or grouting of existing burrows.
Minimally Acceptable (M)	The existing animal eradication and burrow repair program needs to be improved. Several animal burrows present that may lead to seepage or slope stability problems. Burrows must be filled and compacted or grouted.
Unacceptable (U)	Animal burrow control program is not effective or is nonexistent. Significant maintenance is required to fill existing burrows, and the levee will not provide reliable flood protection until this maintenance is complete.

Animal control inspection ratings from the *2009 Annual Inspection Report* (DWR, 2010b) are shown on Figures A-32 and A-33 for the Sacramento and San Joaquin river watersheds, respectively. The inspection data show that several levees were given Minimally Acceptable ratings across the Sacramento River watershed, especially along the upper Sacramento River north of Fremont weir, American River, and Feather River. In the San Joaquin River watershed, Unacceptable and Minimally Acceptable ratings are prevalent throughout the watershed.

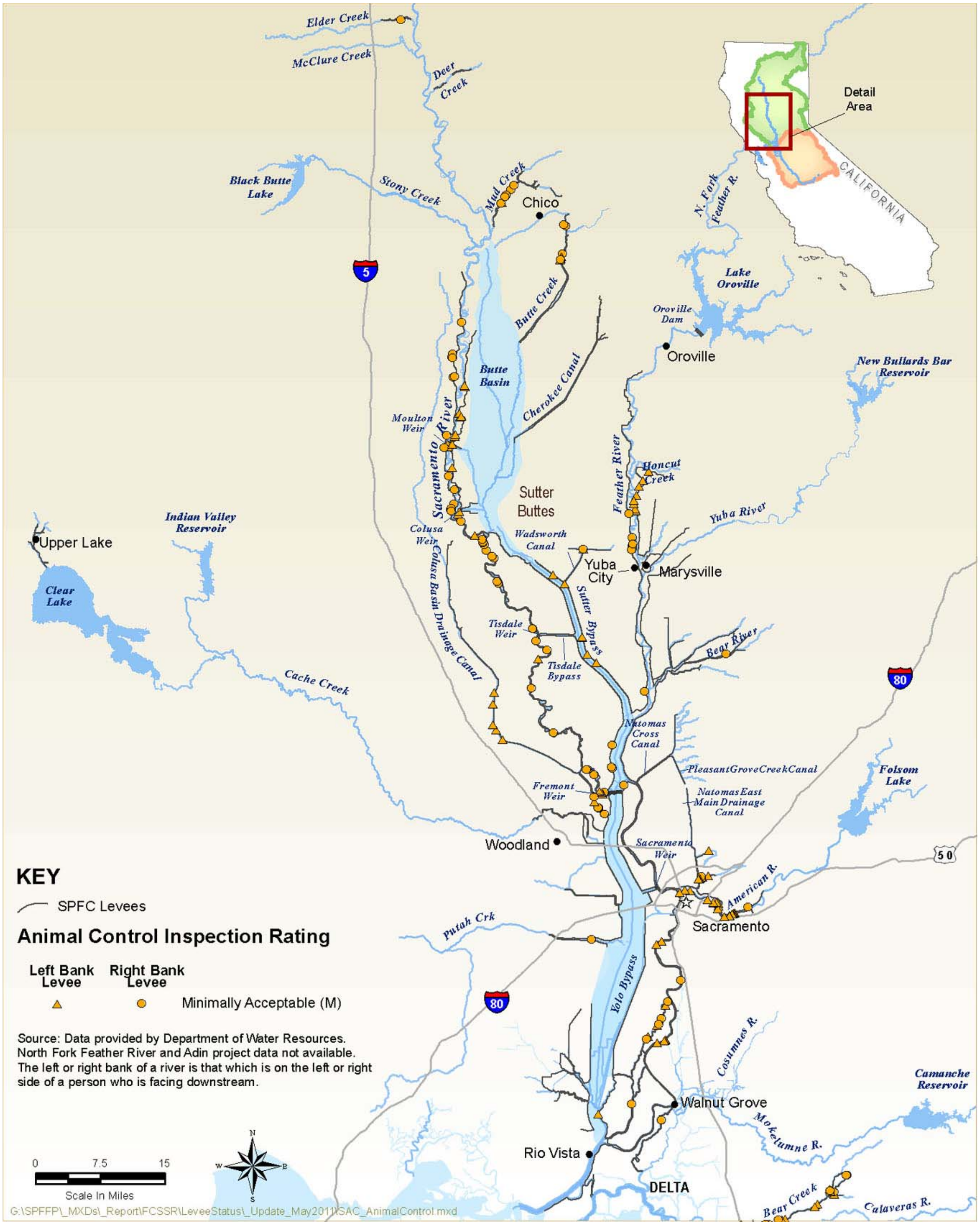

Figure A-32. 2009 Animal Control Inspection Ratings in Sacramento River Watershed

Figure A-33. 2009 Animal Control Inspection Ratings in San Joaquin River Watershed

Summary of Recent Remedial Actions

Maintaining agencies are responsible for rodent abatement and damage repair, and implement their own rodent abatement programs. While rodent abatement practices vary among maintaining agencies, current remedial actions under DWR's Rodent Abatement Program include the following:

- Continuous monitoring of all DWR-maintained levees for rodent activity.
- Year-round application of rodent bait, as needed.
- Application of sulfur gases to some rodent runways and dens in areas frequently visited by the public and domestic animals.
- Grouting all newly discovered rodent runways and dens once a year.

Summary of Ongoing and Planned Remedial Actions

Remedial actions for rodent abatement/damage repair are currently not planned to change. Remedial actions will be implemented annually by maintaining agencies as problems are noted in inspections.

Ongoing Actions to Improve Future Evaluations

Increased communication between USACE and DWR regarding inspections is currently taking place to improve evaluation and lead to quicker and more thorough repair of rodent damage.

With the initial identification of levee reaches affected by animal burrows completed through the DWR Animal Burrow Hole Persistence Study, additional efforts could be performed to further examine the incidence of animal burrows on levees such as (1) measurement of burrow hole density and prevalent hole diameter, (2) assessment of maintenance practices to control animal population and mitigate damage to levees, (3) identification of animal species involved, and (4) correlation of animal species activity with habitat and land use.

A-10 Encroachments

This section includes a description of recent, ongoing, and planned remedial actions, and ongoing actions to improve future evaluations.

Summary of Recent Remedial Actions

The Board is responsible for reviewing applications and issuing permits for encroachments within SPFC easements. DWR inspectors perform the field inspections of most permitted encroachments to determine that they are constructed or installed in accordance with permit conditions. DWR inspectors also document illegal (unpermitted) encroachments and inadequately maintained permitted encroachments in SPFC easements. DWR relies on maintaining agencies to help identify and remove illegal encroachments.

Assembly Bill 1165 was passed in October 2009, which gives the Board more authority for encroachment enforcement. The Board recently developed regulations to implement its new enforcement authorities. The Board has the authority to request removal of unpermitted or inadequately maintained encroachments. The Board created a new Floodway Encroachment and Enforcement Branch to permit, regulate, and enforce the Board's decisions regarding the significant number of encroachments on levees, in floodplains, and near regulated streams within the SPFC. Between May 2009 and December 2010, 50 enforcement actions in Central Valley have been initiated; 14 of those have been resolved.

Summary of Ongoing and Planned Remedial Actions

DWR will continue to inspect construction or installation of newly permitted encroachments in accordance with permit conditions. DWR will also continue to document and report new illegal encroachments and inadequately maintained encroachments to maintaining agencies and the Board for remedial actions.

Each maintaining agency is held responsible for preventing the construction of, or requiring the removal of, any illegally encroaching structures or activities on levees or within the easement at the landward toe of levees. The maintaining agency must also stop any unauthorized modifications or alterations to levees. If any person or organization deems any construction or modification necessary within a levee regulatory easement, that person or organization must apply for an encroachment permit.

Ongoing Actions to Improve Future Evaluations

As a part of ongoing efforts to improve documentation and maintenance for the SPFC, DWR, and the Board have the following efforts currently underway or planned to begin soon, that affect encroachments:

- Continue to update existing levee logs to include data from O&M manuals, existing inspection results, and historical data. This information will be placed into a database format that will function as documentation of system features and structures. All data will be field-verified and georeferenced.

- Create a georeferenced database of the historical encroachment permits and use this effort with the updated levee logs to assist in determining which encroachments are permitted, and the number and type of unpermitted encroachments.

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Acronyms and Abbreviations

Board......................... Central Valley Flood Protection Board
CVFPP .... Central Valley Flood Protection Plan
DWR.......................... California Department of Water Resources
FCSSR .... Flood Control System Status Report
LiDAR........................ Light Detection and Ranging
NULE......................... Non-Urban Levee Evaluations
O&M .... operations and maintenance
RM............................. River Mile
SPFC......................... State Plan of Flood Control
State .... State of California
ULE .... Urban Levee Evaluations
USACE...................... U.S. Army Corps of Engineers

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Flood Control System Status Report Appendix B – Channel Status

December 2011

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Appendix B – Channel Status

Appendix B provides additional supporting information on channel conditions. These data include estimated channel conveyance capacity for the Sacramento and San Joaquin rivers and their major tributaries. Sections B-2, Channel Vegetation, and B-3, Channel Sedimentation, correspond to subsections in Section 5 of the Flood Control System Status Report (FCSSR) main document. Additional inspection and/or evaluation data, recent, ongoing, and planned remedial actions, and ongoing actions to improve future evaluations are described for channel conveyance capacity, channel vegetation, and channel sedimentation.

B-1 Channel Conveyance

This section summarizes estimated channel conveyance capacities along the Sacramento and San Joaquin rivers and their major tributaries. Also included is information on recent, ongoing, and planned remediation actions and ongoing actions to improve future evaluations.

Channel Capacity Status Tabular Results

Tables B-1 and B-2 present a tabulation of estimated channel capacities for the Sacramento and San Joaquin river watersheds, respectively. For each channel reach in the Sacramento River watershed, design capacities from Senate Document No. 23, design capacities from USACE operations and maintenance (O&M) manuals, and design capacities from 1957 revised profile drawings are provided where available (USACE, 1957). The 1957 revised profile drawings are the basis for State operations. Any differences between the 1957 revised profile drawings capacity and O&M manual capacity are noted. For each channel reach in the San Joaquin River watershed, design capacities from the O&M manual and design capacities from the U.S. Army Corps of Engineers (USACE) Design Memorandum No. 1 (USACE, 1955) are provided where available. The USACE Design Memorandum No. 1 includes design capacities corresponding to 1955 profile drawings, which serve as the basis for State operations. Differences between USACE Design Memorandum No. 1 capacity and O&M manual capacity are noted.

Estimated current channel capacities and their data source are also included. As mentioned, existing capacities were estimated using information from the *SPFC Existing Channel Capacity Assessment Technical Memorandum* (CVFED, 2009) and supplemented with project-specific modeling results. Channel capacity conditions were estimated by comparing estimated current capacity with the design channel capacity reported in the USACE O&M manuals, USACE 1957 revised profile drawings, or USACE Design Memorandum No. 1 (1955).

Table B-1. Sacramento River Watershed Channel Capacity Status

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (basis of State operations)	Difference Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Red Bluff to Chico Landing										
Sacramento River										
Deer Creek to Chico Landing	No data	No data	260,000 cfs	Not specified	Not specified	N/A	No data	No data	Estimated flow at Chico Landing is 260,000 cfs (Senate Document No. 23)	None
Tributaries to Sacramento River										
Elder Creek	6	0	Not specified	17,000	17,000	No	9,000 – 17,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by DWR Northern Region Office	None
Deer Creek	7.4	0	Not specified	21,000	21,000	No	11,000 – 21,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by DWR Northern Region Office	None
Chico Landing to Colusa Weir										
Sacramento River										
Chico Landing to head of east levee	175	166	160,000	160,000	160,000	No	195,000	No obvious inadequacy	*Determination of Channel Capacity of the Sacramento River* (USGS, 1976) and EIR for Butte Basin Overflow Area, (Reclamation Board, 1986)	None
East levee head (Parrott Grant Line) to Princeton-Afton Road	166	153	160,000	160,000	160,000	No	159,000	Potential inadequacy; additional evaluation required	Ayers modeling for USACE and Princeton Pump Plant	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Princeton-Afton Road to Moulton Weir	153	148.25	160,000	160,000	160,000	No	110,000 – 184,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis – 184,000 cfs DWR Channel Evaluation Program – 110,000 cfs	150,000 cfs design capacity authorized with Butte Basin Bypass if it was constructed.
Moulton Weir to Colusa Weir	148.25	138	145,000	110,000	135,000	Yes	126,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Tributaries to Sacramento River										
Mud Creek and Big Chico Creek										
Mud Creek – end of levees to Sycamore Creek	8.22	6.82	Not specified	5,500	No data	N/A	No data	No data	N/A	None
Mud Creek – Sycamore Creek to SPRR	6.82	4.32	15,000	15,000	15,000	No	No data	No data	N/A	None
Mud Creek – SPRR to Big Chico Creek	4.32	0.00	13,000	13,000	13,000 – 15,000	No	No data	No data	N/A	None
Tributaries to Mud Creek										
Sycamore Bypass	12.4	11.0	8,500	8,500	8,500	No	>8,500	No obvious inadequacy	DWR Channel Evaluation Program Modeling by Flood Maintenance Office	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Sycamore Creek										
Sycamore Bypass to North Sycamore Creek	11.0	9.4	10,000	10,000	10,000	No	>10,000	No obvious inadequacy	DWR Channel Evaluation Program Modeling by Flood Maintenance Office	Significant scouring of the channel bed has occurred since project was completed and appears to be migrating upstream into the bypass channel.
North Sycamore Creek to Sheep Hollow	9.4	8.6	10,000	10,000	10,000	No	>8,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by Flood Maintenance Office	Recently completed sediment removal at Cohasset Bridge restored localized restriction but much conveyance in the reach remains below design capacity.
Sheep Hollow to Mud Creek	8.6	6.8	11,000	11,000	11,000	No	5,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Sycamore Creek Sediment Removal Project	None
Lindo Channel	10.3	2.75	Not specified	6,000	6,000	No	<4,000-6,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by DWR Northern Region Office	Capacity inadequacies are dispersed throughout. There is a major constriction just downstream from the Lindo Channel Control Structure and at Big Chico Creek, where capacity is limited to less than 4,000 cfs.
Big Chico Creek – Mud Creek to Sacramento River	2.75	0	15,000	15,000	15,000	No	No data	No data	N/A	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Distributaries from Sacramento River										
Overflow to Butte Basin	175	166	100,000 cfs	100,000 cfs from Senate Document No. 23		N/A	150,000	No obvious inadequacy	*Determination of Channel Capacity of the Sacramento River* (USGS, 1976) and EIR for Butte Basin Overflow Area (Reclamation Board, 1986)	None
Moulton Weir [3]	158.5	158.5	15,000	25,000	25,000	No	34,000	No obvious inadequacy	*Two-Dimensional Hydraulic Modeling of Riparian Habitat Restoration from Colusa to Princeton* (Nature Conservancy, 2007)	None
Colusa Weir [3]	146.2	146.2	80,000	70,000	70,000	No	75,300	No obvious inadequacy	*Two-Dimensional Hydraulic Modeling of Riparian Habitat Restoration from Colusa to Princeton* (Nature Conservancy, 2007)	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Colusa Weir to Fremont Weir										
Sacramento River										
Colusa Weir to Colusa Bridge	138.0	135.0	65,000	48,000	65,000	Yes	50,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Colusa Bridge to Butte Slough	135.0	130.0	47,000	48,000	65,000	Yes	50,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Butte Slough to Meridian Road	130.0	126.0	47,000	48,000	66,000	Yes	67,000	No obvious inadequacy	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Meridian Road to Tisdale Weir	126.0	119.5	72,000	48,000	66,000	Yes	47,000	Potential inadequacy; additional evaluation required	Estimate from adjacent project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Tisdale Weir to Wilkins Slough	119.5	118	33,500	30,000	30,000	No	29,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Wilkins Slough to Knights Landing	118.0	90.0	33,500	30,000	30,000	No	29,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Knights Landing to Fremont Weir	90.0	85.0	33,500	30,000	30,000	No	29,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Tributaries to Sacramento River										
Butte Slough Outfall	138.2	138.2	7,000	3,500	1,000	N/A	Not applicable	Not applicable	N/A	This facility is subject to backwater control.
Knights Landing Outfall	90.2	90.2	Not specified	Not applicable	Not applicable	N/A	Not applicable	Not applicable	N/A	This facility is designed to protect the Colusa Basin from backwater from the Sacramento River – thus, capacity is not relevant.
Distributaries from Sacramento River										
Tisdale Weir and Bypass	119.2	119.2	38,500	38,000	38,000	No	15,000 – 32,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program 2006 sediment removal project	Backwater from Sutter Bypass limits the capacity of the weir and bypass during large floods. See Note 4.
Fremont Weir [3]	85.2	82.2	343,000	343,000	343,000	No	No data	Not applicable		Weir flow needs to be analyzed. See Note 4.
Sutter Bypass										
Butte Slough to Wadsworth Canal	93.2	83.0	178,000	178,000	150,000	Yes	111,000 – 150,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis – 111,000 cfs DWR Channel Evaluation Program – 150,000 cfs	DWR Channel Evaluation Program started at 1957 profile elevation, running profile irrespective of upstream levee profile.
Wadsworth Canal to Tisdale Bypass	83.0	77.8	178,000	178,000	155,000	Yes	125,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Tisdale Bypass to Feather River	77.8	67.0	216,500	216,500	180,000	Yes	142,000 – 180,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis – 142,000 cfs DWR Channel Evaluation Program - 180,000 cfs.	In 1997, flood reverse flow occurred for a few hours due to backwater from the Sutter Bypass.
Feather River to Verona	67.0	59.0	416,500	416,500	380,000	Yes	400,000	No obvious inadequacy	Project-specific modeling from MBK Natomas 408 Impact Analysis	Model separates flow at the training levee and splits the flow in the channel.
Tributaries to Sutter Bypass										
Butte Creek										
Little Chico Creek Diversion Channel to Midway	15.32	8.2	12,000 (see comments)	27,000	27,000	No	27,000 to 44,222	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) - 44,222 cfs *Butte Creek Watershed Floodplain Management Plan* (Butte Creek Watershed Conservancy, 2005) - 27,000 cfs	Design flows from Senate Document 23 apply to reach SPRR to US Highway 99. Little Chico Diversion channel not specified in Senate Document 23. *SPFC Existing Channel Capacity Assessment TM* indicates uncertain estimated capacity.
Midway to 1.6 miles downstream from Aguas Frias Road	8.2	0	Not specified	22,000	22,000	No	22,000 – 44,222	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) - 44,222 cfs *Butte Creek Watershed Floodplain Management Plan* (Butte Creek Watershed Conservancy, 2005) - 22,000 cfs	*SPFC Existing Channel Capacity Assessment TM* indicates uncertain estimated capacity.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Cherokee Canal										
Dry Creek to Gold Run Creek at Nelson Road	21.72	20.22	Not specified	8,100	8,100	No	No data	No data	N/A	None
Gold Run Creek at Nelson Road to Cottonwood Creek at Western Canal	20.22	15.82	Not specified	8,500	8,500	No	3,600 – 4,500	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program	4,050 cfs from Cottonwood Creek to Old Nelson-Shippe Road; 3,600 cfs from Old Nelson Shippe Road to Old SNNR; and 4,500 cfs from Old SNRR Road to Nelson Road.
Cottonwood Creek at Western Canal to RD 833 canal entrance at Afton Road	15.82	7.92	Not specified	11,500	12,500	Yes	No data	No data	N/A	None
RD 833 canal entrance at Afton Road to Lower Butte Basin about 1 mile downstream from Colusa-Gridley Road	7.92	0	Not specified	12,500	12,500	No	No data	No data	N/A	None
Wadsworth Canal	5	0.5	No data	1,500	1,500	No	No data	No data	N/A	None
Feather River										
Honcut Creek to end of project	50.9	44.3	180,000	210,000	210,000	No	180,000	Potential inadequacy; additional evaluation required	MBK – Feather Setback Levee – TRLIA	Future design flows may change as a result of the Forecast-Coordinated Operation of Lake Oroville and Bullards Bar Reservoir Project.
Jack Slough to Honcut Creek	44.3	27.4	180,000	210,000	210,000	No	180,000	Potential inadequacy; additional evaluation required	MBK – Feather Setback Levee – TRLIA	Future design flows may change as a result of the Forecast-Coordinated Operation of Lake Oroville and Bullards Bar Reservoir Project.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Mouth of Yuba River to Bear River	27.4	12.0	277,000	300,000	300,000	No	350,000	No obvious inadequacy	MBK – Feather Setback Levee - TRLIA	None
Bear River to (Sutter (Yolo) Bypass	12.0	7.6	295,000	320,000	320,000	No	390,000	No obvious inadequacy	MBK – Feather Setback Levee - TRLIA	None
Tributaries to Feather River										
Honcut Creek										
Honcut Creek-Feather River to WPRR	4.5	0.0	Not specified	5,000	25,000	Yes	9,000	Potential inadequacy; additional evaluation required	Wood Rogers HEC-RAS model	Levees within this reach are designed to protect upstream flows from Honcut Creek and backwater from Feather River (when the river is at design capacity of 210,000 cfs).
Honcut Creek – WPRR to end of project	5.25	4.5	Not specified	5,000	5,000	No	0 – 9,000	No obvious inadequacy	Wood Rogers HEC-RAS model	None
Yuba River										
Yuba River – Feather River to Simpson Lane	1.6	0.5	120,000	120,000	120,000	No	121,000 – 170,000	No obvious inadequacy	MBK – Feather-Yuba River Coordinated Operating Studies – 170,000 cfs DWR Channel Evaluation Program – 121,000 cfs	Capacity is affected by backwater from Feather River.
Yuba River – Simpson Lane to end of project	5 (7.5)	1.6	120,000	120,000	120,000	No	170,000	No obvious inadequacy	MBK – Feather-Yuba River Coordinated Operating Studies	None
Bear River										
Feather River to WPRR	3.5	0.0	30,000	30,000	30,000	No	60,000	No obvious inadequacy	MBK – Feather River Setback Levee – TRLIA	Capacity improved by Feather River Setback Levee Project.
WPRR to Dry Creek	4.5	3.5	Not specified	40,000	37,000	Yes	60,000	No obvious inadequacy	MBK – Feather River Setback Levee – TRLIA	Capacity improved by Feather River Setback Levee Project.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Dry Creek to end of project	13.0	4.5	Not specified	30,000	30,000	No	60,000	No obvious inadequacy	MBK – Feather River Setback Levee – TRLIA	Capacity improved by Feather River Setback Levee Project
Tributaries to Bear River										
WPRR Interceptor – upstream from North Dry Creek	6.3	2.3	Not specified	10,000	5,000	Yes	No data	No data	N/A	None
WPRR Interceptor Channel - Dry Creek to Bear River	2.3	0.0	Not specified	10,000	10,000	No	N/A	Backwater controlled; additional evaluation required	N/A	Capacity is affected by backwater from Bear River.
North Dry Creek	1.50	0.00	Not specified	No data	5,000	No data	No data	No data	N/A	None
South Dry Creek	1.5	0.8	Not specified	7,000	9,000	No data	No data	No data	N/A	None
Yankee Slough	4.2	0.0	Not specified	2,500	2,500	No	2,000	Potential inadequacy; additional evaluation required	Wood Rogers HEC-RAS Model	None
Fremont Weir to American River										
Sacramento River										
Fremont Weir to Sacramento Weir	80.3	63.9	107,000	107,000	107,000	No	76,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM (CVFED, 2009)*	Levees on left bank have been raised by SAFCA and therefore have adequate freeboard.
Sacramento Weir to American River	63.4	51.7	18,000	110,000	18,000	Yes	80,000 – 107,000	No obvious inadequacy	DWR Channel Evaluation Program	The hydraulics of this reach is complex and varies according to operation of the Sacramento Weir. See Note 4.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Tributaries to Sacramento River										
Natomas Cross Canal	4.7	0.1	Not specified	800	22,000	Yes	N/A	Backwater controlled; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	Operates under backwater control during high-water events.
Tributaries to Natomas Cross Canal										
East Side Canal (Coon Creek Intercepter)										
Natomas Cross Canal to Auburn Ravine	1.7	0.1	Not specified	16,000	16,000	No	6,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 6,000 cfs MBK modeling for Natomas 408 Impact Analysis – backwater control designation	Backwater control – flows vary accordingly.
Auburn Ravine to Markham Ravine	2.7	1.7	Not specified	12,000	12,000	No	8,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 8,000 cfs MBK modeling for Natomas 408 Impact Analysis – backwater control designation	Backwater control – flows vary accordingly.
Markham Ravine to Coon Creek	4.7	2.7	Not specified	5,000	5,000	No	6,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)– 6,000 cfs MBK modeling for Natomas 408 Impact Analysis – backwater control designation	Backwater control – flows vary accordingly.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Pleasant Grove Creek Canal										
Sankey Road to Pleasant Grove Creek	10.0	8.0	Not specified	900	800	Yes	No data	Backwater controlled; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis – backwater control designation	Backwater control – flows vary accordingly.
Pleasant Grove Creek to Pierce-Roberts Drain	8.0	7.0	Not specified	2,700	2,300	Yes	2,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 2,000 cfs MBK modeling for Natomas 408 Impact Analysis – backwater control designation	Backwater control – potential inadequacy applies to east bank, SAFCA proposed project will raise levees on west bank to provide adequate freeboard.
Pierce-Roberts Drain to Natomas Cross Canal	7.00	5.00	Not specified	7,000	6,000	Yes	3,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)– 2,000 cfs MBK modeling for Natomas 408 Impact Analysis – backwater control designation	Backwater control – potential inadequacy applies to east bank, SAFCA proposed project will raise levees on west bank to provide adequate freeboard.
American River										
State Fairgrounds to Carmichael Bluffs	5.25	14.50	128,000	115,000 (see comments)	115,000 (with 5 feet of freeboard) 152,000 (with 3 feet of freeboard)	No	115,000 (current) 160,000 (with 3-feet of freeboard after improvements)	No obvious inadequacy	New capacity from SAFCA; former capacities are from 1957 profile and USACE American River Common Features Project	1957 profile capacity and O&M design flood was set as 115,000 cfs in accordance with local desire to match existing height of the left-bank levee. 1957 profile design capacity was 152,000 cfs based on 3 feet of freeboard and 115,000 cfs with freeboard of 5 feet. Capacity, after improvements, will be 160,000 cfs.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Sacramento River to State Fair Grounds	0.0	5.25	128,000	180,000	N/A	N/A	115,000 cfs (current) 160,000 (with 3-feet of freeboard after improvements)	No obvious inadequacy	USACE American River Common Features Project	None
Tributaries to American River										
Natomas East Main Drainage Canal (Steelhead Creek)										
Dry Creek To Sankey Road	12.7	4.00	Not specified	1,100	1,500	Yes	Greater than 1,500 cfs	No obvious Inadequacy	SAFCA	SAFCA levee raising and pump station project did not alter existing capacity.
Arcade Creek to Dry Creek	4.02	1.25	Not specified	12,900	16,300	Yes	19,000 cfs	No obvious Inadequacy	SAFCA	SAFCA levee raising project did not alter existing capacity.
American River to Arcade Creek	1.25	0.0	Not specified	16,000	16,000	No	Backwater Control – flows vary accordingly	Backwater controlled; additional evaluation required	SAFCA	Backwater control – flows vary accordingly.
Tributaries to Natomas East Main Drainage Canal										
Dry Creek (previously, Linda Creek)	1.3	0	Not specified	15,000	15,000	No	18,000 cfs	No obvious Inadequacy	Ensign & Buckley via MBK	SAFCA levee raising project increased capacity.
Arcade Creek	2.0	0	Not specified	3,300	3,300	No	6,900 cfs	No obvious Inadequacy	MBK	SAFCA levee raising project increased capacity.
Distributaries from Sacramento River										
Sacramento Weir and Bypass[3]	45.3	45.3	112,000	112,000	112,000	No	132,000 – 133,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Yolo Bypass										
Fremont Weir to Knights Landing Ridge Cut	57.2	54.2	343,000	343,000	343,000	No	290,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Knights Landing Ridge Cut to Cache Creek	54.2	51.8	362,000	362,000	362,000	No	276,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Cache Creek to Sacramento Bypass	51.8	45.3	377,000	377,000	377,000	No	201,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Sacramento Bypass to Putah Creek	45.3	39.5	480,000	480,000	480,000	No	334,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Putah Creek to RM 29	39.5	29.0	490,000	490,000	490,000	No	322,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
RM 29 to Miner Slough	29.0	18.5	500,000	490,000	500,000	Yes	No data	No data	N/A	The Comprehensive Study UNET model does not provide reliable results in this reach. Additional model development will be required.
Miner Slough to Sacramento River	18.5	14.1	500,000	490,000	500,000	Yes	N/A	Backwater controlled; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	Backwater control – flows vary accordingly.

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Tributaries to Yolo Bypass										
Knights Landing Ridge Cut	2.6	0	16,000	20,000	20,000	No	16,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Colusa Basin Drainage Canal	36.5	0.00	Not specified	20000	20000	No	No data	No data	N/A	None
Cache Creek	12.9	4.50	20,000	30,000	30,000	No	27,000 – >30,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 27,000 cfs DWR Channel Evaluation Program – >30,000 cfs	Recent DWR analysis indicates additional study required due to subsidence of the levees and channel.
Cache Creek Weir and Settling Basin	4.5	0	20,000	30,000	30,000	No	0 – 30,000	Not applicable	DWR Channel Evaluation Program	Recent modeling shows weir submerged in high flows.
Tributaries to Cache Creek										
Middle Creek										
Upstream of Clover Creek Diversion	1.0	0	Not specified	12,500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek Diversion to Clover Creek	2.25	1.0	Not specified	21,500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek to Scott Creek	3.13	2.25	Not specified	19,000	Not applicable	N/A	No data	No data	N/A	None
Scott Creek to Clear Lake	4.18	3.13	Not specified	27,000	Not applicable	N/A	No data	No data	N/A	None
Tributaries to Middle Creek										
Scott Creek	1.38	0	Not specified	11000	Not applicable	N/A	No data	No data	N/A	None
Clover Creek	0.5	0	Not specified	500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek Diversion	1.04	.35	Not specified	8,000	Not applicable	N/A	No data	No data	N/A	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Tributaries to Clover Creek Diversion										
Alley Creek to Clover Creek Diversion Facilities	1.2	1.0	Not specified	8,500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek	.2	0	Not specified	5,000	Not applicable	N/A	No data	No data	N/A	None
Alley Creek	1.53	1.2	Not specified	2,800	Not applicable	N/A	No data	No data	N/A	None
Tributaries to Yolo Bypass										
Willow Slough	7.60	0	Not specified	6,000	6,000	No	No data	No data	N/A	None
Putah Creek	9.7	0	25,000	40,000	62,000	Yes	45,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program	None
Miner Slough	1.68	0	10,000	10,000	10,000	No	N/A	Backwater controlled; additional evaluation required	DWR Channel Evaluation Program	Reach subject to backwater control and flows vary.
Lindsey Slough	5.66	0	Not specified	43,500	30,000	Yes	Not applicable – backwater controls reach	Backwater controlled; additional evaluation required	N/A	Reach subject to backwater control and flows vary.
American River to Collinsville										
Sacramento River										
American River (West Sac levee) to Elk Slough	51.6	42.3	110,000	110,000	110,000	No	128,000	No obvious inadequacy	MBK modeling for Natomas 408 Impact Analysis	None
Elk Slough to Sutter Slough	42.1	34.3	110,000	110,000	110,000	No	120,000	No obvious inadequacy	MBK modeling for Natomas 408 Impact Analysis	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2] From	River Miles[2] To	Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
Sutter Slough to Steamboat Slough	34.1	32.5	84,500	84,500	84,500	No	91,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Steamboat Slough to Georgiana Slough	32.5	26.8	56,500	56,500	56,500	No	80,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Georgiana Slough to Steamboat Slough and Cache Slough (Yolo Bypass Junction)	26.5	14.8	35,900	35,900	35,900	No	75,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Steamboat Slough and Cache Slough (Yolo Bypass Junction) to 3-Mile Slough	14.5	9.8	579,000	579,000	579,000	No	750,000	No obvious inadequacy	MBK modeling for Natomas 408 Impact Analysis	None
3-Mile Slough to Collinsville	9.5	0	514,000	514,000	514,000	No	Not applicable	Backwater controlled; additional evaluation required	N/A	Tidal influence affects water surface elevation and discharge varies.
Distributaries from Sacramento River										
Steamboat Slough – Sacramento River to Sutter Slough	21.8	15.2	28,000	28,000	28,000	No	61,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Steamboat Slough – Sutter Slough to Sacramento River	26.3	21.8	43,500	43,500	43,500	No	53,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Sutter Slough – Sacramento River to Miner Slough	28.5 (6.75)	22.0 (2.40)	25,500	25,500	26,500	No	23,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None

Table B-1. Sacramento River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[2]		Design Flows from Senate Document No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawings (cfs) (Basis of State Operations)	Difference between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Sutter Slough – Miner Slough to Steamboat Slough	2.40	0.00	15,500	15,500	15,500	No	32,000	No obvious inadequacy	MBK modeling for Natomas 408 Impact Analysis	None
Georgiana Slough	10	0	20,600	20,600	20,600	No	19,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
3-Mile Slough	3.10	0.00	65,000	65,000	65,000	No	No data	No data	N/A	None

Notes:
[1] The State operates SPFC facilities in the Sacramento Valley based on the 1957 profile rather than on design flows specified in USACE O&M manuals.
[2] River mile designations are based on the USACE and DWR Comprehensive Study river mile designations (2002).
[3] The river mile was estimated at this location.
[4] The operation of weirs and structures within the system are being handled separately and are not included in this evaluation; however, bypass capacities are estimated. Consequently, while bypasses may have sufficient capacity, this does not imply that the full operation of the weir and bypass does not have inadequacies. Additional modeling and evaluation are required.

Key:
Ayers = Ayers Associates, Engineers, Scientists, Surveyors
cfs = cubic feet per second
DWR = California Department of Water Resources
EIR = Environmental Impact Report
MBK = MBK Engineering Co.
N/A = Not available
No data = No data currently available
O&M = operations and maintenance
RD = Reclamation District
RM = river mile
SAFCA = Sacramento Area Flood Control Agency
SNRR = Sacramento Northern Railroad (now defunct)
SPFC = Existing Channel Capacity – *State Plan of Flood Control, Existing Channel Capacity Assessment, Combined Technical Memorandum*, January 2009, CVFED Team
SPRR = Southern Pacific Railroad Company
State = State of California
TM = Technical Memorandum
TRLIA = Three Rivers Levee Improvement Authority
USACE = U.S. Army Corps of Engineers
Wood Rogers = Wood Rogers, Inc.
WPRR = Western Pacific Railroad

Table B-2. San Joaquin River Watershed Channel Capacity Status

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from USACE Design Memo No. 1	Difference Between O&M Capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Friant Dam to Chowchilla Canal Bypass									
San Joaquin River									
San Joaquin River	224.66	214.03	8,000	Not specified	N/A	4,000 – 8,000	Potential inadequacy; additional evaluation required	LSJLD – 4,000 cfs DWR Hydrologist – 8,000 cfs	Flows above 4,000 cfs cause damage per LSJLD at less than objective release from Friant Dam (8,000 cfs). Achieving the estimated capacity takes several days of sediment movement.
Chowchilla Canal Bypass to Sand Slough Control Structure									
San Joaquin River									
San Joaquin River – Mendota Dam to Chowchilla Canal Bypass	No data	166.44	2,500	Not specified	N/A	>2,500	No obvious inadequacy	LSJLD and MBK Modeling – River Islands Project	Diversion structure capacity <2,500 cfs. See Note 5.
San Joaquin River – Sand Slough to Mendota Dam	170.0	No data	4,500	Not specified	N/A	500	Potential inadequacy; additional evaluation required	LSJLD	Encroachment on the old channel has lowered this capacity to about 500 cfs.
Distributaries from San Joaquin River									
Chowchilla Bypass									
Bifurcation Structure to Fresno River	32.04	15.85	5,500	Not specified	N/A	5,500 – 8,000	No obvious inadequacy	DWR Hydrologist – 6,500 cfs LSJLD – 5,500 cfs RBF Consulting – 8,000 cfs	Estimated capacity of 6,500 cfs once levees are saturated. Flows above 5,500 cfs cause seepage problems per LSJLD.

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4] From	River Miles[4] To	Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
Eastside Bypass									
Fresno River to Berenda Slough	15.85	13.59	10,000	Not specified	N/A	10,000 – 12,000	No obvious inadequacy	LSJLD – 12,000 cfs DWR Hydrologist – 10,000 cfs RBF Consulting – 12,000 cfs *SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 12,000 cfs	Flows above 10,000 cfs cause seepage problems per LSJLD.
Berenda Slough to Ash Slough	13.59	10.48	12,000	Not specified	N/A	12,000 – 19,000	Potential inadequacy; additional evaluation required	DWR Hydrologist - 15,000 cfs LSJLD – 12,000 cfs RBF Consulting – 19,000 cfs	Estimated maximum capacity of 15,000 cfs. Flows above 10,000 cfs cause seepage problems per LSJLD.
Ash Slough to Sand Slough	10.48	0	17,000	Not specified	N/A	13,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Tributaries to Eastside Bypass									
Fresno River	8.36	0	5,000	Not specified	N/A	3,000 – 5,000	Potential inadequacy; additional evaluation required	DWR Hydrologist – 5,000 cfs *SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 3,000 cfs RBF Consulting – 3,000 cfs	None
Berenda Slough	4.28	0	2,000	Not specified	N/A	2,000	No obvious inadequacy	DWR Hydrologist – 2,000 cfs *SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 2,000 cfs RBF Consulting – 2,000 cfs	None

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Ash Slough	4.52	0	5,000	Not specified	N/A	2,000 – 5,000	Potential inadequacy; additional evaluation required	N/A	None
Sand Slough Control Structure to Merced River									
San Joaquin River									
Control Structure to Mariposa Bypass	149.89	145.15	1,500	Not specified	N/A	50	Potential inadequacy; additional evaluation required	LSJLD	None
Mariposa Bypass to Bear Creek	145.15	133.8	10,000	Not specified	N/A	1,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Bear Creek to Merced River	133.8	116.66	26,000	20,000	Yes	7,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Tributaries to San Joaquin River									
Mariposa Bypass	4.23	0	8,500	Not specified	N/A	8,000	Potential inadequacy; additional evaluation required	LSJLD and *SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	Historic channel flows have exceeded 11,000 cfs when encroached into design freeboard, per LSJLD.
Eastside Bypass									
Control Structure to Mariposa Bypass	8.96	16.0	16,500	Not specified	N/A	13,000 – 15,000	Potential inadequacy; additional evaluation required	DWR Hydrologist -15,000 cfs *SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 13,000 cfs	Estimated conveyance of 15,000 cfs in 2006, and 20,000 cfs in 1997 with some levee protection. Channel has conveyed 20,000 cfs when encroached into design freeboard, per LSJLD.

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Mariposa Bypass to Owens Creek	8.96	5.0	12,000	Not specified	N/A	12,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Owens Creek to Bear Creek	5.0	1.0	13,500	Not specified	N/A	10,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Bear Creek to San Joaquin River	1.0	0	18,500	Not specified	N/A	10,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Tributaries to Eastside Bypass									
Owens Creek	0.98	0	2,000	Not specified	N/A	No data	No data	N/A	None
Deadman Creek	6.66	0	9,000	Not specified	N/A	No data	No data	N/A	None
Upper Bear Creek	7.98	4.25	7,000	Not specified	N/A	8,000	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Bear Creek	4.25	0	14,400	Not specified	N/A	9,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Merced River to Stanislaus River									
San Joaquin River									
Merced River to Tuolumne River	110.9	81.5	45,000	45,000	No	22,000 – 35,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	The capacity of this reach needs to be verified by project-specific modeling; 1997 flows exceeded capacity with only minor conveyance problems.

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Tuolumne River to Stanislaus River	81.5	72.6	46,000	46,000	No	25,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	The capacity of this reach needs to be verified by project-specific modeling; 1997 flows exceeded capacity with only minor conveyance problems.
Tributaries to San Joaquin River									
Tuolumne River	0.6	0	15,000	15,000	No	No data	No data	N/A	None
Stanislaus River	11.9	0	12,000	12,000	No	23,000	No obvious inadequacy	N/A	Needs additional analysis – capacity data are for top of levee.
Stanislaus River to Burns Cutoff									
San Joaquin River									
Stanislaus River to Paradise Cut	72.6	58.3	52,000	52,000	No	66,000	No obvious inadequacy	Project-specific modeling by MBK for River Islands Project	None
Paradise Cut to Old River	58.3	53.3	37,000	37,000	No	30,000 – 40,000	Potential inadequacy; additional evaluation required	DWR Hydrologist – 30,000 cfs Project-specific modeling from MBK - 40,000 cfs.	Paradise Weir does not pass the design flow and is also inadequate per MBK modeling.
Old River to Burns Cutoff	53.3	40.6	18,000	Not specified	N/A	15,000 – 20,000	Potential inadequacy; additional evaluation required	DWR Hydrologist – 15,000 cfs Project-specific modeling from MBK – 20,000 cfs	Tidal impacts affect capacity.

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Tributaries to San Joaquin River									
French Camp Slough	6.4	0	3,000	Not specified	N/A	No data	No data	N/A	None
Tributaries to French Camp Slough									
Littlejohns Creek	1	0	1,750	Not specified	N/A	No data	No data	N/A	None
Duck Creek	0.9	0	900	Not specified	N/A	No data	No data	N/A	None
Distributaries from San Joaquin River									
Paradise Cut – San Joaquin River to Old River[3]	0	7.4	15,000	15,000	N/A	17,000	No obvious inadequacy	Modeling by MBK for River Islands Project	None
Old River – downstream from Paradise Cut	5.9	8.2	30,000	Not specified	N/A	19,000 – 30,000	Potential inadequacy; additional evaluation required	DWR Hydrologist – 19,000 cfs Project-specific modeling from MBK River Islands Project - 30,000 cfs	None
Old River – San Joaquin to Middle River	No data	No data	19,000	Not specified	N/A	30,300	No obvious inadequacy	Project-specific modeling from MBK River Islands Project	None
Old River – Middle River to Paradise Cut	No data	No data	19,000	Not specified	N/A	No data	No data	N/A	None
Old River/Salmon Slough – Paradise Cut to Grant Line Canal	No data	No data	No data	Not specified	N/A	No data	No data	N/A	None

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Burns Cutoff to Disappointment Slough									
Tributaries to San Joaquin River									
Calaveras River	5.8	0	15,818	13,500	N/A	31,700	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
Tributaries to Calaveras River									
Mormon Slough	8.4	6.2	15,022	12,500	N/A	30,000	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
Bear Creek – Disappointment Slough to Mosher Creek	0	10	7,630	Not specified	N/A	7,630	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
Bear Creek – Mosher Creek to Paddy Creek	10	13.1	5,000	Not specified	N/A	5,490	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
Bear Creek – upstream from Paddy Creek	13.1	16.7	1,800	Not specified	N/A	3,575	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None

Table B-2. San Joaquin River Watershed Channel Capacity Status (contd.)

River Reach[1]	River Miles[4]		Design Capacity from O&M Manual[2] (cfs)	Design Flows from Corps Design Memo No. 1	Difference between O&M capacities and Design Memo No. 1 (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Current Capacity Estimate	Comments
	From	To							
Tributaries to Bear Creek									
Paddy Creek – Bear Creek to North Paddy Creek	0	0.3	2,000	Not specified	N/A	3,593	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
Paddy Creek – upstream from North Paddy Creek	0.3	1.4	400	Not specified	N/A	434	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
Middle Paddy Creek	0	1.4	750)	Not specified	N/A	No data	No data	N/A	None
North Paddy Creek – Paddy Creek to Middle Paddy Creek	0	1.3	1,800	Not specified	N/A	2,626	No obvious inadequacy	SJAFCA Final Technical Memorandum #2 – Hydraulics (HDR, 1998)	None
North Paddy Creek – upstream from Middle Paddy Creek	0	3.9	1,200	Not specified	N/A	No data	No data	N/A	None

Notes:

1 Sequential river reaches were not necessarily designed as a system. Therefore, the capacities in the table do not add up. In some cases, left- and right-bank levees along the same reach may have different design capacities. In these cases, the lowest capacity was used both for O&M design flow and Estimated Current Channel Conveyance Capacity.

2 The State operates SPFC facilities in the San Joaquin Valley based on the 1955 profile rather than on design flows from the O&M manuals. The design flows from USACE Design Memorandum ranked No. 1 (1957) correspond to the 1955 profile.

3 The river mile was estimated at this location.

4 River mile designations are based on the USACE and DWR Comprehensive Study RM designations (2002).

5 The operation of weirs and structures within the system are being hadnled separately and are not included in this evaluation; however, bypass capacities are estimated. Consequently, while bypasses may have sufficient capacity, this does not imply that the full operation of the weir and bypass does not have inadequacies. Additional modeling and evaluation are required.

6 Where "DWR Hydrologist" is identified as the source of estimated capacity, data was provided by Maury Roos, retired State Hydrologist.

Key:
cfs = cubic feet per second
DWR = California Department of Water Resources
LSJLD = Lower San Joaquin Levee District
MBK = MBK Engineering Co.
N/A = Not available
No data = No data currently presented
O&M = operations and maintenance
RM = river mile
SJAFCA = San Joaquin Area Flood Control Agency
TM = Technical Memorandum
USACE = U.S. Army Corps of Engineers

Summary of Recent Remedial Actions

No recent remedial actions to address channel capacity inadequacies have been conducted other than vegetation management and sediment management activities.

Summary of Ongoing and Planned Remedial Actions

No actions have been planned other than vegetation management and sedimentation management to address channel capacity inadequacies.

Ongoing Actions to Improve Future Evaluations

California Department of Water Resources (DWR) is developing updated and new hydrologic and hydraulic models for major rivers and tributaries in the Central Valley as part of the Central Valley Floodplain Evaluation and Delineation Program. These models will provide a more current data set to identify channel conveyance capacity inadequacies throughout State Plan of Flood Control (SPFC) channels.

DWR is currently in the process of using newly acquired surface elevation data Light Detection and Ranging (LiDAR) and creating project-level hydraulic models for the Sacramento River Flood Control Project that may reveal additional hydraulic capacity issues due to sedimentation. However, DWR is not undertaking this study on the Lower San Joaquin River and Tributaries Project because it is not part of the prescribed channel maintenance per California Water Code Section 8361. Project-level channel capacity evaluations have been completed or are currently underway for the following:

- Bear River (Pleasant Grove Road to Rio Oso)
- Deer Creek
- Elder Creek
- Cherokee Canal
- Cache Creek Settling Basin
- Lindo Channel
- Sutter Bypass
- Sycamore Creek and Sycamore Bypass

Future project-level channel capacity evaluations are planned for the following:

- Feather River

- Little Chico Creek
- Chico Creek
- Butte Slough
- Willow Slough Bypass
- Putah Creek
- American River
- Bear River
- Cherokee Canal
- Colusa Back Borrow Pit
- Mud Creek
- Putah Creek
- Sacramento River
- Tisdale Bypass
- Wadsworth Canal
- Yolo Bypass
- Yuba River
- Natomas Cross Canal
- Linda and Arcade Creek
- Middle Creek

B-2 Channel Vegetation

This section describes recent, ongoing, and planned remedial actions to improve future evaluations. A map of ongoing and planned DWR vegetation management activities is also included.

Summary of Recent Remedial Actions

Routine maintenance work within the channels includes mowing, disking, and burning vegetation, removing dead and downed trees and/or debris that could obstruct flows during high-water events within the channel, and limbing up and/or removing trees. DWR performs these tasks annually to retain an acceptable level of readiness for high-water events.

Areas undergoing active vegetation management, or in which vegetation management has been initiated in the Sacramento River watershed, are shown in Figure B-1. The figure does not represent all channels that DWR is responsible for maintaining. Data were unavailable for the San Joaquin River watershed.

Summary of Ongoing and Planned Remedial Actions

Ongoing and planned remedial actions related to channel vegetation management are also shown in Figure B-1. Nonroutine vegetation management activities are specified in vegetation management plans. Channels for which DWR is currently preparing or will be preparing future vegetation management plans are listed below:

- Feather River
- Lindo Channel
- Deer Creek
- Elder Creek
- Sutter Bypass

Following the completion of project-level channel capacity evaluations, vegetation management plans will be developed, as needed.

Ongoing Actions to Improve Future Evaluations

DWR will continue to compile information on past, current, and future vegetation management actions in the Sacramento River watershed for areas that DWR is responsible for maintaining.

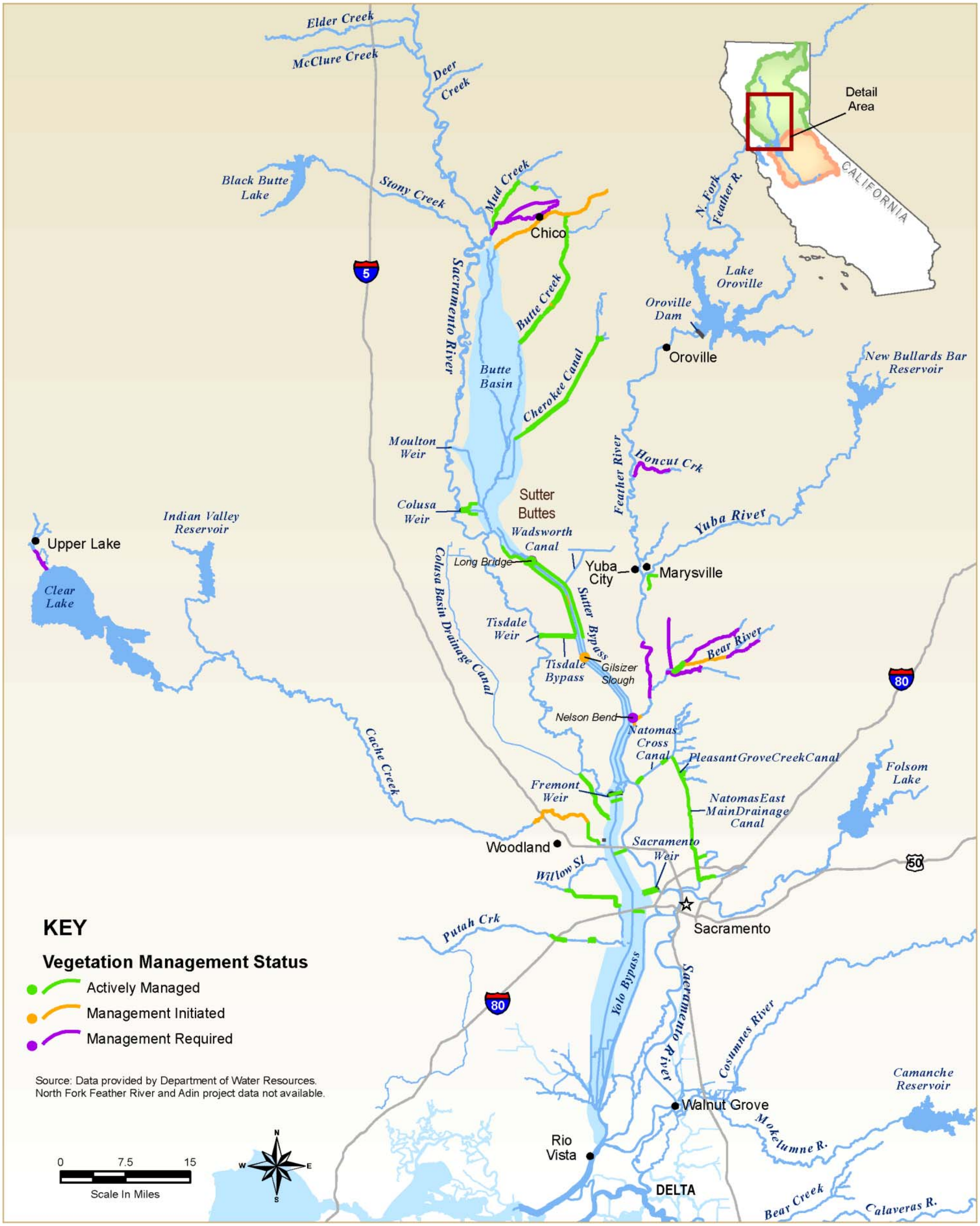

Figure B-1. Channel Vegetation Management Status in Sacramento River Watershed

B-3 Channel Sedimentation

This section describes recent, ongoing, and planned remedial actions to improve future evaluations.

Summary of Recent Remedial Actions

DWR performs sediment management for channels that it maintains within the Sacramento River Flood Control Project per California Water Code Section 8361. Sediment, debris, and rubbish have been removed in the past to retain the required conveyance capacity. Once excess sediment has accumulated in a channel such that the channel does not pass the design flow with adequate freeboard, sediment removal projects are developed.

Large-scale sediment removal projects have been implemented recently in the Sacramento River watershed. Figure B-2 shows the current status of sediment management projects in channels that DWR is responsible for maintaining in the Sacramento River watershed. Graphs embedded on Figure B-2 show annual cubic yards of sediment removed by DWR from 1983 through 2009. Data for sediment management activities in the San Joaquin River watershed are currently not available.

Summary of Ongoing and Planned Remedial Actions

DWR identifies areas of accumulated sediment based on annual visual observations of the channels. In addition, high-water staking may reveal reaches of a channel that do not convey the design capacity, as evidenced by the water surface encroaching on the freeboard. Once visual observations and high-water staking reveal a potential sediment problem, hydraulic models are prepared to evaluate the extent of the problem.

By December 2016, DWR plans to identify all additional SPFC channels within the Sacramento River watershed that are in need of sediment removal and develop channel sediment management plans to safely convey the channel’s design flows without encroaching on design levels of freeboard.

As of July 2010, DWR has completed hydraulic evaluations of upper portions of the Cherokee Canal and the lower portion of Sycamore Creek to determine the water surface elevation impact of observed sediment in the channels. Based on these modeling results, sediment removal projects to restore channel conveyance capacity for portions of Cherokee Canal and Sycamore Creek are being designed and implemented. Planned sediment management studies that are currently in various stages of development by DWR within SPFC channels include Upper Bear River and Cache Creek Settling Basin.

Ongoing Actions to Improve Future Evaluations

An evaluation of channel capacity inadequacy identification, modeling and evaluation techniques, and sediment management planning and project development are underway to improve the process for managing sediment in SPFC channels in the Sacramento River watershed. After identification of channels needing maintenance, hydraulic models and evaluations will be prepared and DWR will develop and implement projects annually to address identified channel sedimentation problems. The goal is to implement these sediment management projects as part of a bigger-picture channel management strategy that incorporates possible changes or effects to the system upstream and downstream from the sedimentation problem areas.

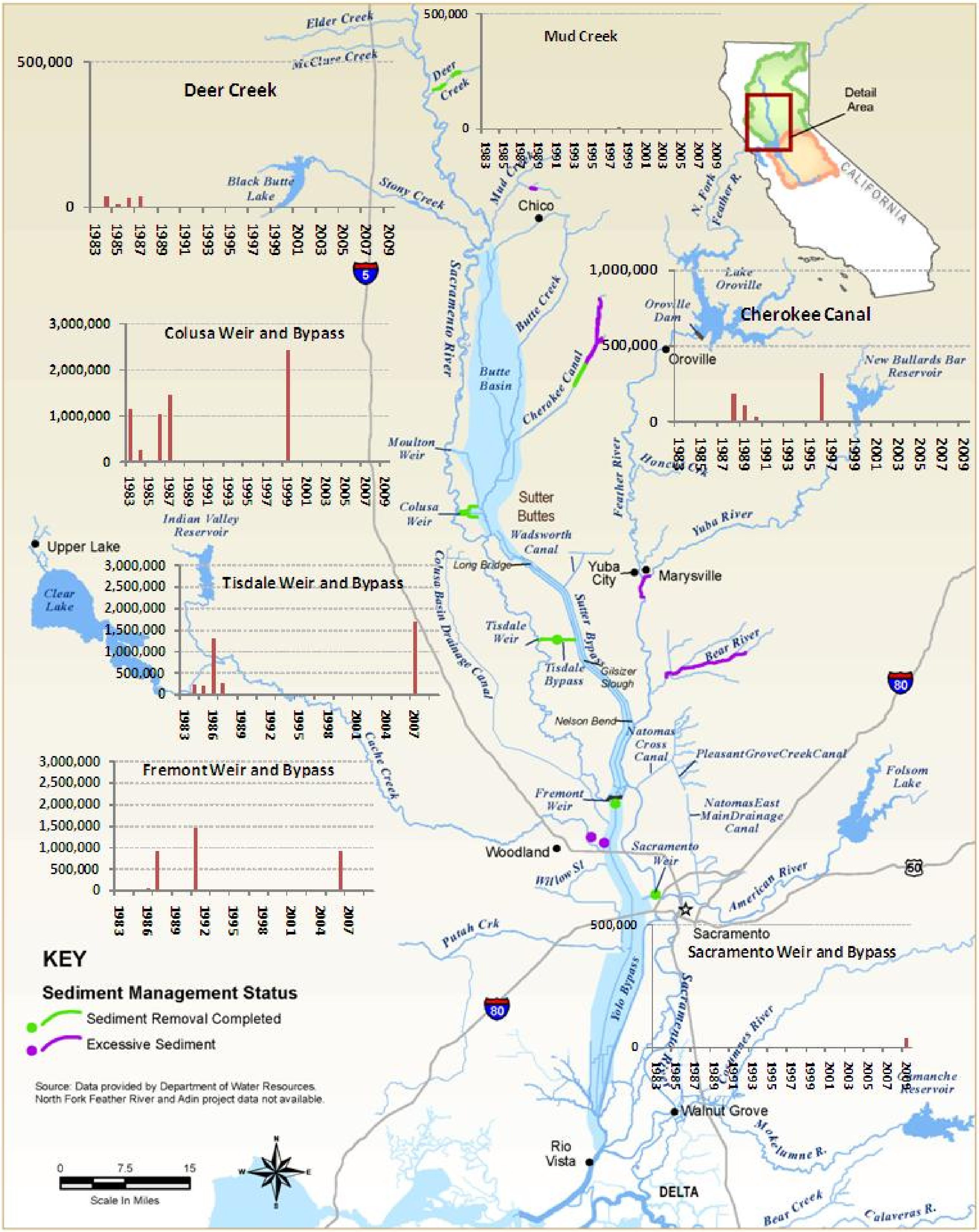

Figure B-2. Channel Sediment Management Status in Sacramento River Watershed

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Acronyms and Abbreviations

DWR	California Department of Water Resources
FCSSR	Flood Control System Status Report
LiDAR	Light Detection and Ranging
O&M	operations and maintenance
SPFC	State Plan of Flood Control
USACE	U.S. Army Corps of Engineers

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Flood Control System Status Report Appendix C – Flood Control Structure Status

December 2011

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Appendix C – Flood Control Structure Status

Appendix C provides supporting information on hydraulic structures, pumping plants, and bridges relative to flood management for the State Plan of Flood Control (SPFC). Sections C-1, Hydraulic Structures, C-2, Pumping Plants, and C-3, Bridges, correspond to subsections in Section 6 of the Flood Control System Status Report (FCSSR) main document. This appendix includes information on recent, ongoing, and planned remedial actions for these structures. Information about ongoing actions to improve future evaluations is also summarized.

C-1 Hydraulic Structures

This section describes recent, ongoing, and planned remedial actions for SPFC hydraulic structures. It also describes actions to improve evaluation of hydraulic structures in the future.

Summary of Recent Remedial Actions

No recent major remedial actions for SPFC hydraulic structures have been documented by the California Department of Water Resources (DWR).

Summary of Ongoing and Planned Remedial Actions

Ongoing and planned remedial actions for SPFC hydraulic structures by DWR include the following:

- **Cache Creek Settling Basin** – A 3-year study is currently underway to determine the Cache Creek Settling Basin trapping efficiency. The Cache Creek Settling Basin Weir will not be inspected until after the study is completed.

- **Willow Slough Weir and Weir No. 2**–Willow Slough Weir (Sutter Bypass East Borrow Canal) was replaced in 2011. Weir No. 2 will be replaced in 2012.

- **Knights Landing Outfall Gates** – Motor controls and communications systems are not functioning and structural materials are deteriorating. Rehabilitation of the Knights Landing Outfall Gates is anticipated to begin in 2012. The outfall gates, motor controls, and communications system will be replaced.

- **Butte Slough Outfall Gates –** A detailed inspection of the Butte Slough Outfall Gates was performed in 2008. A Capital Outlay Budget Change Proposal for Fiscal Years 2010 and 2011 is under consideration to correct the problems found.

Ongoing Actions to Improve Future Evaluations

Under the FloodSAFE California (FloodSAFE) Initiative, DWR has recently created a more robust and thorough inspection program for hydraulic structures (DWR, 2010). The Hydraulic Structures Inspection Program has been established to better track the inspections and maintenance work performed on structures maintained by DWR.

Initial actions of the program involved identifying and cataloging historical records (inspection records, record drawings, operations criteria, operations and maintenance (O&M) manuals, etc.) of all hydraulic structures, and updating the existing inspection procedures in accordance with current U.S. Army Corps of Engineers (USACE) standards. It is expected that biannual inspections and repairs will continue to improve performance of the existing hydraulic structures.

DWR produces Annual Inspection Reports outlining prioritized repairs by June 1. Structures identified are targeted to be repaired between June and November. Before November of each year, the structures will be inspected to document the repairs completed before flood season.

C-2 Pumping Plants

This section describes recent, ongoing, and planned remedial actions for SPFC pumping plants. It also describes actions to improve evaluations of pumping plants in the future.

Summary of Recent Remedial Actions

A project was completed in November 2007 to refurbish the pump motors for each pump at the three pumping plants along the east levee of the Sutter Bypass. The refurbishments were considered in the 2009 inspection results reported in Section 6 of the FCSSR. In 2011, DWR recently completed a project to provide backup power generators and fuel tanks at each of these three pumping plants in the Sutter Bypass. The project also included a remote communications system that enabled automated pump controls from the Sutter Maintenance Yard.

Summary of Ongoing and Planned Remedial Actions

No major ongoing and planned remedial actions for SPFC pumping plants have been documented by DWR.

Ongoing Actions to Improve Future Evaluations

The Hydraulic Structures Inspection Program described above also includes inspection of pumping plants. In addition, DWR is installing new communication and data relay systems with new control systems that will enable real-time monitoring of pumping plants. This technology will allow DWR to track pump efficiencies and discover maintenance problems as they arise.

C-3 Bridges

This section describes recent, ongoing, and planned remedial actions for SPFC bridges maintained by DWR. It also describes actions to improve evaluations of bridges in the future.

Summary of Recent Remedial Actions

Recent remedial actions for SPFC bridges maintained by DWR include the following:

- The decking of several of the collecting canal and intercepting canal bridges in Sutter County have been refurbished since 2003.
- McKee Lane at Western Intercepting Canal (WI-2), maintained by DWR, has been replaced.
- The following bridges maintained by Sutter County have also been replaced in coordination with DWR:
  - Garmire Bridge at Tisdale Bypass
  - Franklin Road Bridge at Wadsworth Canal
  - South Butte Road Bridge at Wadsworth Canal
  - Butte House Road Bridge at Wadsworth Canal
  - Acacia Avenue Bridge at Western Intercepting Canal
  - Mallott Road Bridge at Western Intercepting Canal
  - East Butte Road Bridge at Eastern Intercepting Canal

- Pease Road Bridge at Eastern Intercepting Canal
- Township Road Bridge at Eastern Intercepting Canal
- Obanion Road Bridge at Collecting Canal/State Drain
- Oswald Road Bridge at West Borrow Canal
- Franklin Road Bridge at West Borrow Canal

These recent remedial actions were reflected in the 2009 inspection results reported in Section 6 of the FCSSR.

Summary of Ongoing and Planned Remedial Actions

Ongoing and planned remedial actions include the following:

- Bridge EL-1A has been designated as a bridge needing repair. The bridge decking will be replaced as soon as funding is appropriated.
- Bridge CC-4 has been designated as a bridge needing immediate repair. The bridge decking and abutments will be refurbished as soon as funding is appropriated.

Ongoing Actions to Improve Future Evaluations

Under the FloodSAFE Initiative, DWR has recently created a more robust and thorough inspection program for DWR-maintained bridges to better track the inspections and maintenance work performed on bridges by DWR (DWR, 2009).

Similar to the Hydraulic Structures Inspection Program, DWR produces an *Annual Bridge Inspection Report* (DWR, 2009) outlining a prioritized list of needed repairs in June. Bridges identified on the list are targeted for repair between June and November, and inspections are performed before November on bridges to document repairs.

References

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Acronyms and Abbreviations

DWR .... California Department of Water Resources
FCSSR............................... *Flood Control System Status Report*
FloodSAFE......................... FloodSAFE California
O&M.................................. operations and maintenance
SPFC .... State Plan of Flood Control
USACE.............................. U.S. Army Corps of Engineers

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State of California
The Natural Resources Agency
Department of Water Resources