CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 8F: Flood Damage Analysis

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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1.0 Introduction

This section states the purpose of this attachment, gives background information (including a description of planning areas, goals, and approaches), discusses the types of economic flood damage and the national economic development (NED) approach, and provides an overview of the report organization.

1.1 Purpose of this Attachment

There are many ongoing effects to support the development of the 2012 Central Valley Flood Protection Plan (CVFPP). This technical attachment describes the methodology and results from the economic flood damage analyses for the following:

- No Project condition
- Achieve State Plan of Flood Control (SPFC) Design Flow Capacity Approach
- Protect High Risk Communities Approach
- Enhance Flood System Capacity Approach
- State Systemwide Investment Approach

The flood damage analysis of the No Project condition was conducted to provide a baseline for comparison with the four approaches. While the No Project condition is meant to describe the existing conditions of the flood management systems in the Central Valley, it also includes projects that have been authorized and have funding, or that have begun construction or implementation. The No Project condition includes the following:

- Levee improvements in south Yuba County implemented by the Three Rivers Levee Improvement Authority (TRLIA) since 2004 (TRLIA, 2011)
- Natomas Levee Improvement Program by the Sacramento Area Flood Control Agency (SAFCA) (SAFCA, 2011)

- Folsom Dam Joint Federal Project to improve the ability of Folsom Dam to manage large floods by allowing more water to be safely released earlier in a storm event, leaving more storage capacity for capturing peak inflow (Reclamation, 2009)
- Levee improvements along the American River to safely pass a flow of 160,000 cubic feet per second (cfs) as part of the American River Common Features Project (SAFCA, 2011)
- Marysville levee improvements (USACE, 2009)

This technical attachment also documents the following based on the best available data and tools as of September 2011:

- Geographic planning areas relevant to the CVFPP development process.
- Quantitative economic flood damage estimates for structures, contents, crops, and business loss (direct damages) under the No Project condition as a baseline for comparison with other flood risk management approaches.
- Quantitative flood damage estimates for structures, contents, crops, and business loss (direct damages) under the four flood risk management approaches described below.
- Qualitative description of approach for the estimation of emergency costs under a future CVFPP update.

1.2 Background

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

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

1.3 CVFPP Planning Areas

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

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

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

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

Economic flood damage analysis was conducted in the SPFC Planning Area for flood damages to structures, contents, crops, and business losses. Costs related to emergency response and recovery, regional economic impacts, and other social effects are analyzed for the Systemwide Planning Area and the Central Valley.

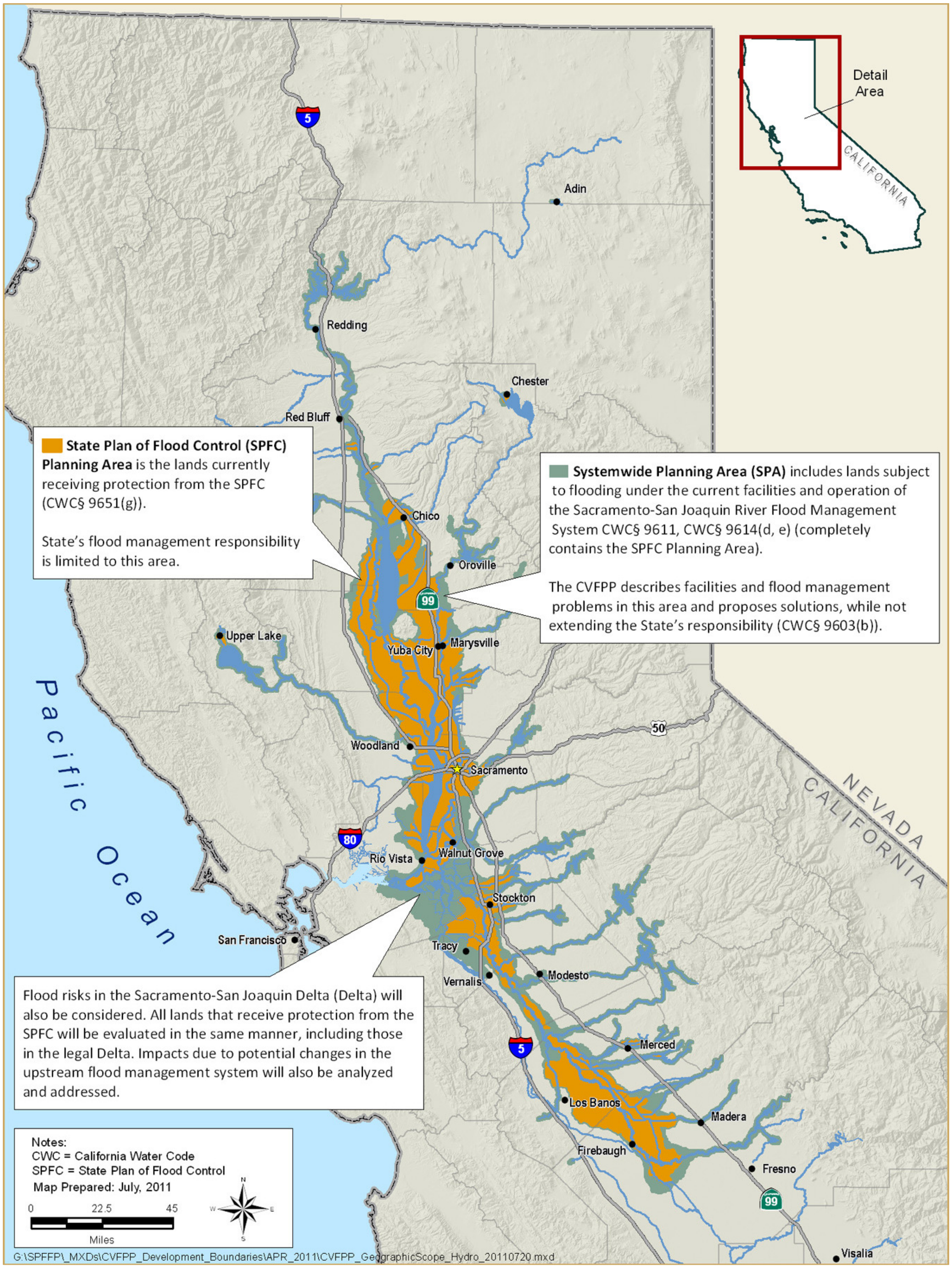

Figure 1-1. Central Valley Flood Protection Plan Planning Areas

1.4 2012 CVFPP Planning Goals

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

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

1.5 2012 CVFPP Planning Approaches

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

- **Achieve SPFC Design Flow Capacity** – Address capacity inadequacies and other adverse conditions associated with existing SPFC facilities, without making major changes to the footprint or operation of those facilities.

- **Protect High Risk Communities** – Focus on protecting life safety for populations at highest risk, including urban areas and small communities.

- **Enhance Flood System Capacity** – Seek various opportunities to achieve multiple benefits through enhancing flood system storage and conveyance capacity.

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

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

This attachment documents economic flood damage analyses conducted for the No Project condition and each of the approaches.

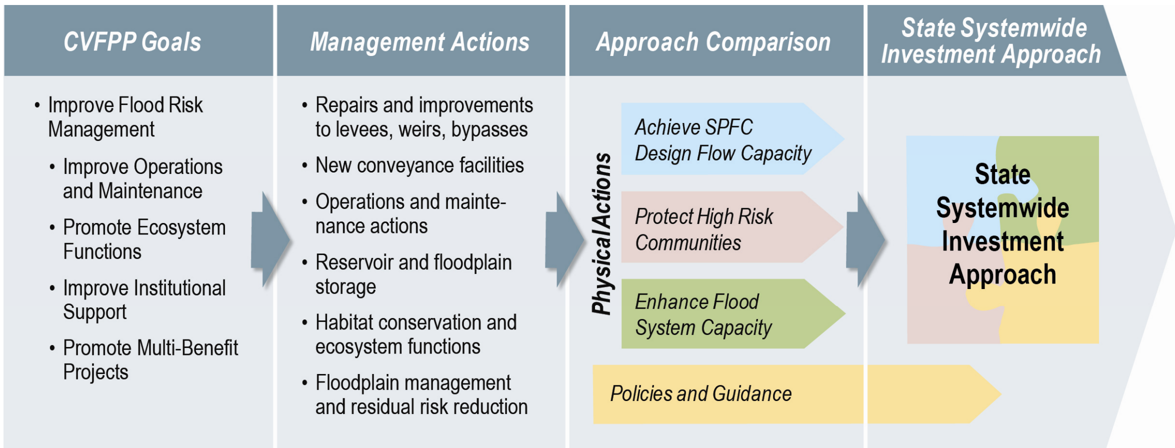

Figure 1-2. Formulation Process for State Systemwide Investment Approach

1.6 Types of Economic Flood Damages

In common with most economic flood damage studies, four types of damages have been defined, as follows:

- Tangible damages include the economic impacts of a flood (e.g., damages to structure and contents of buildings, utility infrastructure, agricultural enterprises).
- Tangible damages, measured in dollars, also include losses from emergency response and disruption of normal economic and social activities that arise from the physical impact of a flood (e.g., costs associated with emergency response; cleanup; community support; disruption to transportation, employment, commerce, tourism).
- Intangible damages consist of losses that are usually not quantified in monetary terms (since market prices cannot be used) (e.g., loss of biodiversity due to habitat damages to the riverbanks).

- Intangible damages also include losses that are also usually not quantified in monetary terms (since market prices cannot be used) (e.g., increase in stress levels for residents following a major flood affecting their homes).

The analyses documented in this attachment focus on (1) quantitative evaluation of tangible flood damages to structure, contents, and crops and (2) a qualitative discussion of other tangible costs related to emergency response and recovery.

1.7 National Economic Development

The *1983 Economic and Environmental Principles and Guidelines* (P&G) *for Water and Related Land Resources Implementation Studies* (WRC, 1983) were established pursuant to the Water Resources Planning Act of 1965 (Public Law 89-80) to promote proper and consistent planning by federal agencies[1] in the formulating and evaluating water and related land resources implementation studies. The federal objective of these studies is to maximize NED through development of an NED plan while protecting the nation's environment, pursuant to applicable laws and requirements. The P&G define the evaluation approach for NED to maximize net benefits.

The CVFPP economic flood damage analyses documented in this attachment adhere to the NED approach. Key elements that comply with the NED approach and U.S. Army Corps of Engineers (USACE) policies and procedures include, but are not limited to, the following:

- Use of risk analysis
- Depreciation of structural value
- Use of uncertainty in first floor elevations, structure values, and contents-to-structure value ratio
- Use of USACE Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) computer program

California's economy is the largest in the United States and, thus, the economies of these two entities are closely linked. It is anticipated that

[1] The federal agencies are U.S. Army Corps of Engineers (USACE), U.S. Department of the Interior, Bureau of Reclamation (Reclamation), Tennessee Valley Authority, and the Natural Resources Conservation Service (NRCS).

implementation of the CVFPP could reduce economic flood damages in the Central Valley of California, increase overall California production, and thus benefit the entire national economy. In other words, implementing the CVFPP could potentially contribute to the NED.

In the future, with appropriate Congressional authorization, California will likely seek federal funding. Using an economic flood damage evaluation compatible with the NED approach could potentially expedite the federal funding process. Also, being compatible with USACE water planning principles and guidelines could help California maximize federal funding.

1.8 Report Organization

Organization of this document is as follows:

- Section 1 describes the purpose of the attachment and provides background information on the CVFPP; describes CVFPP planning areas, the CVFPP planning process, and planning approaches; and discusses types of flood damages and NED.
- Section 2 summarizes results and findings for the economic flood damage analysis.
- Section 3 describes the methodology used in this analysis.
- Section 4 provides complete results for the flood damage analysis by approach.
- Section 5 contains references for the sources cited in this document.
- Section 6 lists abbreviations and acronyms used in this document.

2.0 Results Summary and Findings

Results of the flood damage analysis are given as Estimated Annual Damages (EAD). EAD is not a predictor of damages for a given year, but rather indicates the annualized damages from periodic flooding. For this study, the EAD has three components:

- Annual structure and contents damage
- Annual crop damage
- Annual business losses

Figures 2-1 and 2-2 indicate the total EAD, as well as the components listed above, for the Sacramento and San Joaquin river basins, for the No Project Condition and for each of the four flood management approaches.

In the Sacramento River Basin, the Enhance Flood System Capacity Approach provides the largest reduction in economic flood damages, followed by the State Systemwide Investment Approach (SSIA). This is likely because of the larger percentage of the damages in the basin that would occur in urban areas, and both of these approaches would provide 200-year protection to urban areas plus new and widened bypasses and lengthened weirs.

In the San Joaquin River Basin, the Enhance Flood System Capacity (EFSC) Approach provides the largest reduction in economic flood damages, followed by the Achieve SPFC Design Flow Capacity Approach. This is because of a larger percentage of the damages in the basin would occur in rural areas and both of these approaches would restore all SPFC levees to Design Flow Capacity, including rural areas.

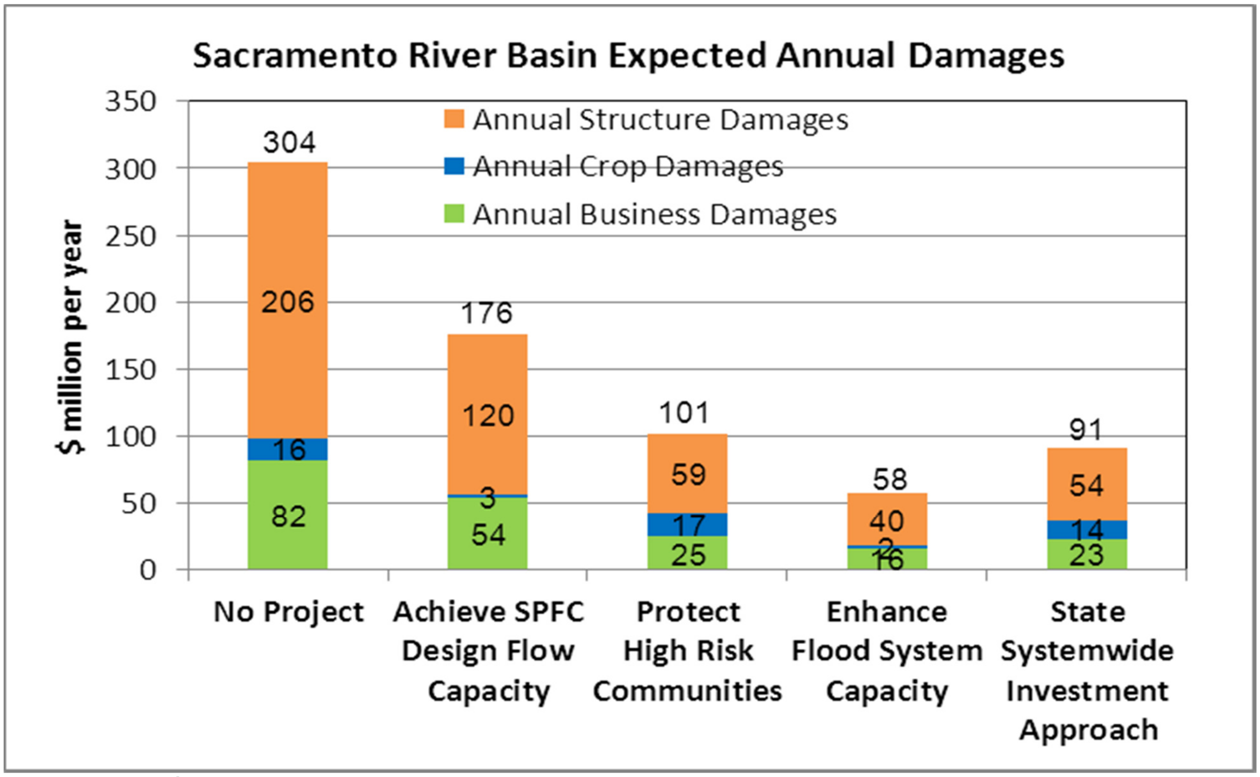

Figure 2-1. Sacramento River Basin Estimated Annual Flood Damages

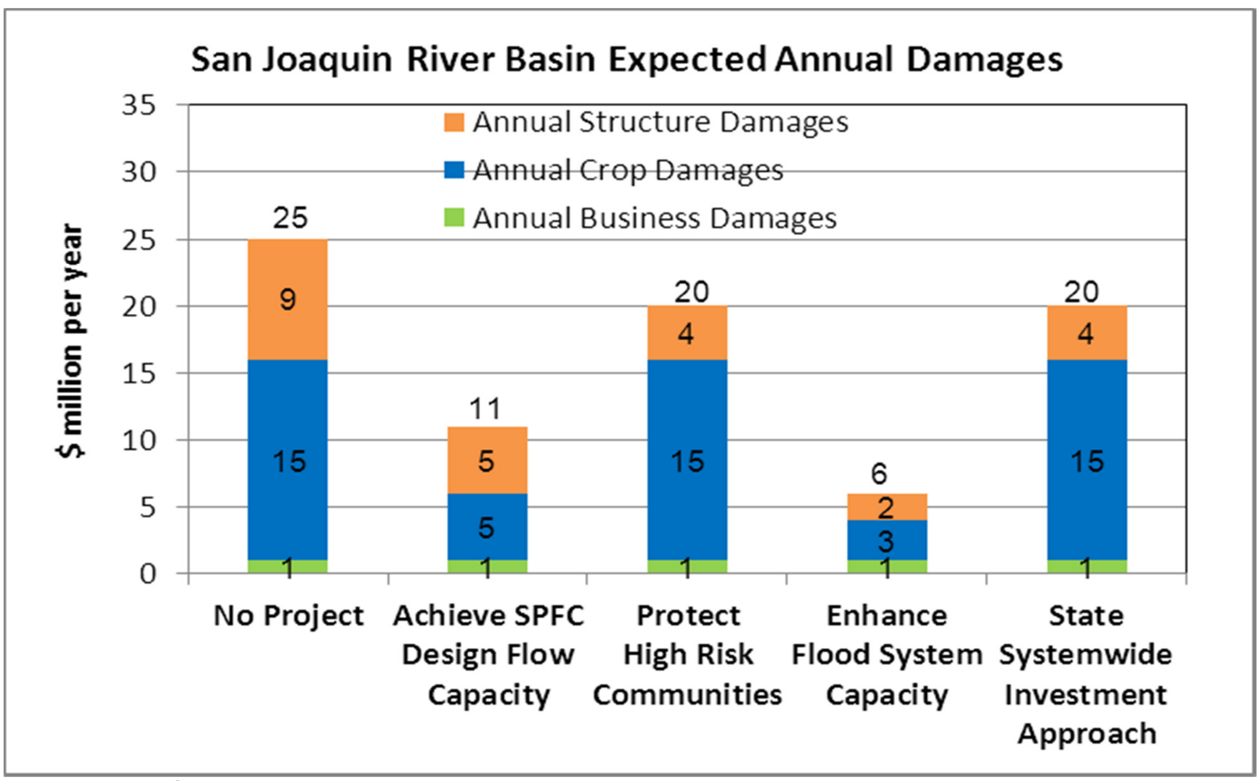

Figure 2-2. San Joaquin River Basin Estimated Annual Flood Damages

3.0 Flood Damage Analysis Methodology

Structure value has evolved as the most widely used indicator of potential economic flood damages and, generally, structure and contents values make up the majority of avoided damages or benefits associated with flood damage reduction projects. Vehicles are a structure contents subcategory that typically represents a small percentage of project damages and were not anticipated to have significant bearing on plan formulation. For agricultural areas, crop loss has been the major economic flood damage category. This document focuses on quantifying the economic flood damages for structures and contents, crops and business losses.

In general, the CVFPP flood damage quantitative analysis for structures, contents, and crops in the Sacramento and San Joaquin river basins follows a similar methodology to that used for the *U.S. Army Corps of Engineers* (USACE) *Sacramento and San Joaquin Basins Comprehensive Study* (Comprehensive Study) (2002a). Structural damages are referred to in this attachment as inundation damages associated with a building structure and its contents, crop damages as damages associated with inundation of agricultural lands. Business losses were not analyzed in the Comprehensive Study, but are used in this attachment to describe direct flood damages associated with decreased business activity caused by flooding.

This section describes overall methodology and common inputs for structural and crop damages. Specific details of structural and crop damages and business losses are given in Section 4.

3.1 Comprehensive Study

In response to extensive flooding and damage experienced during the floods of 1997, Congress authorized the USACE, Sacramento District, to undertake the Comprehensive Study, a comprehensive analysis of the flood management systems in the Sacramento and San Joaquin river basins, and to develop plans for reducing flood damages and improving the riverine environment (USACE, 2002a).

Multidisciplinary modeling and analysis tools were developed and used for the Comprehensive Study. The tools provided hydrologic, hydraulic, geotechnical, economic, and environmental analysis. The CVFPP follows a similar analytical approach for these two river basins. The Calaveras River and Bear Creek in the Stockton area were not evaluated in the Comprehensive Study; however, a similar approach was applied in the Stockton area for the CVFPP with slightly different tools. Details of the modeling and analysis applied to the Stockton area can be found in Attachment 8C: Riverine Channel Evaluations.

3.2 Overall CVFPP Modeling Framework

During CVFPP development, flood management approaches were identified and their corresponding EAD were developed and compared against the No Project condition EAD to determine their effectiveness as flood management strategies. Multiple modeling tools and analyses were conducted to support the approach evaluation (Figure 3-1); using existing tools that were updated with best available data.

The technical tools needed for the evaluation include hydrology that is used to develop unregulated flow hydrographs into reservoirs and streams. Next, reservoir models are used to simulate regulated flows for input to the downstream river hydraulic models. The regulated flows downstream from reservoirs and unregulated local flows are sent to the river hydraulic models that are used to simulate water stages, flow rates, levee breaches, out-of-system flows, etc., in the rivers. Geotechnical studies identify levee failure probability used both in the river hydraulic models to determine levee breaches and subsequent out-of-system flows, and in the economic models to determine stage-damage curves. Economic models identify damages using stage-damage curves derived from structure and crop inventories. Any CVFPP management actions could change some of the model inputs and thus change the EAD.

Input sources for the economic flood damage analysis are summarized below:

- Levee performance curves using data developed for the Urban Levee Evaluation (ULE) Project and the Non-Urban Levee Evaluation (NULE) Project under the DWR FloodSAFE California (FloodSAFE) Levee Evaluation Program (see Attachment 8E: System/Levee Performance for details).

- Hydraulic modeling outputs from (1) UNET (Unsteady flow through a NETwork of open channels) models for the Sacramento and San

Joaquin river basins, (2) RMA Delta Model for Delta islands, and (3) Hydrologic Engineering Center River Analysis System (HEC-RAS) for the Stockton area (see Attachment 8C: Riverine Channel Evaluations and Attachment 8D: Estuary Channel Evaluations for details).

- Flood depth information derived from (1) Comprehensive Study FLO-2D[2] flood depth grids, and (2) FLO-2D flood depth grids for Stockton area

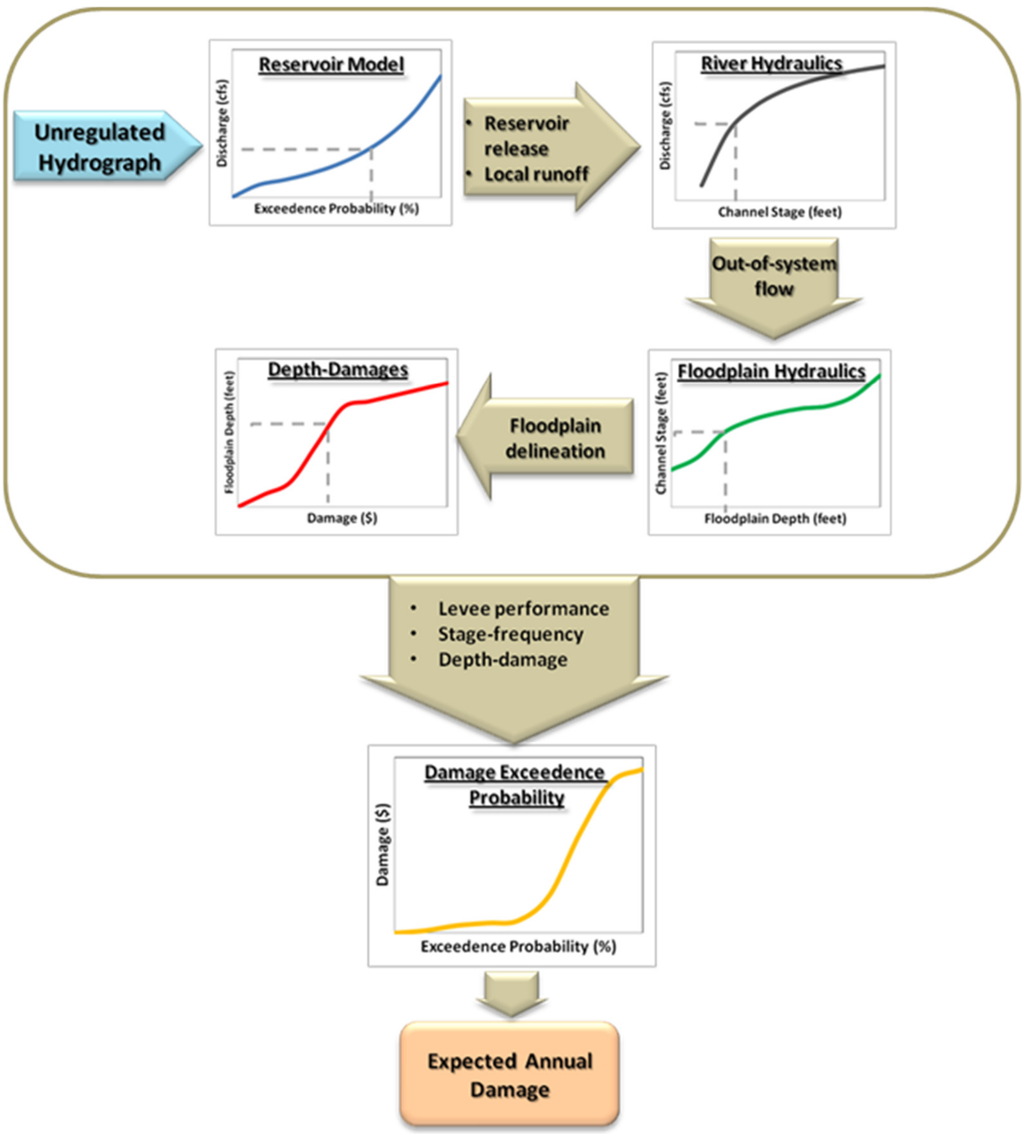

Figure 3-1. Schematic of Overall Modeling Framework

[2] FLO-2D is an integrated river and floodplain model developed by FLO-2D Software, Inc. It is a dynamic flood routing model that simulates channel flow, unconfined overland flow, and street flow, with consideration of topography and roughness.

- A reconnaissance-level structure inventory developed using field surveys conducted in 2010 and 2011.
- DWR May 2010 spatial geographic information system (GIS) dataset for Central Valley landuse conditions, focusing on agricultural lands.
- Comprehensive Study agricultural damage spreadsheets (Ag damage spreadsheet) (USACE 2010b).
- USACE contents-structure ratios and depth-damage functions (USACE, 2008)

3.3 Flood Damage Reduction Analysis Methods

In the Comprehensive Study, USACE used the HEC-FDA computer program to analyze flood inundation damage and project performance by return period and EAD. The HEC-FDA program provides state-of-the-art analysis for formulating and evaluating flood damage reduction plans using risk-based analysis methods.

The HEC-FDA calculations took into account information and uncertainties from interrelated hydrologic, hydraulic, geotechnical, and economic information (UASCE, 2002b), as follows:

- **Hydrologic –** A discharge-frequency function describes the probability of floods equal to or greater than a given discharge. Uncertainty factors include hydrologic data record lengths that are often short or do not exist, precipitation-runoff computational methods that are not precisely known, and imprecise knowledge of flow regulation effectiveness.
- **Hydraulics –** A stage-frequency function describes the maximum water surface elevation (stage) that the flow of water in a river channel would reach for a given annual exceedence probability (AEP) flood event. Uncertainty in this number may be from the use of simplified models to describe complex hydraulic phenomena, including the lack of detailed geometric data, misalignments of hydraulic structures, material variability, and errors in estimating slope and roughness factors.
- **Geotechnical –** A geotechnical levee performance curve describes levee failure (breach) probabilities corresponding to water stages in a channel. As the stage on the channel side of a levee rises, the probability of levee failure increases. Once a levee fails and water enters the floodplain through the resulting breach, stages in the floodplain are applied in the HEC-FDA computation. Uncertainty

results from estimation of the geotechnical performance of levees and flood control structures during floods. Other uncertainties may include assumptions for geotechnical parameters, mathematical simplifications in the analysis models, frequency and magnitude of physical changes or failure events, and the uncertainty of unseen features such as rodent burrows, cracks within the levee, or other defects.

- **Flood Damages –** A stage-damage function describes the amount of damage that might occur given certain floodplain stages. Uncertainty may be from land uses, depth/damage relationships, structure/contents values, structure locations, first-floor elevations, floodwater velocity, the amount of debris and mud, flood duration, and warning time and the response of floodplain inhabitants. Some of these uncertainties (warning time and response) are not accounted for in the flood damage analysis.

To quantify the above uncertainties and incorporate them into an economic and engineering performance analysis, HEC-FDA applies Monte Carlo simulation, a numerical-analysis procedure that computes the expected value of damage while explicitly accounting for uncertainty in basin parameters used to determine flood inundation damage. Additional information can be found in the *HEC-FDA User's Manual* (USACE, 2008a)

3.4 Flood Damage Analysis Output Types

The primary outputs of HEC-FDA for flood damage analysis in this attachment are as follows:

- EAD is defined as the average or mean of all possible values of damage determined by Monte Carlo sampling of stage-exceedence probability, the geotechnical levee performance curve, and stage-damage relationships and their associated uncertainties. EAD is calculated as the integral of the damage-probability function.

- Expected annual exceedence probability (AEP) measures the chance of a flood occurring in any given year.

- Long-term risk provides the probability of one or more damaging floods occurring over a period of time (10-, 30-, and 50-year periods).

- Conditional nonexceedence probability for flood events (i.e., the probability of passing specific flood events) of 10, 4, 2, 1, 0.4, and 0.2 percent (10-, 25-, 50-, 100-, 200-, and 500-year return period).

3.5 CVFPP HEC-FDA Coverage

The total floodplain area protected by the SPFC in the Sacramento and San Joaquin river basins is approximately 2.1 million acres (or about 3,300 square miles). These floodplains are not homogenous; they contain areas subject to different types of flooding. For example, the Colusa Basin in the upper Sacramento River Basin is prone to "overland" flooding while areas in and near the Delta in the lower San Joaquin River Basin are prone to "bathtub" flooding. In HEC-FDA, floodplains are represented by a collection of damage areas for (1) the Sacramento River Basin, (2) the San Joaquin River Basin, and (3) the Stockton area. HEC-FDA simulations are performed for each damage area in the CVFPP.

The Sacramento River Basin is represented by 63 damage areas (about 1.36 million acres in total, Figure 3-2) and the San Joaquin River Basin by 43 damage areas (about 0.70 million acres in total, Figure 3-3). The original Comprehensive Study damage areas in these two basins were revised by DWR in early 2010 within the 500-year (0.2 percent) floodplains[3] to include the largest flood deemed reasonably possible. There are six damage areas in the Stockton area (about 60,000 acres in total, Figure 3-3) covering areas inside SPFC Planning Area but outside of Comprehensive Study HEC-FDA for the San Joaquin River Basin.

Each damage area is unique and is located along a stream or waterway with beginning and ending stations. As described above, each damage area extends to include the 500-year floodplain. Each damage area has a unique index point on a bounding watercourse, where channel and floodplain water surface elevations are coupled. The index point, which represents its corresponding section of river reach and the properties of the levees, is also the location where flood damages for a damage area (through the stage-damage function) are developed, and then linked to hydrology, hydraulics, and geotechnical considerations through a Monte Carlo simulation to calculate a flood risk. The index point location for each damage area has been defined through the ULE and NULE efforts and is shown in Attachment 8E: Levee Performance Curves.

[3] DWR used the 500-year floodplain GIS file from the Comprehensive Study to modify the damage area boundaries in early 2010. The intent of the modification was to better align the damage areas with the floodplain boundary. Portions or the entirety of the cities of Chico, Davis, Los Banos, Merced, Tracy, and Woodland are inside the SPFC planning area, but their flood damage effects were not evaluated under the CVFPP because the Comprehensive Study did not develop HEC-FDA damage areas for each of these cities. It is anticipated that these cities will be part of the 2017 CVFPP flood damage analysis.

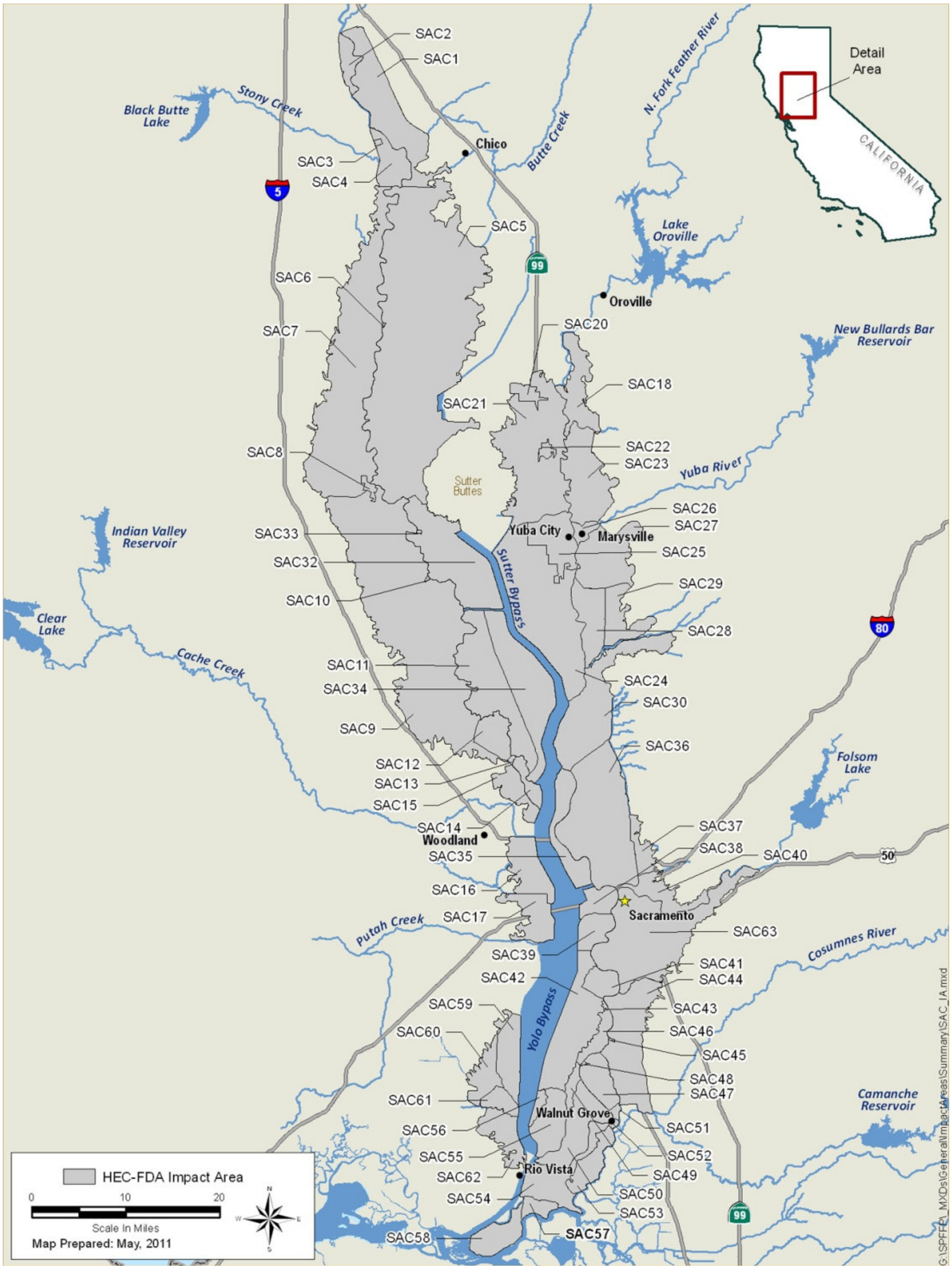

Figure 3-2. HEC-FDA Damage Areas in Sacramento River Basin

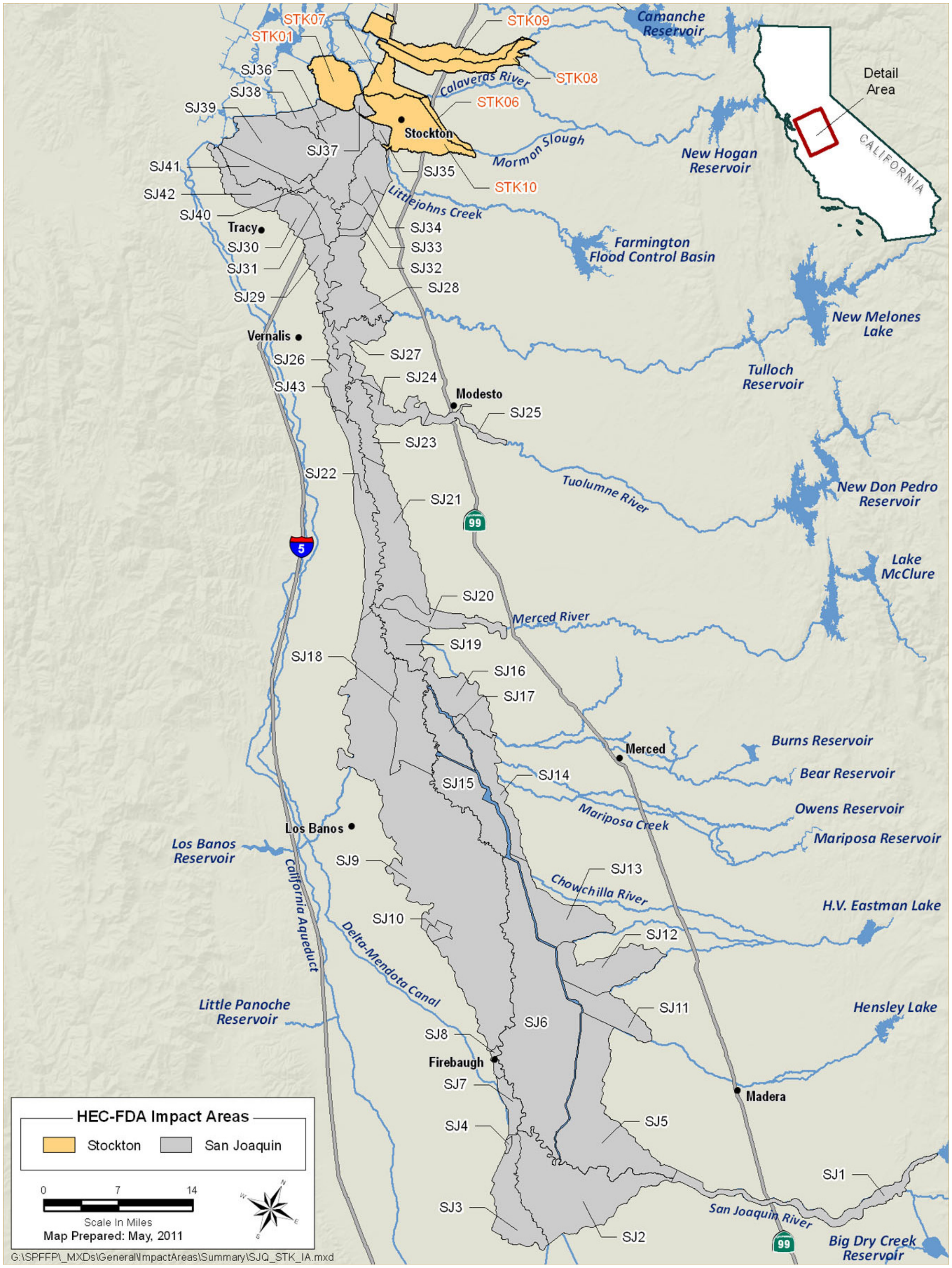

Figure 3-3. HEC-FDA Damage Areas in San Joaquin River Basin and Stockton Area

3.6 Major HEC-FDA Inputs

Risk analyses for structure and crop damage require three types of hydraulic and geotechnical inputs to HEC-FDA:

- Stage-frequency curve (stream hydraulics and hydrology)
- Levee performance curve (geotechnical considerations)
- Flood depth grid (floodplain hydraulics)

3.6.1 Stage-Frequency Curve

For each damage area, the stage-frequency curve function at the corresponding index point was developed and incorporated into the HEC-FDA as input based on flood events with AEPs of 10, 4, 2, 1, .5, and .2 percent (10-, 25-, 50-, 100-, 200-, and 500-year return period). UNET simulations for a 100 percent AEP were not performed because hydrology for this event was not available; instead, stages for the 100 percent AEP (1-year return period event) at each index point are based on the interior levee toe elevations (as developed by the ULE and NULE projects in DWR's Levee Evaluation Program). Assumptions from the Comprehensive Study hybrid stage-frequency curves were applied in cases where no other data were available.

In some reaches, simulated stages were substantially below the levee failure elevation, especially in downstream reaches. This was due to the progressive loss of floodwater through multiple upstream levee breaches. After a levee breach occurs, the water surface elevation remains relatively constant for all higher flood frequencies because flows are escaping into the floodplain through the levee breach, causing the stage-frequency curves to tail over or flatten at the breach elevation. Monte Carlo sampling in HEC-FDA requires a stage-frequency curve that covers a full range of potential flood frequencies. Consequently, two sets of simulations were required to construct the stage-frequency curves in reaches with levees: one that assumes levee failures occur (termed finite channel, see Figure 3-4) and one that assumes all flow is contained within the channel (termed infinite channel, see Figure 3-4). The portion of the curve below the levee failure point is developed using the levee-failure simulations and the upper portion of the curve above the frequency of levee failure is formed using the infinite channel simulation in which the stage-frequency curve always increases.

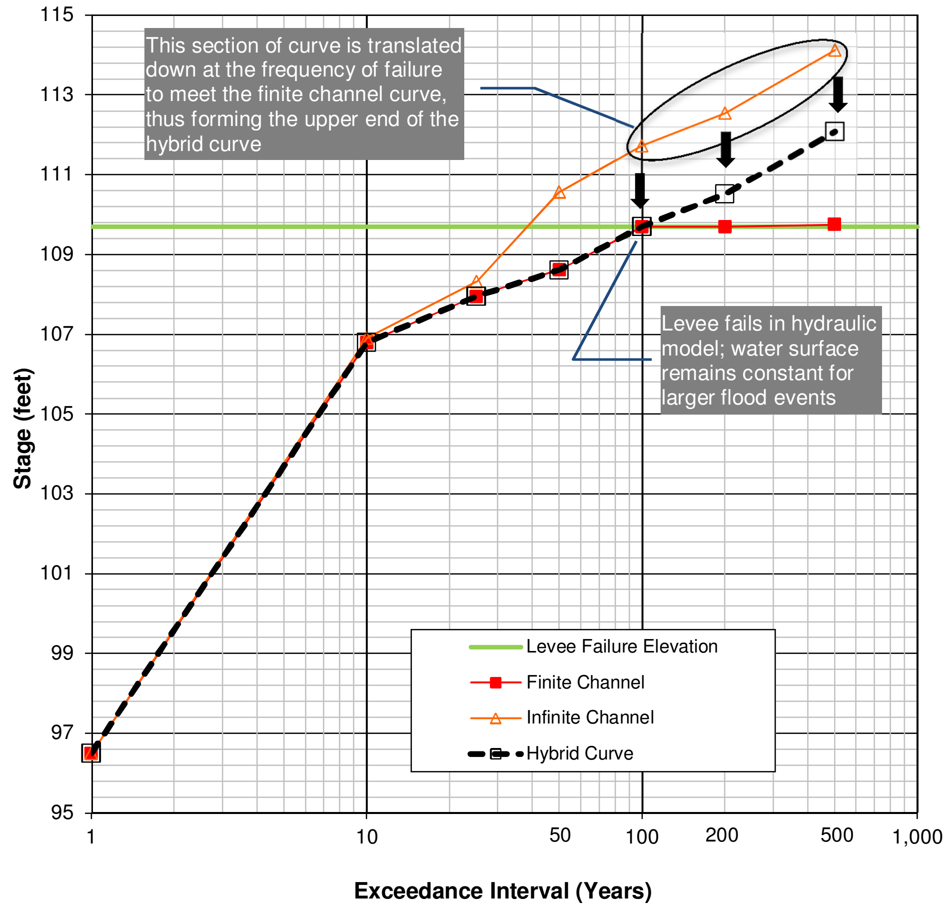

Figure 3-4. Example of Hybrid Stage-Frequency Curve

UNET was used to simulate in-channel flow rates and stages, and flows leaving river channels through breaches and entering the floodplain under different levee failure scenarios based on levee performance curves described in the following section. In-channel hydraulic information from UNET was used to develop a hybrid stage-frequency curve at the index point of each damage area. Figure 3-4 shows an example of a hybrid stage-frequency curve for an index point of a damage area. Details of the methodology to develop hybrid stage-frequency curves are described in the Comprehensive Study Technical Studies Documentation, Appendix E (USACE, 2002b).

3.6.2 Levee Performance Curve

Levee performance curves establish geotechnical relationships between river water stage and the probability that a levee segment will fail or breach (water from the waterside of the levee flows in an uncontrolled manner to the landside of the levee) at that stage. Under the ULE Project, levee performance curves were developed for levees (subdivided into reaches ranging in length from 1,000 to 3,000 feet) protecting populations of 10,000 or more people through (1) about 400 miles of SPFC levees, and (2) appurtenant non-SPFC levees. The NULE Project developed levee performance curves for levees (in 2- to 25-mile-long segments) protecting populations of fewer than 10,000 people (see Attachment 8E: System/Levee Performance for details).

During curve development, four levee failure modes were considered: steady-state under-seepage, steady-state through-seepage, steady-state landside stability, and erosion. Past flood information, field data, and laboratory geotechnical data were used to calculate or validate the levee performance curves. Note that, although an earthquake could cause damage resulting in a levee to breach, levee performance curves from the NULE and ULE projects did not consider the potential risk from seismic activities on levee breach.

Levee failure conditions for each approach are described in Attachment 8E: System/Levee Performance for the Sacramento River and San Joaquin river basins and Attachment 8C: Riverine Channel Evaluations for the Stockton area. Riverine hydraulic results (Attachment 8C: Riverine Channel Evaluations) that account for the likely performance of upstream levees were used to generate hybrid stage-frequency curves as inputs to the CVFPP HEC-FDA as described above.

3.6.3 Flood Depth Grid

A key input to HEC-FDA is a flood depth grid for each floodplain for various flood events. For each damage area, flood depth information was overlaid on the geospatial structure and crop inventory to estimate the total structure and crop damages under different flood events and thus develop the stage-damage relationship. (Development of flood depth grid information for the Stockton area is described in detail in Attachment 8C: Riverine Channel Evaluations.) This section describes the derivation of flood depth information from the Comprehensive Study FLO-2D outputs for the Sacramento and San Joaquin river basins. Simulated maximum floodplain water depths for the Sacramento and the San Joaquin river basins in the Comprehensive Study are shown in Figures 3-5 and 3-6, respectively.

Under the 2002 Comprehensive Study, USACE developed a set of levee performance curves for the No Project condition UNET simulation. No Project condition UNET overbank flow results were then used in FLO-2D floodplain models to generate flood depth grids for the 10-, 50-, 100-, 200-, and 500-year floods.

Under the CVFPP, a new set of levee performance curves (see Attachment 8E: System/Levee Performance) and other assumptions were developed and incorporated into the UNET models to represent the different approaches. New flood depth grids for the No Project condition, as well as for the four approaches, were derived from the Comprehensive Study FLO-2D outputs as described below.

The interior floodplain depth is a combination of three factors: 1) the levee breach location; 2) when the levee breaks in relation to the stage in the river; and 3) the period of time during which floodwaters enter the floodplain through the levee breach.[4] Assumptions (e.g., new levee performance curves) made in the CVFPP result in differences between the factors described above as used in the CVFPP and the Comprehensive Study. As a result, the original Comprehensive Study interior-exterior stage relationships (i.e., the relationship between water depth in the floodplain and water stage in the river) could not be used in the CVFPP.

It was therefore necessary to derive new interior-exterior stage relationships based on the assumption that the total volume of water entering the floodplain, and the resulting interior stage, is proportional only to the exterior (river) stage and not the physical location, exceedence probability, or duration of the levee breach. By comparing a CVFPP exterior stage with a Comprehensive Study exterior stage at an index point, a new interior floodplain depth can be derived for any given hydraulic model run in the CVFPP. The new interior floodplain depth and associated exterior stage are applied as FDA inputs for that particular hydraulic model run.

A land parcel in Damage Area SJ14 was selected as an example to illustrate the derivation process. First, interior water depth for the land parcel and a given flood AEP was taken from the Comprehensive Study FLO-2D No Project flood depth grid. Next, the UNET exterior (in-channel) water stage at the index point corresponding to the parcel was extracted from the Comprehensive Study UNET runs for all flood AEPs. The data points were then plotted (see Comprehensive Study Baseline data in Table 3-1 and Figure 3-7) to develop a Comprehensive Study interior-exterior stage curve.

[4] In UNET, levee breaches are simulated using simple failure mode. The simple failure method, identified by the SF record, uses a simple spillway concept whereby the volume of available storage multiplied by a linear routing factor gives flow through the breach. This simple method, often used in cases where the details of a breach are unknown, does not simulate the erosion of material from the breach, but assumes a maximum breach length. This method acknowledges that flow into the storage area is proportional to available storage; thus, flow is greatest at the onset of the breach and decreases as the available floodplain storage decreases.

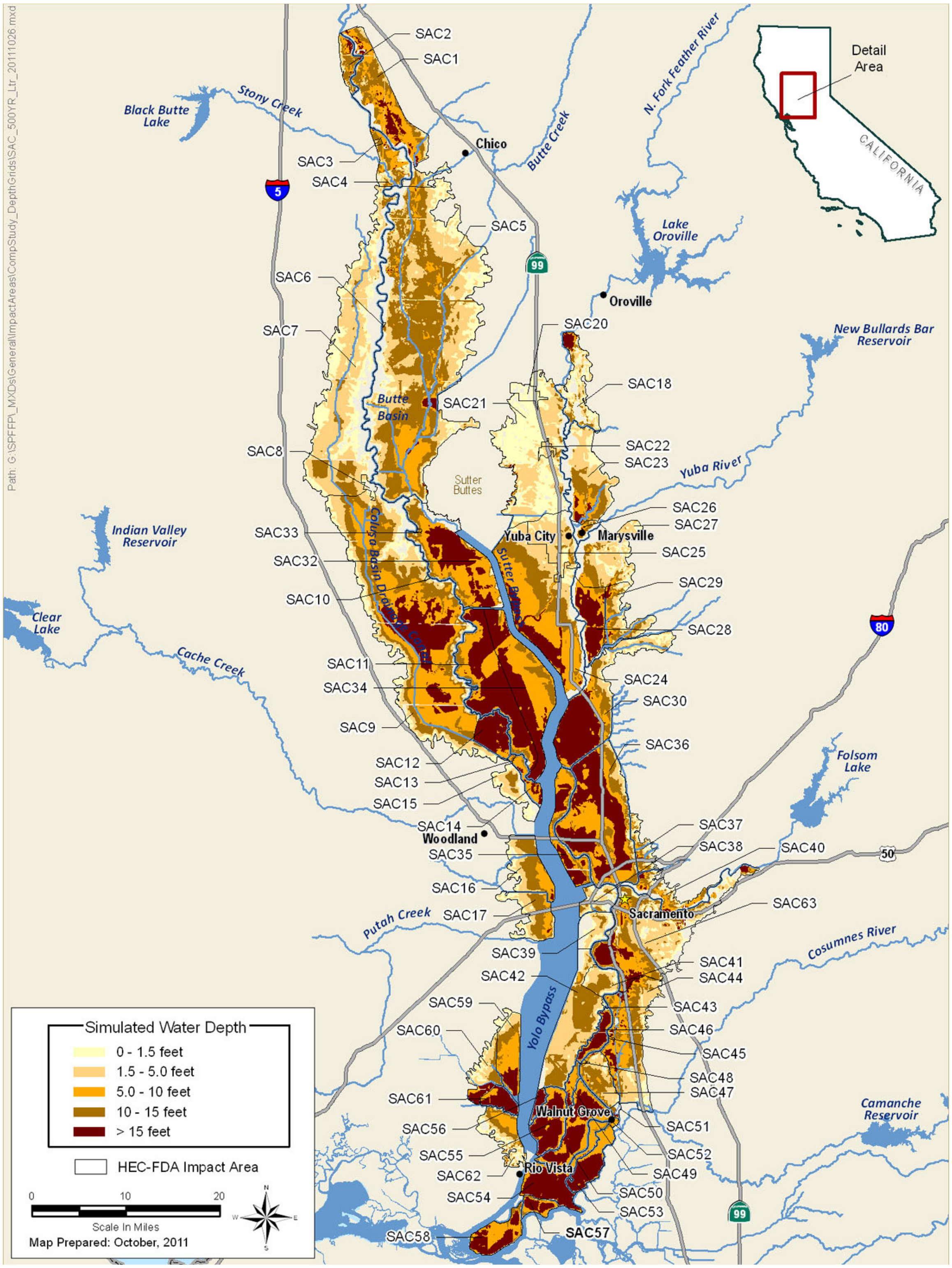

Figure 3-5. Simulated Maximum Water Depths for Sacramento River Basin in Comprehensive Study

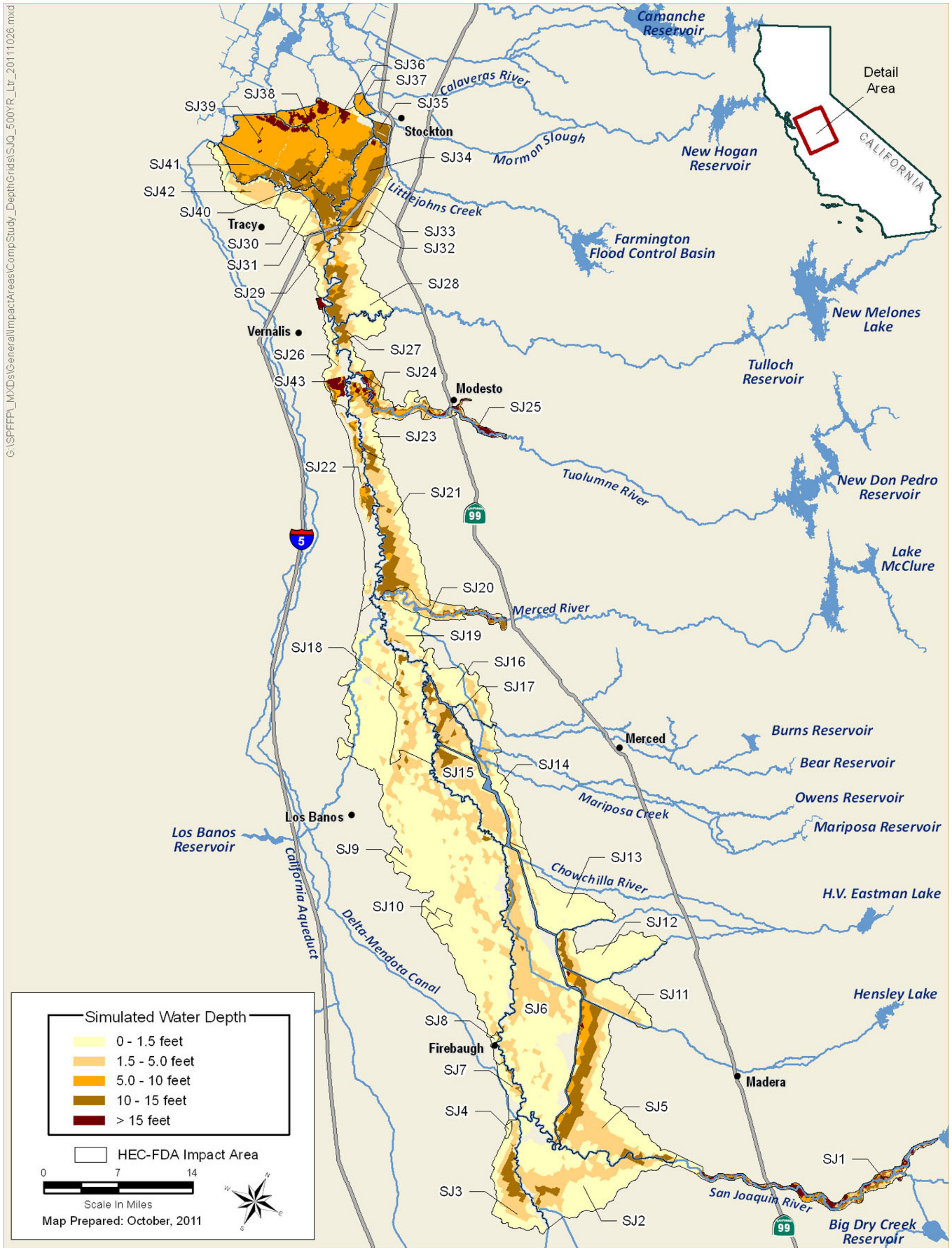

Figure 3-6. Simulated Maximum Water Depths for San Joaquin River Basin in Comprehensive Study

A new exterior stage-frequency curve at the SJ14 index point was developed from UNET for the CVFPP (see CVFPP No Project condition in Table 3-1). Using the original interior-exterior stage-frequency relationship taken from Comprehensive Study data give the curve shown in Figure 3-7. Interior water depths at the parcel related to the new CVFPP stages at the SJ14 index point can be identified through interpolation (extrapolation in some cases), as shown by the red dots in Figure 3-8 for each exterior (river) stage. The interior water depths at the parcel for the CVFPP No Project condition were taken from Figure 3-8, as shown in Table 3-1. The interior-exterior curve was extended down to the interior toe of the levee because when the maximum exterior water stage is below the interior levee toe elevation, levee failure probability is assumed to be zero, and the interior grid is dry (zero water depth). The approach described above was repeated to develop new flood depth stages for all parcels in each of the damage areas.

Table 3-1. Interior and Exterior Water Stage Data for SJ14 Index Point and Parcel

	AEP (percent)				
	10	**2**	**1**	**.5**	**.2**
Comprehensive Study Baseline					
SJ14 Index Point River Stage (feet, from UNET)	107.21	108.27	109.61	110.33	110.58
Water Depth at a parcel (feet, from FLO-2D)	0.00	2.68	4.82	5.20	5.44
CVFPP No Project					
SJ14 Index Point River Stage (feet; from UNET)	107.31	107.44	107.46	107.56	108.88
Water Depth at a parcel (feet; from interpolation)	0.26	0.58	0.62	0.89	3.65

Key;
AEP = annual exceedence probability
APN = Assessor Parcel Number
Comprehensive Study = USACE 2002a, Sacramento and San Joaquin River Basins Comprehensive Study
CVFPP = Central Valley Flood Protection Plan

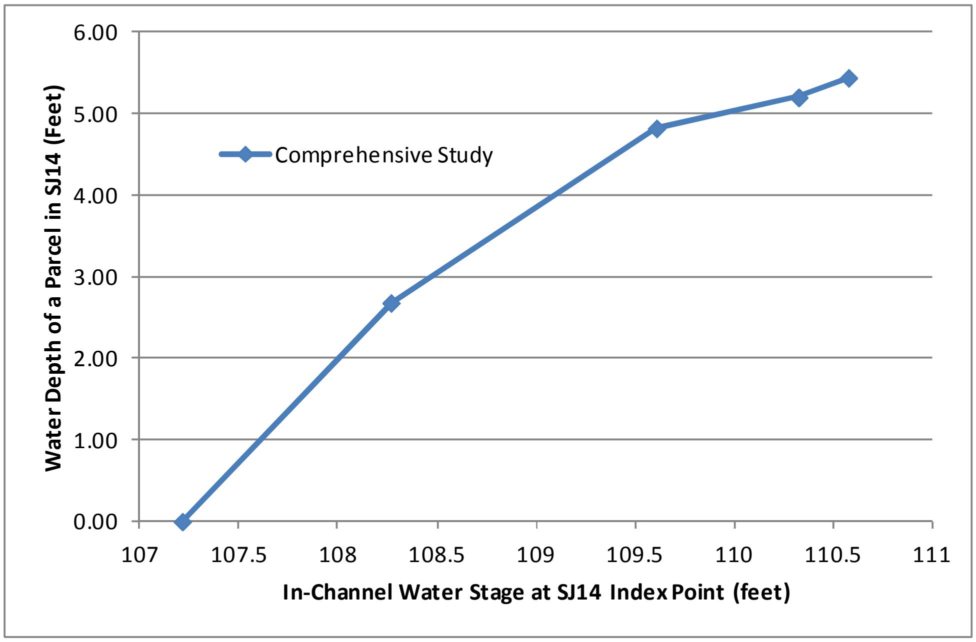

Figure 3-7. Interior-Exterior Stage Curve from Comprehensive Study for a Parcel in Damage Area SJ14

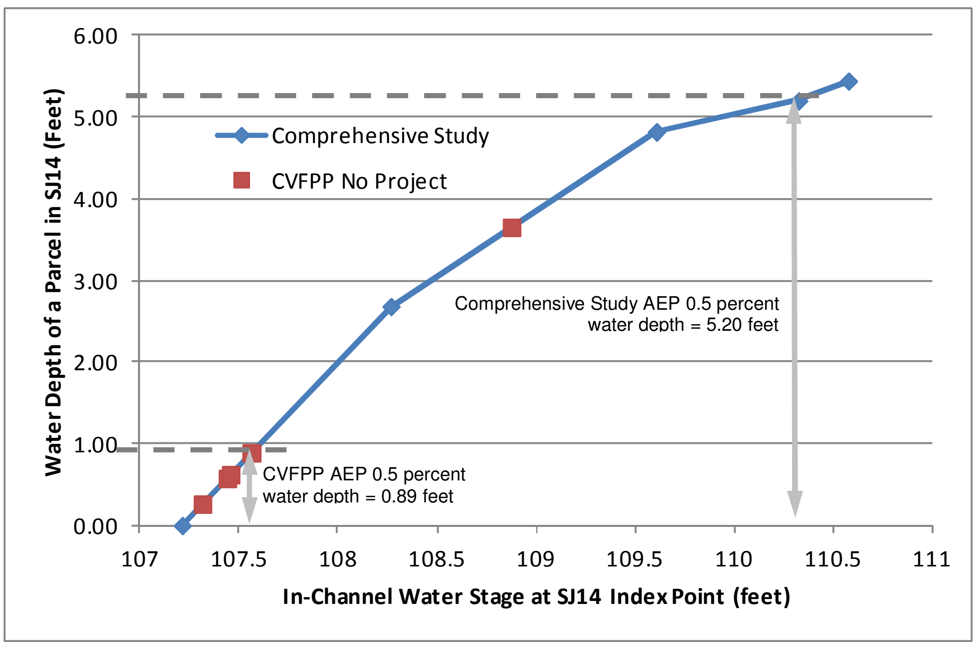

Figure 3-8. Interpolated Interior Water Depth Based on Interior-Exterior Curve for a Parcel in Damage Area SJ14 and New CVFPP No Project Exterior Water Stages

3.7 Structure Inventory Development

Development of a structure inventory is an integral step in the economic flood damage analysis. This section describes the context and methodology for the structure inventory. In general, the following steps were taken to complete the economic flood damage analysis:

- **Step 1** – Develop a structure inventory by conducting a reconnaissance-level field survey for areas inside the CVFPP HEC-FDA damage areas in the Sacramento and San Joaquin river basins and the Stockton area.

- **Step 2** – Populate missing data based on existing parcel data and survey results.

- **Step 3** – Identify building costs per square foot, and calculate the structure and contents cost for each structure inside the CVFPP HEC-FDA damage areas of the Sacramento and San Joaquin river basins.

- **Step 4** – Calculate total damages (summation of structure and contents damages) under different floods in HEC-FDA based on the derived depth grids from the Comprehensive Study FLO-2D outputs and depth-damage functions to develop the stage-damage curve for each damage area.

- **Step 5** – Perform risk analysis in HEC-FDA for each damage area.

This section describes Steps 1 through 3 in detail.

3.7.1 Inventory Development Overview

Developing the structure inventory for the CVFPP damage areas in the Sacramento and San Joaquin river basins was a major activity of the economic flood damage analysis. The 2010 June parcel data compiled by ParcelQuest[5] were used as the basis for developing the structure inventory needed to complete the structure economic flood damage analysis. Reconnaissance-level field surveys were conducted to obtain the following information to support development of structure values and subsequent economic flood damage analyses in HEC-FDA:

[5] ParcelQuest is a company that operates in the State of California and provides parcel and map data in digital format.

- **Structure categories** – Public, industrial, commercial, urban[6] residential, and rural residential
- **Occupancy type** – A subcategory of the structure category with additional landuse information (see Tables 3-2 and 3-3)
- **Number of buildings** and corresponding **number of stories** (with or without a basement) in a parcel
- **Number of units per residential parcel**
- **Construction class for a building** – Class A for a steel-reinforced frame, B for a reinforced-concrete frame, C for a masonry or concrete frame, D for a wood frame, and S for a metal frame per the Marshall Valuation Service construction indicators for each occupancy type (M&S, 2010)
- **Construction quality for the building** – “Cheap/minimal, ” “low cost,” “average,” “good,” and “excellent” per descriptions in the Marshall Valuation Service (M&S, 2010)
- **Depreciation percentage** – Loss in value compared to its new-cost estimate because of (1) physical depreciation, (2) functional/technical obsolescence, and (3) external, locational, or economic obsolescence per guidance from the Marshall Valuation Service (M&S, 2010)
- **Foundation height** – Estimated difference between the average ground elevation of a parcel and the first floor of a structure, as observed from the survey, representing the first point where water could enter and damage the contents of the structure

Under the attribute “County Use” in the ParcelQuest data is a code that varies by county, but which represents the landuse condition of a parcel. For each parcel, this “County Use” code was matched to one of five structure categories (commercial, industrial, public, urban residential, and rural residential) and an occupancy type from Table 3-3 was then assigned in accordance with the landuse description provided by the specific county. Appendix A summarizes lookup tables for counties that match the “County Use” code to structure category and occupancy types of Table 3-2. Table 3-3 is an example excerpt from the lookup table for Butte County.

[6] Urban area definition is from the ESRI dataset dated on January 2010. These data were originally extracted from the U.S. Bureau of the Census TIGER/Line 2000 database.

3.7.2 Field Survey

Reconnaissance-level field structure inventory surveys were conducted in 14 counties of the Central Valley from August through early October 2010 and in April 2011 (see Table 3-4). The field surveys collected data to support the development of structure values and subsequent economic flood damage analyses in HEC-FDA. All counties inside the HEC-FDA damage areas were surveyed.

The goals of the survey were as follows:

- Determine/verify the percentage of empty parcels
- Determine structure characteristics (e.g., foundation height and depreciation percentage)
- Verify structure characteristics (e.g., building class, quality class, occupancy types, number of stories)

For each county, random parcel samples were selected from the ParcelQuest database, as follows:

- **Step 1** – Identify parcels inside the CVFPP HEC-FDA damage areas.
- **Step 2** – Assign a random number to all parcels from Step 1.
- **Step 3** – Identify parcels with land uses that belong to the five structure categories from Table 3-2.
- **Step 4** – Sort the parcels based on the five survey categories.
- **Step 5** – For each structure category, rank the parcels in ascending order based on the random number assigned in Step 2.
- **Step 6** – For each survey category, assign a survey number from 1 to 30 to the first 30 parcels. These 30 samples are used provide statistical information on the empty parcel rate and structure characteristics if a building(s) exists on a parcel.
- **Step 7** – Assign a survey number to the parcel next in the sorted list until there are 30 parcels with structures (based on aerial photos). Samples with a survey number greater than 30 provide statistical information on structure characteristics (e.g., foundation height, depreciation percentage, quality class).

Table 3-2. Structure Category and Corresponding Occupancy Type as Defined by CVFPP

Structure Category	Occupancy Type	Occupancy Type Description
Commercial	C-RET	Retail
	C-DEAL	Full-Service Auto Dealership
	C-FURN	Furniture Store
	C-HOS	Hospital
	C-AUTO	Auto Sales
	C-HOTEL	Hotel
	C-FOOD	Food-Retail
	C-RESTFF	Fast Food Restaurant
	C-GROC	Grocery Store
	C-MED	Medical
	C-OFF	Office
	C-SHOP	Shopping Center
	C-REST	Restaurants
	C-SERV	Auto Service
	ELDER	Eldercare
	MISC-COM	Miscellaneous Commercial
Industrial	I-LT	Light Industrial
	I-HV	Heavy Manufacturer
	I-WH	Warehouse
	MISC-IND	Miscellaneous Industrial
Public	P-CH	Church
	P-GOV	Government Building (including police stations, airports, ports, jails, judicial buildings)
	P-REC	Recreation/Assembly
	P-SCH	Schools
	FIRE	Fire Station
	MISC-PUB	Miscellaneous Public
Urban Residential	SFR	Single-Family Residential
	MISC-RES	Miscellaneous Residential
	MFR	Multifamily Residential
	MH	Mobile Home
	FARM	Farm Buildings, Including Primary Residential
	MISC-FARM	Miscellaneous Farm

Table 3-2. Structure Category and Corresponding Occupancy Type as Defined by CVFPP (contd.)

Structure Category	Occupancy Type	Occupancy Type Description
Rural Residential	SFR	Single-Family Residential
	MISC-RES	Miscellaneous Residential
	MFR	Multifamily Residential
	MH	Mobile Home Single/Double
	FARM	Farm Buildings, including Primary Residential
	MISC-FARM	Miscellaneous Farm
Occupancy Type Not Surveyed	CROP	Crops
	MISC-AG	Miscellaneous Agriculture
	MISC	Miscellaneous

Key:
CVFPP = Central Valley Flood Protection Plan

The structure inventory applied to the Sacramento River Basin HEC-FDA is provided in Table 3-5, the San Joaquin River Basin HEC-FDA in Table 3-6, and the Stockton area in Table 3-7. In the Sacramento River Basin, SAC63 (Sacramento South) has the greatest total number of structures (121,733), as well as for all structure categories. For SAC25 (Yuba City) and SAC36 (Natomas) total buildings total more than 20,000. In the San Joaquin River Basin, SJ34 (French Camp) has the greatest number of total structures (6,161), followed by SJ33 (Lathrop) and SJ25 (Modesto) with 5,106 and 3,011 buildings total, respectively. For the Stockton area, the total number of buildings is 65,281; the majority of the structures are in STK10, STK07, and STK08.

Because each parcel needs to have a value for all required structure information, @RISK (an add-in to Microsoft Excel from Palisade Corporation that performs risk analysis using Monte Carlo simulation) was used. The statistical distributions (e.g., normal, uniform) from survey results and parcel records were developed and missing parcel values were then populated using the @RISK software application as described below.

Table 3-3. Example Excerpt of Butte County "County Use" Code Lookup Table

County Use	Description	Structure Category	Occupancy Type	Occupancy Description
AY	Mixed Agricultural	CROP	CROP	Crops
AZ	Miscellaneous	CROP	CROP	Crops
CC	Service (garage, shop, mini-mart)	COM	C-SERV	Commercial Service-Auto
CI	Institutional (church, hospital)	COM	C-HOS	Hospital
CP	Commercial/Professional (bank, etc.)	COM	C-RET	Commercial Retail
CR	Residential (motel, hotel, mobile home park)	COM	C-HOTEL	Hotel
CS	Commercial Retail (stores, etc.)	COM	C-RET	Commercial Retail
CT	Recreational (theatre, golf, etc.)	PUB	P-REC	Public Recreation/Asse mbly
CU	Utilities	PUB	P-GOV	Public Government Building
CZ	Miscellaneous Commercial	COM	MISC-COM	Miscellaneous Commercial
IM	Manufacturing	IND	I-HV	Industrial Heavy Manufacture
IW	Warehouse/Wholesale Operations	IND	I-WH	Industrial Warehouse
IZ	Miscellaneous Industrial	IND	MISC-IND	Miscellaneous Industrial
R2	Duplex	RES	MFR	Multifamily Residential
R3	Triplex	RES	MFR	Multifamily Residential
R4	Fourplex	RES	MFR	Multifamily Residential
R7	Multiple Residential, not matching	RES	MFR	Multifamily Residential
RA	Five or more units – apartments	RES	MFR	Multifamily Residential

Source: Cowdin pers. Comm., 2010.
Key:
COM = Commercial
IND = Industrial
PUB = Public
RES = Residential

Table 3-4. Counties Where Structure Field Surveys Were Conducted

Sacramento River Basin	San Joaquin River Basin
Butte	Fresno
Colusa	Madera
Glenn	Merced
Sacramento	San Joaquin
Solano	Stanislaus
Sutter	
Tehama	
Yolo	
Yuba	

3.7.3 Populating Missing Parcel Data

For some parcels, structure information from ParcelQuest was incomplete; the missing data include the following:

- Building area
- Structure class
- Structure quality class
- Number of stories
- Depreciation percentage
- Foundation height

Building Area

- **Step 1** – Sort the parcel data in descending order based on building area records from ParcelQuest.
- **Step 2** – For records with values larger than zero (excluding the top and bottom 5 percent samples), identify the best-fit distribution using @RISK software based on Chi-squared statistics (between normal and log-normal).
- **Step 3** – Populate building area values based on the identified distribution for parcels with zero value from the records. Discount the populated areas based on the vacancy rate identified from the first 30 survey samples.
- **Step 4** – Rank the parcels with zero building area in an ascending order based on the random number originally used to select the parcels for field survey.

Table 3-5. Structure Inventory for Sacramento River Basin

Damage Area	Description	COM	IND	PUB	RES	Total
SAC01	Woodson Bridge East	9	3	0	120	132
SAC02	Woodson Bridge West	2	1	0	57	60
SAC03	Hamilton City	28	0	10	564	602
SAC04	Capay	1	1	4	18	24
SAC05	Butte Basin	6	3	49	213	271
SAC06	Butte City	8	1	0	37	46
SAC07	Colusa Basin North	22	6	129	510	667
SAC08	Colusa	187	8	75	1,768	2,038
SAC09	Colusa Basin South	20	29	73	381	503
SAC10	Grimes	8	0	10	91	109
SAC11	RD 1500 West	2	8	22	58	90
SAC12	Sycamore Slough	0	0	0	1	1
SAC13	Knight's Landing	32	5	8	276	321
SAC14	Ridge Cut (North)	0	0	1	1	2
SAC15	Ridge Cut (South)	0	0	0	5	5
SAC16	RD 2035	2	5	6	38	51
SAC17	East of Davis	8	5	15	706	734
SAC18	Upper Honcut	10	1	0	167	178
SAC20	Gridley	194	22	3	2,295	2,514
SAC21	Sutter Buttes East	26	19	43	1,334	1,422
SAC22	Live Oak	57	8	82	2,082	2,229
SAC23	Lower Honcut	3	15	37	403	458
SAC24	Levee Dist. No.1	26	19	77	1,316	1,438
SAC25	Yuba City	830	312	288	19,073	20,503
SAC26	Marysville	326	56	439	3,257	4,078
SAC27	Linda-Olivehurst	176	76	269	8,303	8,824
SAC28	RD 784	28	7	86	2,565	2,686
SAC29	Best Slough	2	2	17	92	113
SAC30	RD 1001	13	7	36	260	316
SAC32	RD 70-1660	0	5	27	102	134
SAC33	Meridian	6	4	8	110	128
SAC34	RD 1500 East	6	7	16	77	106
SAC35	Elkhorn	2	0	5	23	30
SAC36	Natomas	405	194	935	24,612	26,146
SAC37	Rio Linda	60	108	370	6,753	7,291
SAC38	West Sacramento	524	476	84	6,128	7,212
SAC39	RD 900	45	54	35	7,258	7,392

Table 3-5. Structure Inventory for Sacramento River Basin (contd.)

Damage Area	Description	COM	IND	PUB	RES	Total
SAC40	Sacramento North	966	300	609	12,705	14,580
SAC41	RD 302	0	0	2	26	28
SAC42	RD 999	2	4	2	102	110
SAC43	Clarksburg	22	6	3	130	161
SAC44	Stone Lake	102	14	480	15,686	16,282
SAC45	Hood	5	8	15	76	104
SAC46	Merritt Island	0	0	0	33	33
SAC47	RD 551	0	3	11	50	64
SAC48	Courtland	11	4	17	78	110
SAC49	Sutter Island	0	0	2	9	11
SAC50	Grand Island	11	2	27	312	352
SAC51	Locke	20	3	26	40	89
SAC52	Walnut Grove	44	9	28	131	212
SAC53	Tyler Island	2	5	4	3	14
SAC54	Andrus Island	73	20	117	482	692
SAC55	Ryer Island	0	0	2	90	92
SAC56	Prospect Island	0	0	4	0	4
SAC57	Twitchell Island	0	0	17	3	20
SAC58	Sherman Island	1	0	70	41	112
SAC59	Moore	0	0	1	58	59
SAC60	Cache Slough	0	3	2	58	63
SAC61	Hastings	0	0	0	11	11
SAC62	Lindsey Slough	8	10	13	2,868	2,899
SAC63	Sacramento South	3,953	1,542	3,554	112,684	121,733
Total		**8,294**	**3,400**	**8,265**	**236,730**	**256,689**

Key:
COM = commercial
IND = industrial
PUB = public
RD = reclamation district
RES = residential

Table 3-6. Structure Inventory for San Joaquin River Basin

Damage Area	Description	COM	IND	PUB	RES	Total
SJ01	Fresno	21	8	9	323	361
SJ02	Fresno Slough East	0	1	6	100	107
SJ03	Fresno Slough West	2	0	0	40	42
SJ04	Mendota	7	4	3	318	332
SJ05	Chowchilla Bypass	0	0	0	66	66
SJ06	Lone Willow Slough	0	0	0	194	194
SJ07	Mendota North	0	0	0	6	6
SJ08	Firebaugh	119	19	14	1,172	1,324
SJ09	Salt Slough	39	20	364	1,795	2,218
SJ10	Dos Palos	113	11	104	1,811	2,039
SJ11	Fresno River	0	0	0	10	10
SJ12	Berenda Slough	1	3	0	203	207
SJ13	Ash Slough	1	3	0	104	108
SJ14	Sandy Mush	0	0	13	28	41
SJ15	Turner Island	0	0	0	50	50
SJ16	Bear Creek	1	3	12	89	105
SJ17	Deep Slough	0	0	10	14	24
SJ18	West Bear Creek	0	0	76	0	76
SJ19	Fremont Ford	1	16	16	314	347
SJ20	Merced River	0	11	15	208	234
SJ21	Merced River North	1	20	20	398	439
SJ22	Orestimba	4	1	24	377	406
SJ23	Tuolumne South	0	0	16	87	103
SJ24	Tuolumne River	12	1	9	731	753
SJ25	Modesto	96	71	126	2,718	3,011
SJ26	Three Amigos	3	0	12	44	59
SJ27	Stanislaus South	0	0	31	71	102
SJ28	Stanislaus North	7	4	72	942	1,025
SJ29	Banta Carbona	1	4	16	435	456
SJ30	Paradise Cut	3	6	12	186	207
SJ31	Stewart Tract	3	1	7	6	17
SJ32	East Lathrop	16	78	13	64	171
SJ33	Lathrop/Sharpe	55	72	141	4,838	5,106
SJ34	French Camp	29	47	49	6,036	6,161
SJ35	Moss Tract	27	85	27	2,695	2,834
SJ36	Roberts Island	0	1	13	143	157
SJ37	Rough and Ready Island	0	3	5	0	8

Table 3-6. Structure Inventory for San Joaquin River Basin (contd.)

Damage Area	Description	COM	IND	PUB	RES	Total
SJ38	Drexler Tract	2	1	2	20	25
SJ39	Union Island	0	2	4	54	60
SJ40	Union Island Toe	0	0	0	8	8
SJ41	Fabian Tract	2	0	6	20	28
SJ42	RD 1007	33	18	54	265	370
SJ43	Grayson	2	0	6	235	243
Total		**601**	**514**	**1307**	**27,218**	**29,640**

Key:
COM = commercial
IND = industrial
PUB = public
RD = reclamation district
RES = residential

Table 3-7. Structure Inventory for Stockton Area

Damage Area	Description	COM	IND	PUB	RES	Total
STK01	Lower Roberts Island	0	1	21	32	54
STK06	Stockton East	19	69	18	95	201
STK07	Calaveras River	729	14	259	13,406	14,408
STK08	Bear Creek South	63	10	139	10,055	10,267
STK09	Bear Creek North	39	14	220	5,097	5,370
STK10	Central Stockton	1,694	968	853	31,466	34,981
Total		**2,544**	**1,076**	**1,510**	**60,151**	**65,281**

Key:
COM = commercial
IND = industrial
PUB = public
RES = residential

- **Step 5** – Assign the discounted populated areas to these parcels.
- **Step 6** – For nonresidential parcels, discount building area to two stories if the building is three stories or taller (e.g., multiplying a factor of two-thirds for a three-story building) because depth-damage functions for two stories were applied to these buildings.

Structure Class

In the ParcelQuest database, some parcels had an entry for structure class; however, for most of the counties, such entries do not match the definitions from Marshall & Swift. Also, some of the parcels did not have an entry for building class. For each county, @RISK was used to populate all parcels that had invalid and missing structure class entries, as follows:

- **Step 1** – Add or modify the structure class entry for parcels where the survey was conducted.
- **Step 2** – Use survey results and valid ParcelQuest records (i.e., entries consistent with Marshall & Swift) to identify the distribution.
- **Step 3** – Use @RISK software to populate discrete entries for parcels without a structure class (based on the random number, originally used to select the parcels for field survey, in an ascending order). The discrete probability is based on a normal distribution.[7]
- **Step 4** – Rank the parcels with no structure class entry in ascending order based on the random number originally used to select the parcels for field survey.
- **Step 5** – Assign the populated structure class to these parcels.

Structure Quality Class

In the ParcelQuest database, some parcels had an entry for the structure quality class in numerical values (from zero to 10) that did not match definitions from Marshall & Swift. Also, some of the parcels did not have an entry for structure quality class. For each county, @RISK was used to populate parcels that were missing structure quality class entries, as follows:

- **Step 1** – For surveyed parcels with a ParcelQuest entry for structure quality class, correlate the structure quality in the Marshall & Swift scale to the ParcelQuest numerical entry (e.g., for Butte County, “cheap/minimal” for zero through 2, “low cost” for 2.5 through 3.5, “average” for 4 through 7.5, “good” for 8 through 9, and “excellent” for 9.5 and 10).
- **Step 2** – For parcels with a numerical entry for structure quality class, identify the corresponding Marshall & Swift quality.
- **Step 3** – Use the survey results and the translated Marshall & Swift quality to identify the distribution.
- **Step 4** – Use @RISK software to populate discrete entries for parcels without a quality class (based on the random number, originally used to select the parcels for field survey, in an ascending order). The discrete probability is based on a normal distribution.

[7] All mobile homes were assigned a “D” building class to accurately reflect mobile home construction.

- **Step 5** – Rank the parcels without a quality entry in an ascending order based on the random number originally used to select the parcels for field survey.

- **Step 6** – Assign the populated structure quality class to these parcels.

Number of Stories

In the ParcelQuest database, some of the parcels do not have an entry for the number of stories. For each county, @RISK was used to populate the parcels that were missing number of stories data, as follows:

- **Step 1** – Add or modify the number of stories entries for parcels where the survey was conducted.

- **Step 2** – Use the survey results and available ParcelQuest records to identify the distribution.

- **Step 3** – Use @RISK software to populate discrete entries for parcels without the stories class (based on the random number in an ascending order). The discrete probability is based on a normal distribution.

- **Step 4** – Rank the parcels without the number of stories entry in an ascending order based on the random number, originally used to select the parcels for field survey.

- **Step 5** – Assign the populated number of stories to these parcels.

Depreciation Percentage

In the ParcelQuest database, no parcels have an attribute for depreciation. For each county, @RISK was used to populate the depreciation attribute for parcels for which no survey was conducted as follows:

- **Step 1** – Add depreciation entry for parcels for which a survey was conducted.

- **Step 2** – Use survey values to identify the distribution with an increment of 5 percent.

- **Step 3** – Use @RISK software to populate discrete entries for parcels without depreciation (based on the random number, originally used to select the parcels for field survey, in an ascending order). The discrete probability is based on a normal distribution.

- **Step 4** – Rank parcels without a depreciation entry in an ascending order based on the random number originally used to select the parcels for field survey.
- **Step 5** – Assign the populated depreciation to these parcels.

Foundation Height

In the ParcelQuest database, there is no attribute for foundation height for all parcels. For each county, @RISK was used to populate the foundation height for parcels for which no survey was conducted as follows:

- **Step 1** – Add a foundation height entry for parcels for which a survey was conducted.
- **Step 2** – Use the survey values to identify the distribution with an increment of 0.5 feet.
- **Step 3** – Use @RISK software to populate discrete entries for parcels without a foundation height (based on the random number, originally used to select the parcels for field survey, in an ascending order). The discrete probability is based on a normal distribution.
- **Step 4** – Rank parcels without a foundation height entry in an ascending order based on the random number originally used to select the parcels for field survey.
- **Step 5** – Assign the populated foundation height to these parcels.

3.7.4 Building Cost per Square Foot

For the CVFPP economic evaluation, the cost per square foot of a new building was identified based on a combination of its occupancy type, construction class, and structure quality, and the October 2010 price level of the cost per square foot. This price level was developed from the third quarter, October 2010, edition of Marshall & Swift and was adjusted based on the current cost multiplier and local multiplier.[8] Appendix B documents the costs per square foot for all buildings applicable to the CVFPP analysis. Table 3-8 is an excerpt of the M&S table for the commercial retail occupancy type.

[8] Aggregate California local multiplier was used to bring prices to October 2010 levels in all impact areas because Marshall Valuation Service does not provide local multipliers for every locality within the CVFPP planning areas.

Table 3-8. Excerpt of Marshall & Swift Table for Commercial Retail Occupancy Type – Building Cost per Square Foot

Structure Class	Construction Quality				
	Excellent	Good	Average	Low Cost	Cheap/ Minimal
A	$147.44	$110.63	$87.06	$66.18	N/A
B	$144.68	$107.96	$84.60	$63.97	N/A
C	$122.02	$90.08	$68.44	$49.27	N/A
D	$118.63	$87.07	$65.84	$47.07	N/A
S	N/A	$85.05	$63.15	$44.22	N/A

Sources: M&S 2010a
Note: Expiration Date: April 2010
Key: N/A = not available

Since @Risk was used to populate data not available from the original ParcelQuest database, a combination of populated features might result in a structure that cannot be identified by Marshall & Swift. In such cases, unit cost for structures with features closest to the combination was used to represent the unit cost. For example, if populating data with @Risk resulted in an auto facility (commercial category) of Class A in construction and low cost in construction quality, such a structure cannot be identified in the Marshall Valuation Service. Therefore, the unit cost for an auto facility of Class A in construction and average in construction quality was used (Table 3-9) to represent an auto facility of Class A in construction and low cost in construction quality.

For each of the five structure categories, the cost-per-square-foot values for miscellaneous buildings were determined by taking the average cost per square foot of their respective categories in the entire river basin. For example, the cost per square foot for miscellaneous commercial buildings in Sacramento County was determined by taking the average cost per square foot of all commercial buildings in the Sacramento River Basin.

3.7.5 Estimate of Structure and Contents Value

After identifying the cost per square foot for new construction, the structure value was estimated by multiplying the per-square-foot cost by the total square footage of the building. The depreciated replacement value was calculated by deducting the depreciation percentage from the structure value as new.

The contents value inside of the structure was estimated in HEC-FDA as a function of the structure value, by multiplying the depreciated replacement value by the contents-to-structure ratio. These ratios were from the

USACE *American River Watershed Project, Folsom Dam Modifications and Folsom Dam Raise Project Final Economic Reevaluation Report* (USACE, 2008b). Because of the nature of the building usage, this contents-to-structure ratio varies with occupancy type, as shown in Table 3-10.

Table 3-9. Modified Cost per Square Foot for Commercial Auto Facility

Structure Class	Construction Quality				
	Excellent	Good	Average	Low Cost	Cheap/ Minimal
A	N/A	N/A	$70.38	$70.38*	N/A
B	N/A	N/A	$70.38	N/A	N/A
C	$92.93	$65.37	$47.31	$34.42	N/A
D	N/A	$56.85	$41.65	$30.68	N/A
S	N/A	$55.47	$40.10	$29.15	N/A

Sources: M&S 2010a
Notes:
* Number for Class A and average construction quality was used to represent this category because a structure of this category cannot be identified in Marshall Valuation Service. Expiration Date: January 2012
Key:
N/A = Not available

The structure and contents values of buildings in the Sacramento River Basin are shown in Tables 3-11 and 3-12, respectively. In the Sacramento River Basin, SAC63 (Sacramento South) has the highest structure values ($15.1 billion) and contents values ($7.7 billion), followed by SAC36 (Natomas) and SAC25 (Yuba City). Total structure and contents values in the Sacramento River Basin are $33.2 billion and $17.2 billion, respectively.

The structure and contents values of structures in the San Joaquin River Basin are shown in Tables 3-13 and 3-14, respectively. In the San Joaquin River Basin, SJ34 (French Camp) has the highest structure values ($778 million) and contents values ($395 million), followed by SJ33 (Lathrop/Sharpe) with $667 million in structure values and $341 million in contents values. Total structure and contents values in the San Joaquin River Basin are $2.9 billion and $1.6 billion, respectively.

The structure and contents values of structures in the Stockton area are included in Tables 3-13 and 3-14, respectively. In the Stockton area, STK10 has the highest structure values ($3.1 billion) and contents values ($1.6 billion). Total structure and contents values in the Stockton area are $7.0 billion and $3.6 billion, respectively.

3.7.6 Structure and Contents Damage Function

To determine structure and contents damages under different flood depths, HEC-FDA selects a damage function based on the number of stories and occupancy type of a building. The damage percent is then identified based on the water depth above the foundation of the building (positive represents a water depth higher than the foundation and vice versa). Figure 3-9 is an example of the structure damage functions for a one-story public recreational building; the greater the water depth, the larger the percent of structure damage. The contents value of the building is calculated in a similar manner, but the damage function is used for structure contents. Appendix C documents the structure damage functions, as well as contents damage functions, for this CVFPP economic flood damage analysis. These damage functions are from the USACE *American River Watershed Project, Folsom Dam Modifications and Folsom Dam Raise Project Final Economic Reevaluation Report* (USACE, 2008b).

Table 3-10. Contents-to-Structure Ratio

Occupancy Type	Description	Ratio	Occupancy Type	Description	Ratio
C-RET1	Retail – one-story	51%	I-LT1	Light industrial – one-story	188%
C-RET2	Retail – two-story	47%	I-LT2	Light industrial – two-story	126%
C-DEAL1	Full service auto dealership - one-story	69%	I-HV1	Heavy manufacturer – one-story	31%
C-DEAL2	Full service auto dealership - two-story	69%	I-HV2	Heavy manufacturer – two-story	20%
C-FURN1	Furniture store – one-story	55%	I-WH1	Warehouse – one-story	89%
C-FURN2	Furniture store – two-story	36%	I-WH2	Warehouse – two-story	85%
C-HOS1	Hospital – one-story	92%	P-CH1	Church – one-story	20%
C-HOS2	Hospital – two-story	87%	P-CH2	Church – two-story	17%
C-AUTO1	Auto sales – one-story	62%	P-GOV1	Government building – one-story	35%
C-AUTO2	Auto sales – two-story	62%	P-GOV2	Government building – two-story	26%
C-HOTEL1	Hotel – one-story	69%	P-REC1	Recreation/assembly – one-story	132%
C-HOTEL2	Hotel – two-story	69%	P-REC2	Recreation/assembly – two-story	58%
C-FOOD1	Food-retail – one-story	42%	P-SCH1	School – one-story	38%
C-FOOD2	Food-retail – two-story	43%	P-SCH2	School – two-story	32%
C-RESTFF1	Fast food restaurant – one-story	42%	SFRB1	Single-family – one-story with basement	50%
C-RESTFF2	Fast food restaurant – two-story	42%	SFRB2	Single-family – two-story with basement	50%
C-GROC1	Grocery store – one-story	106%	SFRBS	Single-family split with basement	50%
C-GROC2	Grocery store – two-story	106%	SFR1	Single-family – one-story	50%
C-MED1	Medical – one-story	148%	SFR2	Single-family – two-story	50%
C-MED2	Medical – two-story	121%	SFRS	Single-family split	50%
C-OFF1	Office – one-story	34%	MFR1	Multi-family – one-story	50%
C-OFF2	Office – two-story	28%	MFR2	Multi-family – two-story	50%
C-SHOP1	Shopping center – one-story	67%	MH	Mobile Home	50%
C-SHOP2	Shopping center – two-story	54%	MISC-COM1	Miscellaneous commercial – one-story	*
C-REST1	Restaurant – one-story	134%	MISC-COM2	Miscellaneous commercial – two-story	*
C-REST2	Restaurant – two-story	118%	MISC-IND1	Miscellaneous industrial – one-Story	*

Table 3-10. Contents-to-Structure Ratio (contd.)

Occupancy Type	Description	Ratio	Occupancy Type	Description	Ratio
C-SERV1	Auto service – one-story	193%	MISC-IND2	Miscellaneous industrial – two-story	*
C-SERV2	Auto service – two-story	193%	MISC-PUB1	Miscellaneous public – one-story	*
ELDER1*	Miscellaneous commercial – one-story	*	MISC-PUB2	Miscellaneous public – two-story	*
ELDER2*	Miscellaneous commercial two-story	*	MISC-RES1	Miscellaneous residential – one-story	*
FIRE1	Government building – one-story	35%	MISC-RES2	Miscellaneous residential – two-story	*
FIRE2	Government building – two-story	26%			

Note:
*Structure and contents values for miscellaneous categories are calculated based on the distribution of occupancy types and therefore vary between each damage area.

Table 3-11. Structure Depreciated Replacement Values in 2010 October $1,000 – Sacramento River Basin

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SAC01	Woodson Bridge East	788	583	0	10,328	11,699
SAC02	Woodson Bridge West	616	157	0	4,089	4,862
SAC03	Hamilton City	6,757	0	4,033	33,539	44,330
SAC04	Capay	602	1,604	5,971	1,406	9,582
SAC05	Butte Basin	377	2,878	5,952	21,713	30,920
SAC06	Butte City	1,135	25	0	1,857	3,017
SAC07	Colusa Basin North	8,373	1,399	15,649	51,392	76,814
SAC08	Colusa	41,522	1,780	10,174	143,530	197,006
SAC09	Colusa Basin South	3,802	7,110	10,556	39,095	60,563
SAC10	Grimes	1,117	0	983	6,723	8,823
SAC11	RD 1500 West	1,259	654	4,090	7,118	13,120
SAC12	Sycamore Slough	0	0	0	131	131
SAC13	Knight's Landing	10,215	5,316	1,596	36,091	53,219
SAC14	Ridge Cut (North)	0	0	30	138	169
SAC15	Ridge Cut (South)	0	0	0	1,020	1,020
SAC16	RD 2035	315	14,691	1,139	7,077	23,222
SAC17	East of Davis	944	3,070	3,403	187,435	194,852
SAC18	Upper Honcut	1,302	55	0	11,908	13,265
SAC20	Gridley	51,396	12,784	546	188,162	252,889
SAC21	Sutter Buttes East	9,172	32,208	11,964	137,974	191,318
SAC22	Live Oak	11,916	4,882	23,333	188,644	228,775
SAC23	Lower Honcut	104	3,319	2,432	41,692	47,546
SAC24	Levee District No.1	8,011	2,286	21,322	162,809	194,429
SAC25	Yuba City	384,626	89,143	108,676	2,062,691	2,645,136
SAC26	Marysville	58,704	18,512	32,344	280,785	390,345
SAC27	Linda-Olivehurst	88,435	21,974	15,834	670,612	796,855
SAC28	RD 784	2,460	344	5,128	312,281	320,214
SAC29	Best Slough	161	36	924	13,005	14,126
SAC30	RD 1001	1,037	1,387	13,072	28,272	43,768
SAC32	RD 70-1660	0	808	4,452	11,377	16,637
SAC33	Meridian	594	681	881	8,397	10,552
SAC34	RD 1500 East	1,599	1,849	6,054	7,272	16,773
SAC35	Elkhorn	414	0	655	3,857	4,926
SAC36	Natomas	166,186	84,924	752,590	2,628,562	3,632,262
SAC37	Rio Linda	19,253	58,460	347,938	519,191	944,843
SAC38	West Sacramento	281,448	432,103	17,229	523,871	1,254,650

Table 3-11. Structure Depreciated Replacement Values in 2010 October $1,000 – Sacramento River Basin (contd.)

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SAC39	RD 900	17,667	53,677	7,721	1,062,248	1,141,313
SAC40	Sacramento North	377,472	161,251	608,956	1,258,308	2,405,988
SAC41	RD 302	0	0	598	3,272	3,870
SAC42	RD 999	1,821	2,755	192	15,408	20,176
SAC43	Clarksburg	6,928	2,770	527	20,545	30,770
SAC44	Stone Lake	31,858	5,271	331,873	1,707,428	2,076,430
SAC45	Hood	963	4,545	14,635	4,814	24,957
SAC46	Merritt Island	0	0	0	5,426	5,426
SAC47	RD 551	0	4,637	7,721	5,697	18,055
SAC48	Courtland	2,055	1,619	10,496	5,657	19,828
SAC49	Sutter Island	0	0	1,831	1,110	2,941
SAC50	Grand Island	3,396	362	12,826	31,795	48,378
SAC51	Locke	7,550	768	32,644	3,160	44,123
SAC52	Walnut Grove	14,123	6,566	34,266	8,897	63,853
SAC53	Tyler Island	436	2,583	1,162	376	4,557
SAC54	Andrus Island	26,197	6,790	82,877	32,346	148,209
SAC55	Ryer Island	0	0	73	5,013	5,086
SAC56	Prospect Island	0	0	253	0	253
SAC57	Twitchell Island	0	0	13,479	375	13,854
SAC58	Sherman Island	343	0	49,147	3,100	52,589
SAC59	Moore	0	0	4	3,258	3,262
SAC60	Cache Slough	0	1,025	99	3,203	4,327
SAC61	Hastings	0	0	0	578	578
SAC62	Lindsey Slough	3,806	9,487	956	166,792	181,040
SAC63	Sacramento South	1,502,804	792,463	3,398,289	9,431,240	15,124,796
Grand Total		**Commercial**	**Industrial**	**Public**	**Residential**	**Total**
		3,162,059	**1,861,594**	**6,039,573**	**22,134,088**	**33,197,315**

Key:
RD = Reclamation District

Table 3-12. Building Contents Costs in 2010 October $1,000 – Sacramento River Basin

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SAC01	Woodson Bridge East	535	221	0	5,164	5,920
SAC02	Woodson Bridge West	334	295	0	2,045	2,674
SAC03	Hamilton City	4,262	0	1,550	16,769	22,582
SAC04	Capay	309	1,196	2,295	703	4,503
SAC05	Butte Basin	257	710	2,599	10,856	14,423
SAC06	Butte City	764	22	0	929	1,715
SAC07	Colusa Basin North	4,813	2,536	7,386	25,696	40,430
SAC08	Colusa	25,535	3,124	3,203	71,765	103,627
SAC09	Colusa Basin South	2,224	10,751	4,350	19,547	36,872
SAC10	Grimes	835	0	323	3,361	4,519
SAC11	RD 1500 West	647	715	1,360	3,559	6,281
SAC12	Sycamore Slough	0	0	0	65	65
SAC13	Knight's Landing	8,010	5,547	1,082	18,046	32,685
SAC14	Ridge Cut (North)	0	0	40	69	109
SAC15	Ridge Cut (South)	0	0	0	510	510
SAC16	RD 2035	107	13,200	638	3,539	17,483
SAC17	East of Davis	1,059	5,713	1,715	93,718	102,205
SAC18	Upper Honcut	1,240	17	0	5,954	7,211
SAC20	Gridley	46,918	7,526	510	94,081	149,035
SAC21	Sutter Buttes East	6,422	11,927	4,617	68,987	91,953
SAC22	Live Oak	6,847	4,176	7,497	94,322	112,842
SAC23	Lower Honcut	69	5,778	798	20,846	27,491
SAC24	Levee District No.1	4,320	1,962	7,866	81,405	95,553
SAC25	Yuba City	201,399	94,602	36,449	1,031,345	1,363,795
SAC26	Marysville	37,883	22,315	12,189	140,392	212,780
SAC27	Linda-Olivehurst	41,889	17,991	7,485	334,969	402,334
SAC28	RD 784	1,649	494	1,735	156,141	160,019
SAC29	Best Slough	70	45	542	6,503	7,159
SAC30	RD 1001	543	1,013	4,710	14,136	20,401
SAC32	RD 70-1660	0	1,177	1,552	5,689	8,418
SAC33	Meridian	625	584	484	4,198	5,892
SAC34	RD 1500 East	789	1,586	2,078	3,636	8,090
SAC35	Elkhorn	194	0	516	1,929	2,639
SAC36	Natomas	89,538	87,252	335,047	1,314,281	1,826,117
SAC37	Rio Linda	13,455	70,446	111,094	259,596	454,591
SAC38	West Sacramento	199,776	451,815	8,779	261,935	922,304

Table 3-12. Building Contents Costs in 2010 October $1,000 – Sacramento River Basin (contd.)

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SAC39	RD 900	12,533	51,074	6,481	531,124	601,212
SAC40	Sacramento North	204,151	208,392	211,411	629,154	1,253,107
SAC41	RD 302	0	0	237	1,636	1,873
SAC42	RD 999	1,099	4,828	67	7,704	13,698
SAC43	Clarksburg	4,784	2,961	256	10,272	18,274
SAC44	Stone Lake	18,076	5,496	157,399	853,714	1,034,686
SAC45	Hood	405	7,552	4,298	2,407	14,661
SAC46	Merritt Island	0	0	0	2,713	2,713
SAC47	RD 551	0	4,569	2,521	2,848	9,938
SAC48	Courtland	2,415	2,264	3,647	2,829	11,155
SAC49	Sutter Island	0	0	639	555	1,194
SAC50	Grand Island	3,038	680	3,810	15,897	23,424
SAC51	Locke	3,868	767	12,148	1,580	18,363
SAC52	Walnut Grove	7,500	7,850	13,232	4,449	33,030
SAC53	Tyler Island	214	3,213	399	188	4,014
SAC54	Andrus Island	14,316	10,876	25,387	16,173	66,752
SAC55	Ryer Island	0	0	25	2,506	2,532
SAC56	Prospect Island	0	0	88	0	88
SAC57	Twitchell Island	0	0	4,666	187	4,854
SAC58	Sherman Island	149	0	15,720	1,550	17,419
SAC59	Moore	0	0	1	1,629	1,630
SAC60	Cache Slough	0	1,924	71	1,601	3,596
SAC61	Hastings	0	0	0	289	289
SAC62	Lindsey Slough	1,897	15,765	334	83,396	101,392
SAC63	Sacramento South	848,709	1,014,337	1,122,307	4,715,620	7,700,973
Grand Total		**Commercial**	**Industrial**	**Public**	**Residential**	**Total**
		1,826,469	**2,167,284**	**2,155,632**	**11,066,707**	**17,216,093**

Note:
RD = Reclamation District

Table 3-13. Structure Depreciated Replacement Values in 2010 October $1,000 – San Joaquin River Basin and Stockton Area

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SJ01	Fresno	3,494	20,646	2,383	51,653	78,175
SJ02	Fresno Slough East	0	3,314	1,050	8,574	12,938
SJ03	Fresno Slough West	427	0	0	3,554	3,981
SJ04	Mendota	569	3,961	516	22,300	27,347
SJ05	Chowchilla Bypass	0	0	0	3,221	3,221
SJ06	Lone Willow Slough	0	0	0	10,794	10,794
SJ07	Mendota North	0	0	0	531	531
SJ08	Firebaugh	16,000	4,990	4,773	106,881	132,645
SJ09	Salt Slough	2,898	1,927	36,762	81,569	123,156
SJ10	Dos Palos	8,778	368	10,898	68,998	89,043
SJ11	Fresno River	0	0	0	506	506
SJ12	Berenda Slough	61	863	0	12,159	13,083
SJ13	Ash Slough	16	590	0	5,946	6,553
SJ14	Sandy Mush	0	0	1,216	1,117	2,333
SJ15	Turner Island	0	0	0	1,900	1,900
SJ16	Bear Creek	98	85	1,218	3,474	4,876
SJ17	Deep Slough	0	0	1,095	557	1,652
SJ18	West Bear Creek	0	0	7,871	0	7,871
SJ19	Fremont Ford	98	689	1,636	12,420	14,844
SJ20	Merced River	0	499	1,519	9,333	11,352
SJ21	Merced River North	91	3,204	1,689	35,451	40,436
SJ22	Orestimba	257	160	1,675	19,474	21,566
SJ23	Tuolumne South	0	0	723	4,887	5,610
SJ24	Tuolumne River	2,978	1,944	462	38,262	43,646
SJ25	Modesto	12,218	119,673	7,568	178,699	318,158
SJ26	Three Amigos	427	0	511	2,213	3,150
SJ27	Stanislaus South	0	0	1,688	4,759	6,446
SJ28	Stanislaus North	1,886	112	3,076	122,176	127,249
SJ29	Banta Carbona	65	158	732	19,630	20,585
SJ30	Paradise Cut	479	262	465	14,109	15,315
SJ31	Stewart Tract	648	34	305	459	1,446
SJ32	East Lathrop	2,981	2,609	468	4,159	10,217
SJ33	Lathrop/Sharpe	16,618	3,609	6,073	640,822	667,121
SJ34	French Camp	8,524	2,204	2,049	765,390	778,167
SJ35	Moss Tract	7,238	3,641	1,150	250,731	262,759
SJ36	Roberts Island	0	45	763	11,123	11,931

Table 3-13. Structure Depreciated Replacement Values in 2010 October $1,000 – San Joaquin River Basin and Stockton Area (contd.)

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SJ37	Rough and Ready Island	0	106	245	0	351
SJ38	Drexler Tract	559	34	69	1,562	2,224
SJ39	Union Island	0	86	182	2,310	2,578
SJ40	Union Island Toe	0	0	0	795	795
SJ41	Fabian Tract	516	0	210	1,340	2,066
SJ42	RD 1007	14,693	864	2,161	20,377	38,094
SJ43	Grayson	179	0	515	11,640	12,334
STK01	Lower Roberts Island	0	36	4,357	2,865	7,259
STK06	Stockton East	2,322	2,959	38,781	11,129	20,227
STK07	Calaveras River	88,182	529	38,049	1,783,018	1,909,778
STK08	Bear Creek South	6,267	457	23,003	1,146,374	1,176,100
STK09	Bear Creek North	3,594	653	37,744	757,570	799,562
STK10	Central Stockton	186,179	42,523	150,746	2,682,835	3,062,284
Grand Total:		**Commercial**	**Industrial**	**Public**	**Residential**	**Total**
		389,340	**223,834**	**396,396**	**8,939,646**	**9,914,255**

Note:
RD = Reclamation District

Table 3-14. Building Contents Costs in 2010 October $1,000 – San Joaquin River Basin and Stockton Area

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SJ01	Fresno	1,920	38,635	2,970	25,826	69,352
SJ02	Fresno Slough East	0	6,220	1,389	4,287	11,895
SJ03	Fresno Slough West	219	0	0	1,777	1,997
SJ04	Mendota	302	3,544	104	11,150	15,100
SJ05	Chowchilla Bypass	0	0	0	1,611	1,611
SJ06	Lone Willow Slough	0	0	0	5,397	5,397
SJ07	Mendota North	0	0	0	265	265
SJ08	Firebaugh	9,556	5,972	1,361	53,441	70,329
SJ09	Salt Slough	1,483	3,164	22,705	40,784	68,135
SJ10	Dos Palos	4,553	662	3,624	34,499	43,338
SJ11	Fresno River	0	0	0	253	253
SJ12	Berenda Slough	65	1,374	0	6,080	7,519
SJ13	Ash Slough	31	1,107	0	2,973	4,112
SJ14	Sandy Mush	0	0	491	559	1,050
SJ15	Turner Island	0	0	0	950	950
SJ16	Bear Creek	50	160	425	1,737	2,373
SJ17	Deep Slough	0	0	441	278	719
SJ18	West Bear Creek	0	0	2,746	0	2,746
SJ19	Fremont Ford	50	1,294	571	6,210	8,125
SJ20	Merced River	0	937	530	4,667	6,134
SJ21	Merced River North	47	2,733	576	17,725	21,081
SJ22	Orestimba	167	300	620	9,737	10,825
SJ23	Tuolumne South	0	0	328	2,443	2,771
SJ24	Tuolumne River	2,655	609	144	19,131	22,538
SJ25	Modesto	12,294	123,435	2,661	89,349	227,739
SJ26	Three Amigos	189	0	178	1,106	1,474
SJ27	Stanislaus South	0	0	589	2,379	2,968
SJ28	Stanislaus North	1,164	186	1,386	61,088	63,824
SJ29	Banta Carbona	57	267	358	9,815	10,496
SJ30	Paradise Cut	271	492	263	7,055	8,081
SJ31	Stewart Tract	596	28	135	229	989
SJ32	East Lathrop	3,658	4,348	166	2,080	10,251
SJ33	Lathrop/Sharpe	14,152	4,083	2,358	320,411	341,004
SJ34	French Camp	7,786	3,736	889	382,695	395,107
SJ35	Moss Tract	6,968	5,396	436	125,365	138,164
SJ36	Roberts Island	0	40	436	5,562	6,037
SJ37	Rough and Ready Island	0	139	81	0	220

Table 3-14. Building Contents Costs in 2010 October $1,000 – San Joaquin River Basin and Stockton Area (contd.)

Damage Area	Description	Commercial	Industrial	Public	Residential	Total
SJ38	Drexler Tract	644	30	24	781	1,479
SJ39	Union Island	0	161	67	1,155	1,382
SJ40	Union Island Toe	0	0	0	397	397
SJ41	Fabian Tract	503	0	188	670	1,360
SJ42	RD 1007	10,181	1,411	1,087	10,188	22,867
SJ43	Grayson	185	0	168	5,820	6,173
STK01	Lower Roberts Island	0	68	1,499	1,433	3,000
STK06	Stockton East	2,775	4,481	1,476	5,565	14,298
STK07	Calaveras River	39,710	518	25,034	891,509	956,771
STK08	Bear Creek South	4,898	686	11,080	573,187	589,850
STK09	Bear Creek North	2,036	870	20,758	378,785	402,447
STK10	Central Stockton	154,353	59,899	68,055	1,341,417	1,623,724
		Commercial	**Industrial**	**Public**	**Residential**	**Total**
	Grand Total	**283,516**	**276,985**	**178,397**	**4,469,821**	**5,208,718**

Note:
RD = Reclamation District

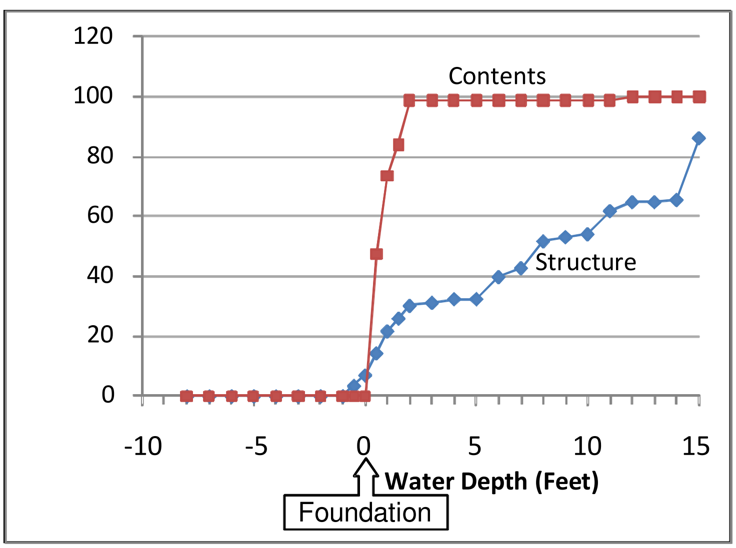

Figure 3-9. Damage Functions for Contents and Structures of One-Story Public Recreational Buildings

3.8 Crop Flood Damage Analysis

Of the total 2.2 million acres of the CVFPP HEC-FDA planning area (floodplains) in the Sacramento and San Joaquin river basins, about 1.6 million acres are irrigated crop land. Crop flood damages under the CVFPP No Project condition were evaluated using the same approach as in the Comprehensive Study (i.e., using the Comprehensive Study Ag damage spreadsheet as the tool to estimate damage values for the Sacramento and San Joaquin river basins (USACE, 2010b). Flood events evaluated were for AEPs of 10, 2, 1, .5, and .2 percent (i.e., 10-, 50-, 100-, 200-, and 500-year floods).

In the Comprehensive Study Ag damage spreadsheet, a table for each HEC-FDA damage area calculates crop flood damage (USACE, 2010b). The May 2010 DWR GIS landuse dataset for Central Valley landuse conditions was laid over the derived flood depth grid (the same dataset used for the structure damage analysis and derived from the Comprehensive Study flood depth grid data, as described previously) to calculate total inundated acreage for different crops under each flood event. The Comprehensive Study Ag damage spreadsheet was next used to estimate total damages for each damage area by multiplying the inundated acreages with the updated unit damage cost for each flood event. Outputs from the spreadsheet were used as input to HEC-FDA to calculate the EAD for crop damages.

For each damage area, the crop stage-damage curve for the CVFPP No Project condition was developed based on the relationship between river stage at the index point (from UNET output and applied in structure damage analysis) and total crop damage for the entire damage area under different flood events. The No Project crop stage-damage curves were applied in HEC-FDA to calculate the crop damage EAD for all CVFPP approaches based on the assumption that this interior-exterior relationship remains independent of conditions such as hydrology and levee performance.

3.8.1 Crop Types

The DWR GIS landuse dataset has a total of 204 different classes of agricultural land use, 117 of which can be found in the CVFPP HEC-FDA damage areas. These 117 classes were then categorized into eight land uses that could produce 20 different types of crops (see Table 3-15). (In the original Comprehensive Study Ag damage spreadsheet for the Sacramento and San Joaquin river basins, there were 19 predominant crop types (USACE, 2010b). For the CVFPP, citrus was added for a total of 20 crop types.) Appendix D documents the complete designation of the DWR landuse classes to the 20 crops for the CVFPP economic flood damage analysis.

For each of the 20 crop types, there are two kinds of unit damage cost per acre: one for short-term flood duration (shorter than five days) and one for long-term flood duration (longer than five days). Weighted unit damage cost per acre was developed based on the assumed percentage of short- and long-term inundation. Flood duration assumptions were from the Comprehensive Study Ag damage spreadsheet (USACE, 2010).

3.8.2 Crop Assumptions Update

Values in the Comprehensive Study Ag damage spreadsheets were in 2001 October dollars; they were updated to present day dollars (i.e., 2010 October dollars) for the CVFPP using the price adjustment approach outlined in the DWR Flood Rapid Assessment Model (F-RAM) Development (DWR, 2008). Also, as mentioned, citrus was added to the original Comprehensive Study predominant crop list for a total of 20 crop types; thus, income and damage assumptions were developed to calculate unit damages for citrus.

Components of Crop Damage

Estimates of agricultural damages include cultivation costs (growing costs), harvest costs, establishment costs, land cleanup and rehabilitation costs, and loss of gross income:

- Cultivation costs were obtained from the University of California, Davis (UC Davis), Department of Agricultural and Resource Economics. These typically include costs such as subsoil treatment, irrigation, weed control, pest control, and fertilization, as well as other costs that are more crop-specific (UC Davis, 2010).

- Harvest/post-harvest costs were obtained from the UC Davis Department of Agricultural and Resource Economics. These include costs related to harvesting, and typically include costs such as cutting, hauling, and packing (UC Davis, 2010).

- Establishment costs were obtained from the UC Davis Department of Agriculture and Resource Economics. These are costs necessary to completely reestablish a crop that has been severely damaged (e.g., if a flood duration is longer than five days for some crops or three days for alfalfa) and must be replanted or reseeded and regrown. Establishment costs would be especially high for crops that need more than one year to mature in order to be harvested, such as orchard crops. Establishment costs typically include expenses such as land preparation, planting, production expenses, and cash overhead for growing the crops through the first year of viable harvest (UC Davis, 2010).

- Land cleanup and rehabilitation costs are added as a fixed cost to each estimate. These costs are assumed to be the same for all crops (UC Davis, 2010).

Table 3-15. Crop Types and Unit Damage Costs for CVFPP Flood Damage Analysis

Crop Types	Products	Sacramento Valley (damage/acre in 2010 October dollars)		San Joaquin Valley (damage/acre in 2010 October dollars)	
		Short-Term[1]	Long-Term[2]	Short-Term[1]	Long-Term[2]
Citrus	Oranges	222	3,463	222	3,463
Fruit and Nuts	Almonds	1,320	4,819	1,387	4,819
	Walnuts	739	4,120	820	4,176
	Peaches	1,257	6,181	1,381	6,425
	Pears	2,514	9,777	2,619	9,917
	Prunes	594	4,819	684	4,889
Field	Cotton	497	497	654	654
	Beans	342	363	397	448
	Safflower	337	373	387	427
	Wheat	489	508	506	511
	Corn	361	361	391	391
Pasture and Alfalfa	Pasture	419	698	394	752
	Alfalfa	547	1,057	608	1,085
Rice	Rice	323	323	372	376
Truck	Melons	652	652	700	700
	Tomatoes	947	947	1,205	1,205
Vine	Wine grapes	824	6,076	905	6,285
Other	Idle	291	291	291	291
	Semi agricultural	291	291	291	291
	Native vegetation	145	145	145	145

Notes:
[1] Inundation shorter than 5 days.
[2] Inundation longer than 5 days.
Key:
CVFPP = Central Valley Flood Protection Plan

- Gross income from each crop originates from the *Agricultural Commissioner's Report for San Joaquin County* (UC Davis, 2010).

Effects of seasonality and flooding duration are considered in the computation of agricultural flood damages for each crop (DWR, 2008). Monthly data are gathered into a weighted average annual damage estimate based on income, costs, probability of flood in that month, and percent of damages that would occur if there were a flood.

Citrus Damage Cost Development

The 2001 agricultural damage estimates for all crop categories, except citrus, were obtained from the Comprehensive Study Ag damage spreadsheets (USACE, 2010b). The agricultural damage estimates for citrus crops were calculated using the approach outlined in the F-RAM Development (DWR, 2008).

Gross income for citrus crops was estimated using the income from oranges; all values used were obtained from the California Agricultural Production Statistics, provided by the California Department of Food and Agriculture (CDFA, 2009a and 2009b). The latest gross-income data available were for the 2007 to 2008 period.

Cultivation cost, harvest/post-harvest cost, and establishment costs were obtained from UC Davis (UC AIC, 2009). The latest agricultural cost data available from UC Davis was for 2009; however, the CDFA gross income data for 2009 were not available. The most recent year when both the gross income data from CDFA and agricultural cost data from UC Davis were available was 2007. These costs were updated to 2010 October dollars by the Prices Paid Multiplier, as described in the next section (CDFA, 2009a and 2009b).

Gross income was obtained by taking the rolling average of dollar value per carton from 2003 to 2007 to correct for any cyclical market highs or lows; the average was then multiplied by the number of cartons yield per acre in 2007:

$$Gross\ Income = Rolling\ Average\ of\ \frac{\$}{Carton}_{2003-2007}\ x \frac{Cartons}{Acre}_{2007}$$

$$= \left[\frac{\frac{\$3.67}{Carton_{2003}} + \frac{\$5.51}{Carton_{2004}} + \frac{\$4.68}{Carton_{2005}} + \frac{\$5.19}{Carton_{2006}} + \frac{\$5.64}{Carton_{2007}}}{5}\right] x484 \frac{Cartons}{Acre}$$

$$= \frac{\$2398.70}{Acre}$$

The gross income of citrus crops in 2007 was then updated to 2010 October dollars by the Prices Received Multiplier, as described in the next section.

Price Level Update

A price index is an indication of how prices have changed over time. The most well-known price index is the Consumer Price Index (CPI). However, U.S. Department of Agriculture (USDA) indices are more appropriate for agriculture-specific price adjustments. The latest USDA indices available were for 2010.

USDA indices are separated into different categories. Table 3-16 summarizes the placement of each product in its respective USDA category and its multipliers for prices paid and received.

The categories listed in Table 3-16 under Prices Paid Multiplier were used to adjust the estimates for (1) cultivation cost, (2) harvest/post-harvest cost, (3) establishment cost, and, (4) land cleanup and rehabilitation cost.

However, USDA indices for agriculture for prices received were used to adjust the estimates for gross income. USDA categories used for the price level update can be seen under Price Received Multiplier in Table 3-16.

To update the dollar values from 2001 to 2010, the same price adjustment approach documented in the F-RAM Development was used, as summarized below:

- To correct for cyclical highs or lows, a 5-year moving average was calculated for the indices for the period of 2006 through 2010 to prevent the data from being skewed when changes from 2001 to 2010 were made. However, price indices for the entire year of 2010 were not available as this work was being done. Price indices for the month of April were used to match the dollar values of the housing stock.

- The Prices Paid Multiplier and Price Received Multiplier were calculated using the following equation:

$$multiplier = \frac{(Rolling\ Average\ Price\ Index_{2006-2010})}{Price\ Index_{2001}}$$

- Unit damage cost assumptions from the Comprehensive Study Ag damage spreadsheets (USACE, 2010b) for all crops, except citrus, were adjusted from 2001 to 2010 dollars using the Prices Paid Multiplier only because gross income was a comparatively small part of the entire damage.

Acreage Update

Flood depth grid data were obtained from the Comprehensive Study FLO-2D modeling. New interior-exterior stage relationships were derived from that data using the new exterior river stages from the CVFPP for flood events with AEP of 10, 4, 2, 1, .5, and .2 percent (10-, 25-, 50-, 100-, 200-, and 500-year return period) (the same approach described in Section 3). The DWR GIS landuse dataset for the Central Valley was overlaid over on the new flood depth grid data to calculate the total inundated acreage for different crops under each flood event. Per DWR landuse data, more than 100 different crops are grown in the SPFC Planning Area. Each DWR crop type was represented by one of the 20 predominant crops types for analytical purposes (see Table 3-15).

Table 3-17 shows total crop acres in the Sacramento River Basin, San Joaquin River Basin, and Stockton area, respectively.

3.9 Business Loss Analysis

Direct flood damages associated with decreased business activity (business losses) caused by flooding were estimated for all affected non-residential structures in damage areas. Flooding in damage areas would force some businesses to temporarily or permanently close (no permanent closures were considered for this analysis), resulting in a decline in business production. Expected annual business losses were estimated for both the Sacramento and San Joaquin river basins. Flood events evaluated were for AEPs of 10, 2, 1, 0.5, and 0.2 percent (10-, 50-, 100-, 200-, and 500-year flood).

Using the structure inventory (described previously), each non-residential structure occupancy type was matched to an Energy Information Administration (EIA) business type and associated Damage Analysis for PLANning (IMPLAN)[9] sector, developed for this project, to obtain economic output per day values per non-residential structure (EIA, 2006; MIG Inc, 2009).

[9] 2009 California County Dataset. The current IMPLAN I-O database and model is maintained and sold by MIG Inc. (MIG Inc., 2009)

Table 3-16. Prices Received and Prices Paid Multipliers for Price Level Update from 2001 to October 2010

Product	Prices Received		Prices Paid	
	USDA Category	Prices Received Multiplier	USDA Category	Prices Paid Multiplier
Alfalfa	Feed Grains and Hay	1.8308	Feed	1.5505
Almonds	Fruits and Nuts	1.3817	Commodity	1.3967
Beans	Potatoes and Dry Beans	1.3624	Commodity	1.3967
Corn	Feed Grains and Hay	1.8308	Feed	1.5505
Cotton	Cotton	1.4531	Commodity	1.3967
Idle	All Other Crops	1.1113	Commodity	1.3967
Melons	Commercial Vegetables	1.1308	Commodity	1.3967
Native Vegetable	All Other Crops	1.0716	Commodity	1.3967
Oranges*	Fruits and Nuts	0.9532	Commodity	1.0671
Pasture	Feed Grains and Hay	1.8308	Feed	1.5505
Peaches	Fruits and Nuts	1.3817	Commodity	1.3967
Pears	Fruits and Nuts	1.3817	Commodity	1.3967
Prunes	Fruits and Nuts	1.3817	Commodity	1.3967
Rice	Food Grain	2.1121	Commodity	1.3967
Safflower	Oil-Bearing Crops	1.9975	Commodity	1.3967
Semi-ag	All Other Crops	1.0716	Commodity	1.3967
Tomatoes	Commercial Vegetables	1.1308	Commodity	1.3967
Walnuts	Fruits and Nuts	1.3817	Commodity	1.3967
Wheat	Food Grain	2.1121	Commodity	1.3967
Wine Grapes	Fruits and Nuts	1.3817	Commodity	1.3967

Source: USDA, 2010
Note:
* Multipliers for oranges to adjust price level from 2007 to October 2010.
Key:
USDA = U.S. Department of Agriculture

Table 3-17. Total Crop Acres

Crop Type	Product	Sacramento River Basin	San Joaquin River Basin	Stockton Area
Citrus				
	Citrus	2,316	117	42
Fruit and Nuts				
	Almonds	25,877	29,356	85
	Walnuts	54,491	5,761	1,996
	Peaches	19,616	494	16
	Pears	8,775	1	0
	Prunes	63,777	1,952	1,340
	Subtotal	**172,536**	**37,563**	3,437
Field				
	Cotton	2,321	77,531	0
	Beans	33,904	13,080	620
	Safflower	62,862	10,015	2,378
	Wheat	82,437	33,406	5,275
	Corn	80,186	64,405	3,351
	Subtotal	**261,709**	**198,438**	11,624
Pasture and Alfalfa				
	Pasture	32,934	31,279	1,040
	Alfalfa	35,159	114,797	3,703
	Subtotal	**68,093**	**146,076**	4,742
Rice				
	Rice	284,507	80	0
Truck				
	Melons	28,717	19,677	4,069
	Tomatoes	56,065	35,295	1,731
	Subtotal	**84,782**	**54,972**	5,801
Vine				
	Wine grapes	13,041	34,716	2,921
Other				
	Idle	29,912	3,392	896
	Semi-agricultural	7,258	9,071	365
	Native vegetation	153,597	180,550	3,374
	Subtotal	**190,767**	**193,014**	4,635
	Total	**1,077,751**	**664,976**	**33,201**

Each non-residential structure was matched with the corresponding grid from the derived flood depth grid (the same dataset that was used for the structure damage analysis and derived from the Comprehensive Study flood depth grid data as described previously) to calculate temporary business interruption days for each non-residential structure using a depth-damage function (DDF) provided by the Federal Emergency Management Agency (FEMA). Temporary business interruption days for each non-residential structure were then multiplied by the corresponding economic output per day values to calculate economic output losses per non-residential structure per flood event. Capacity utilization factors were used to account for substitute production of unaffected businesses that would be able to meet a portion of demand for flooded businesses' goods and services. The economic output losses, or business losses, for each non-residential structure were then aggregated for each damage area for each flood event.

A business loss stage-damage curve for the No Project condition was developed for each damage area based on the relationship of the river stage at the index point (from UNET output and applied in the structure damage analysis) and total business losses of the entire damage area under different flood events. These No Project business loss stage-damage curves were applied in HEC-FDA to calculate the business loss EAD for all CVFPP approaches based on the assumptions that this interior-exterior relationship remains independent of conditions like hydrology and levee fragility.

3.9.1 Business Output Relationships Based on Structure Inventory

To estimate total lost business output, it was necessary to estimate the relationship between business output/sales and square footage of inundated businesses. Information used to estimate this relationship is displayed in Table 3-18.

The number of workers per square foot at affected businesses was estimated using data from the EIA[10]. Non-residential occupancy types from the structure inventory (described above) were matched with EIA business categories, and the square footage of each business was divided by square feet per employee to arrive at an estimated number of employees per business. Then, business types were matched to IMPLAN sectors developed for this project, based on counties that damage area reside, and daily production values per employee were taken from IMPLAN per

[10] Energy Information Administration (2006). *2003 Commercial Buildings Energy Consumption Survey - Building Characteristics Tables*, Revised June 2006. Table B1. Summary Table: Total and Means of Floorspace, Number of Workers, and Hours of Operation for Non-Mall Buildings, 2003.

business type. Finally, to obtain daily economic output per business values, the estimates of the number of employees per business were multiplied by daily output per employee figures estimated in the appropriate IMPLAN sector for each affected business.

3.9.2 Business Interruption Days Based on Depth Grid

In addition to daily business output relationships, it was also necessary to understand the temporal implications of business interruption or days of "loss of function". Business interruption is related to the time period businesses are unable to occupy an area and perform economic activities that normally would take place if flooding had not occurred. Businesses, like local residents, would in many cases be unable to occupy structures because of structural damage. Resident displacement was not considered for this analysis, and accordingly no change in the demand for business production was assumed.

Each non-residential structure was matched with the corresponding grid from the derived flood depth grid (the same dataset that was used for the structure damage analysis and derived from the Comprehensive Study flood depth grid data as described previously) to calculate temporary business interruption days for each non-residential structure using a DDF provided by FEMA. Floods evaluated were for AEPs of 10, 2, 1, .5, and .2 percent (i.e., 10-, 50-, 100-, 200-, and 500-year flood). The DDF relates depth of flooding to structure damage and subsequently, business interruption. Business interruption time includes periods for dewatering, mobilization, building/health inspection, and cleanup. The DDF used is shown in Table 3-19.

Considering the expected flood depth above foundation height, each non-residential structure's number of days of business interruption was estimated for all five flood frequencies. Business interruption times are capped at 365 days for all non-residential structures to avoid overestimation of expected business losses.

3.9.3 Business Loss per Flood Event and Capacity Utilization

For each flood frequency, the number of business interruption days was multiplied by the estimated daily production value for each non-residential structure, which resulted in the potential lost business output for each flood frequency at each non-residential structure. However, it is unlikely that all output would be lost in each area because other businesses in the unaffected parts of the regions would be able to meet some portion of interrupted production. This includes businesses that provide comparable services, as well as alternative locations of the same firm within the region.

The extent of this substitution effect depends on the excess capacity (e.g., ability to increase production) of unaffected businesses in each region.

Capacity utilization data were obtained from two sources – the Federal Reserve and the Institute for Supply Management. The Federal Reserve periodically issues a statistical release on industrial production and capacity utilization for the United States[11]. Historical estimates issued by the Federal Reserve show that capacity utilization has averaged approximately 80.4 percent between 1972 and 2010 (i.e., industrial production operates at 80.4 percent of maximum capacity). These data were applied to the light and heavy industry land use categories used in this study. For all other nonindustrial categories, data from the Institute of Supply Management[12] were used, which showed that current nonmanufacturing utilization of capacity is approximately 82.9 percent.

Potential lost business output for each flood frequency at each non-residential structure was multiplied by the corresponding capacity utilization factor, which resulted in business loss estimates for each non-residential structure for each flood frequency by damage area. Finally, estimated business losses across all nonresidential structures were aggregated for each flood frequency by damage area to determine a business loss frequency-damage curve for each damage area. The frequency-damage curves were then input into HEC-FDA, and expected annual business losses were estimated for No Project and each approach.

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[11] Federal Reserve. 2011. Industrial Production and Capacity Utilization, Statistical Release G.17. August 16, 2011

[12] Institute for Supply Management. 2010. December 2010 Semiannual Economic Forecast. Available at:
< http://www.ism.ws/about/MediaRoom/newsreleasedetail.cfm?ItemNumber=20976>

Table 3-18. Employee and Output (2010 $) Relationships for Non-Residential Categories

Non-Residential Category	Principle Business Categories (EIA)	Square Feet Per Employee (EIA)	Daily Output Per Employee (IMPLAN)
C-AUTO	Retail (Other than Mall)	1,246	$206
C-DEAL	Retail (Other than Mall)	1,246	$206
C-FOOD	Food Sales	877	$209
C-FURN	Retail (Other than Mall)	1,246	$232
C-GROC	Food Sales	877	$209
C-HOS	Health Care; Inpatient; Outpatient	501	$356
C-HOTEL	Lodging	2,074	$265
C-MED	Health Care; Inpatient; Outpatient	501	$165
C-OFF	Office	434	$324
C-REST	Food Service	528	$159
C-RESTFF	Food Service	528	$159
C-RET	Retail (Other than Mall)	1,246	$115
C-SERV	Service	1,105	$268
C-SHOP	Retail (Enclosed / Strip Malls)	838	$156
MISC-COM	Retail (Other than Mall)	1,246	$115
IND-HV	Other	956	$835
IND-LT	Other	956	$921
IND-WH	Warehouse and Storage	2,306	$272
MISC-IND	Other	956	$272
PUB-CH	Religious Worship	2,200	$98
PUB-GOV	Public Order and Safety; Office	451	$235
PUB-REC	Public Assembly	1,645	$132
PUB-SCH	Education	791	$153
MISC-PUB	Public Assembly	1,645	$235

Table 3-19. Depth-Damage Function: Depth of Flooding versus Business Interruption

Depth of Flooding Relative to Structure FFE* (feet)	Business Interruption (days)
-2	0
-1	0
0	0
1	45
2	90
3	135
4	180
5	225
6	270
7	315
8	360
9	405
10+	450

Source: FEMA BCA Tool (v4.5.5)4 (FEMA, 2009)
Note:
*FFE is the 1st finished floor elevation. All flood depths are relative to the elevation of the FFE.

3.9.4 Caveats to Business Loss Analysis

Business losses are measured as gross business output or sales. A more appropriate measure of business losses is net income because functional downtime reduces costs as well as receipts. Though net income is a more appropriate measure of business losses, output per employee values used in this analysis are proxy estimates for net income to support approach comparison. At feasibility level analyses, avoided business net income losses will be calculated to support benefit cost evaluation.

If a business is flooded it can (1) make up some of the lost business once it reopens, (2) relocate to a temporary location and continue business while experiencing displacement costs, or (3) go completely out of business. No attempt was made to include these factors in the analysis due to unavailability of required data and detailed analyses.

Labor income is a component of business output losses and includes hourly wages as well as salary compensation. Salaried employees are likely to be paid during short post-disaster business interruptions. Because business losses include hourly wages and salary compensation, it may be the case that only a portion of salary compensation would be lost and business losses may be lower than estimated in this analysis.

3.10 Estimate of Emergency Costs

Emergency costs can be categorized into 18 economic activities that are placed into five groups, and each group has either direct or indirect tangible damages. This section gives an overview of the five groups and also summarizes the different types and numbers of at-risk infrastructure in the Systemwide Planning Area, as well as the at-risk population.

Much has been researched and documented on direct flood damages. However, flood damage data for indirect damages, such as emergency costs, are more limited. Expert-opinion elicitation has been one method used to develop emergency costs. Under the American River Watershed Common Features Project, USACE conducted an expert-opinion elicitation in March 2009 to derive unit flooding emergency cost and relief.

The concept of an emergency cost category is only described in this attachment; the associated cost calculation could be conducted in the 2017 CVFPP economic analysis. It is anticipated that the higher the EAD for a region, the emergency costs will be correspondingly higher.

3.10.1 Emergency Cost Groups

As mentioned, emergency costs can be categorized into 18 economic activities that were placed into five groups (see Table 3-20):

- **Group 1** – Evacuation activities, including evacuation, subsistence, and reoccupation; direct tangible damages
- **Group 2** – Debris removal and cleanup; direct tangible damages
- **Group 3** – Public services patronized, including education, public agencies, library and indoor recreation facilities, and medical facilities; direct tangible damages
- **Group 4** – Public services produced, including police, incarceration, fire, legislative, and judicial facilities; indirect tangible damages
- **Group 5** – Public utilities, including telecommunications, electricity, gas, water, and wastewater treatment/sewer; direct tangible damages

Table 3-20. Emergency Cost Groups and Categories

Economic Activities	Description
Group 1: Evacuation Activities	
1. Evacuation	Cost of labor, capital, and transportation, for evacuation.
2. Subsistence	Cost of housing people in emergency shelters and providing food and water; includes housing during evacuation.
3. Reoccupation	Costs associated with travel time and transportation modes to preoccupied destinations.
Group 2: Debris Removal and Cleanup	
4. Debris activities	Cost associated with sorting, transporting, processing, and disposal of different types of debris.
Group 3: Public Services Patronized	
5. Education	Cost to continue schooling in new locations to enable the routine mission of education.
6. Public agencies	Cost to continue routine services to maintain social functions.
7. Library and indoor recreation facilities	Cost of loss to serving the public's general information and recreational needs.
8. Medical	Cost to continue providing routine service to people who would have been injured regardless of a flood, at unflooded facilities. Cost of hospital evacuation, disaster medical assistance team, and elder care.
Group 4: Public Services Produced	
9. Police	Cost to continue routine police services for flooded areas and cost to provide emergency flood responses, and relocation of facilities, if necessary.
10. Incarceration	Cost associated with increased security and different transportation modes for evacuation and reoccupation of inmates.
11. Fire	Cost to continue routine fire services for flooded areas, cost to provide emergency flood responses, and relocation of facilities, if necessary
12. Legislative	Costs associated with temporary facilities, increased security needs, and relocation of facilities, if necessary.
13. Judicial	Costs associated with temporary facilities, increased security needs, and relocation of facilities, if necessary.
Group 5: Public Utilities	
14. Telecommunications	Cost associated with increased use of tele-communication equipment and services to carry out routine activities and flood activities. Cost of repairing the physical infrastructure of the telecommunications utility system. Value associated with loss of services.
15. Electricity	Cost of repairing the physical infrastructure of the electricity distribution utility system. Value associated with loss of services.
16. Gas	Cost of repairing the physical infrastructure of the gas utility system. Value associated with loss of services.
17. Water	Cost of repairing the physical infrastructure of the water distribution utility system. Value associated with loss of services.
18. Wastewater treatment/sewer	Cost of repairing the physical infrastructure of the wastewater treatment/sewer utility system. Value associated with loss of services

Group 1 – Evacuation Activities
For evacuation, subsistence, and reoccupation, it is assumed that the population number would remain the same (i.e., no deaths would occur), and that people would use least-cost alternatives and make rational decisions. The analysis for this category also assumes an orderly mandatory evacuation before a flood. Search and rescue activities would be conducted for unevacuated persons, those who declined to evacuate or were unable to successfully evacuate during early evacuation efforts.

Group 2 – Debris Removal and Cleanup
Under debris removal and cleanup activities, it is assumed that no goods would be removed from residences when occupants were evacuated, and that no special measures would be taken to reduce debris generation. Travel needs would increase during a flood because debris material would need to be transported to unflooded destination facilities. Also, temporary structures, such as debris staging areas, would likely be created for flood response.

Group 3 – Public Services Patronized
For public services such as education, public agencies, library, indoor recreation facilities, and medical facilities, it is assumed that the number of users would not change, nor would demand for the service, and that lost service days would be kept to the minimum of time necessary to restart a school. Operations would be the same before and after flooding.

For the acute care portion of a hospital, the economic loss also includes costs to establish alternative facilities and transfer patient services to existing hospitals, as well as the setup cost for a disaster medical assistance team and operation costs.

Group 4 – Public Services Produced
For police, incarceration, fire, legislative, and judicial services, it is assumed that there would be no downscale in operations. For incarceration, it is also assumed that emergency protocols would be made before the flood and other incarceration areas would have excess capacity to absorb inmates; there would be no decline in employees because of the flood; and additional security would be available.

Group 5 – Public Utilities
Infrastructure damage costs are determined from the estimated percent of damage to each infrastructure component over a square mile for residential, commercial, and industrial areas. It is assumed that demand for utilities would remain the same before and after the flood. Also, a value is associated with loss of services due to flood damages to public utilities.

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4.0 Flood Damage Analysis Results

Annual exceedence probability or AEP describes the "protection" against flooding for an impact area, i.e. the likelihood of being flooded in a given year. For example, an impact area with AEP of 6 percent means there is a 6 percent probability that it will be flooded in any given year. In other words, the flooding would occur in 6 years out of 100 on average, or roughly once every 17 years. Calculation of AEP considers the stage-frequency curve and levee performance curve associated with the impact area. The stage-frequency curve is conditionally based on hydrology and assumed upstream levee performance. Changes in upstream levee performance could result in different downstream stage-frequency curves, and thus change the AEP of downstream impact areas even without any risk management actions being taken for the impact area. Therefore, AEP is conditioned on the performance of the entire system.

There are other ways besides AEP to characterize "level of protection." For example, communities sometimes have levee systems that provide a 100-year level of protection in order to meet the minimum standard under the National Flood Insurance Program. In this context, 100-year level of protection is not an estimate of the levee's performance for a given set of conditions. Rather, it is a criteria-based standard under which the levee must meet minimum safety factors when subjected to a 100-year (1 percent AEP) stage that was developed using conservative assumptions about performance of other levees in the region. The AEP for such a levee would typically be much less than 0.01.

All graphic and tabular results referenced in this section have been placed at the end of this section for easier access and readability.

4.1 No Project Condition

Through Monte Carlo sampling of the stage-frequency, levee performance, and stage-damage curves, along with their uncertainties for each parcel in a damage area, the EAD for the No Project condition was calculated for each damage area of the Sacramento River Basin, the San Joaquin River Basin, and the Stockton area.

4.1.1 Sacramento River Basin

Table 4-1 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SAC63

(Sacramento South) has the highest EAD, followed by SAC25 (Yuba City). For crop damages, SAC05 (Butte Basin) has the highest EAD, followed by SAC30 (RD 1001). For business loss damages, SAC63 (Sacramento South) has the highest EAD, followed by SAC40 (Sacramento North).

Table 4-2 shows the AEP for the Sacramento River Basin for the No Project condition and all approaches. For AEP, the larger the number, the greater the flood risk to the damage area (i.e., an AEP of 0.10 (10-year return period) has a greater flood risk than an AEP of 0.010 (100-year return period)).

4.1.2 San Joaquin River Basin

Table 4-3 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, STK10 (Central Stockton) has the highest EAD, followed by SJ33 (Lathrop/Sharpe). For crop damages, SJ12 (Berenda Slough) has the highest EAD, followed by SJ15 (Turner Island). For business loss damages, SJ25 (Modesto) has the highest EAD, followed by SJ33 (Lathrop/Sharpe).

Table 4-4 shows the AEP for the San Joaquin River Basin and Stockton area for the No Project condition and all approaches.

4.2 Achieve SPFC Design Flow Capacity Approach

Through Monte Carlo sampling of the stage-frequency, levee performance, and stage-damage curves, along with their uncertainties for each parcel in a damage area, the EAD for the Achieve SPFC Design Flow Capacity Approach was calculated for each damage area in the Sacramento and San Joaquin river basins and Stockton area.

4.2.1 Sacramento River Basin

Table 4-5 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SAC63 (Sacramento South) has the highest EAD, followed by SAC36 (Natomas). For crop damages, SAC04 (Capay) has the highest EAD, followed by SAC35 (Elkhorn). For business loss damages, SAC63 (Sacramento South) has the highest EAD, followed by SAC40 (Sacramento North).

Table 4-2 shows the AEP for the Sacramento River Basin for the No Project condition and all approaches.

4.2.2 San Joaquin River Basin

Table 4-6 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SJ34 (French Camp) has the highest EAD, followed by SJ09 (Salt Slough). For crop damages, SJ09 (Salt Slough) has the highest EAD, followed by SJ20 (Merced River). For business loss damages, SJ25 (Modesto) has the highest EAD, followed by SJ24 (Tuolumne River).

Table 4-4 shows the AEP for the San Joaquin River Basin and Stockton area for the No Project condition and all approaches.

4.3 Protect High Risk Communities

Through Monte Carlo sampling of the stage-frequency, levee performance, and stage-damage curves, along with their uncertainties for each parcel in a damage area, the EAD for the Protect High Risk Communities Approach was calculated for each damage area in the Sacramento and San Joaquin river basins and Stockton area.

4.3.1 Sacramento River Basin

Table 4-7 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SAC63 (Sacramento North) has the highest EAD, followed by SAC40 (Sacramento North). For crop damages, SAC05 (Butte Basin) has the highest EAD, followed by SAC24 (Levee District No.1). For business loss damages, SAC63 (Sacramento South) has the highest EAD, followed by SAC40 (Sacramento North).

Table 4-2 shows the AEP for the Sacramento River Basin for the No Project condition and all approaches.

4.3.2 San Joaquin River Basin

Table 4-8 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SJ09 (Salt Slough) has the highest EAD, followed by SJ28 (Stanislaus North). For crop damages, SJ12 (Berenda Slough) has the highest EAD, followed by SJ15 (Turner Island). For business loss damages, SJ25 (Modesto) has the highest EAD, followed by SJ09 (Salt Slough).

Table 4-4 shows the AEP for the San Joaquin River Basin and Stockton area for the No Project condition and all approaches.

4.4 Enhance Flood System Capacity

Through Monte Carlo sampling of the stage-frequency, levee performance, and stage-damage curves, along with their uncertainties for each parcel in a damage area, the EAD for the Enhance Flood System Capacity Approach was calculated for each damage area in the Sacramento and San Joaquin river basins and Stockton area.

4.4.1 Sacramento River Basin

Table 4-9 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SAC63 (Sacramento North) has the highest EAD, followed by SAC40 (Sacramento North). For crop damages, SAC04 (Capay) has the highest EAD, followed by SAC01 (Woodson Bridge East). For business loss damages, SAC63 (Sacramento South) has the highest EAD, followed by SAC40 (Sacramento North).

Table 4-2 shows the AEP for the Sacramento River Basin for the No Project condition and all approaches.

4.4.1 San Joaquin River Basin

Table 4-10 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SJ09 (Salt Slough) has the highest EAD, followed by SJ33 (Lathrop/Sharpe). For crop damages, SJ09 (Salt Slough) has the highest EAD, followed by SJ20 (Merced River). For business loss damages, SJ25 (Modesto) has the highest EAD, followed by SJ09 (Salt Slough).

Table 4-4 shows the AEP for the San Joaquin River Basin and Stockton area for the No Project condition and all approaches.

4.5 State Systemwide Investment Approach

Through Monte Carlo sampling of the stage-frequency, levee performance, and stage-damage curves, along with their uncertainties for each parcel in a damage area, the EAD for the State Systemwide Investment Approach was calculated for each damage area in the Sacramento River Basin, the San Joaquin River Basin, and Stockton area.

4.5.1 Sacramento River Basin

Table 4-11 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SAC63 (Sacramento North) has the highest EAD, followed by SAC40 (Sacramento

North). For crop damages, SAC05 (Butte Basin) has the highest EAD, followed by SAC35 (Elkhorn). For business loss damages, SAC63 (Sacramento South) has the highest EAD, followed by SAC40 (Sacramento North).

Table 4-2 shows the AEP for the Sacramento River Basin for the No Project condition and all approaches.

4.5.2 San Joaquin River Basin

Table 4-12 shows the EAD for structure and contents, crops, and business loss for each damage area. For structure and contents damages, SJ09 (Salt Slough) has the highest EAD, followed by SJ28 (Stanislaus North). For crop damages, SJ12 (Berenda Slough) has the highest EAD, followed by SJ15 (Turner Island). For business loss damages, SJ25 (Modesto) has the highest EAD, followed by SJ09 (Salt Slough).

Table 4-4 shows the AEP for the San Joaquin River Basin and Stockton area for the No Project condition and all approaches.

Table 4-1. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – No Project

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC01	Woodson Bridge East	26	213	8	246
SAC02	Woodson Bridge West	4	9	0	13
SAC03	Hamilton City	495	0	31	526
SAC04	Capay	38	730	74	842
SAC05	Butte Basin	239	2,339	187	2,764
SAC06	Butte City	6	0	0	6
SAC07	Colusa Basin North	67	65	18	151
SAC08	Colusa	32	1	3	35
SAC09	Colusa Basin South	159	515	55	728
SAC10	Grimes	8	1	0	10
SAC11	Reclamation District 1500 West	109	190	56	355
SAC12	Sycamore Slough	1	44	0	45
SAC13	Knight's Landing	1,207	3	354	1,564
SAC14	Ridge Cut (North)	1	38	0	39
SAC15	Ridge Cut (South)	8.7	68	0	76
SAC16	Reclamation District 2035	3	265	1	269
SAC17	East of Davis	109	7	20	136
SAC18	Upper Honcut	23	60	0	83
SAC20	Gridley	407	17	9	433
SAC21	Sutter Buttes East	500	495	45	1,040
SAC22	Live Oak	780	7	39	827
SAC23	Lower Honcut	162	147	58	367
SAC24	Levee District No.1	496	460	113	1,069
SAC25	Yuba City	47,862	123	10,959	58,944
SAC26	Marysville	281	0	84	365
SAC27	Linda-Olivehurst	1,611	18	451	2,080
SAC28	Reclamation District 784	721	76	22	818
SAC29	Best Slough	388	323	29	740
SAC30	Reclamation District 1001	217	1,538	34	1,789
SAC32	Reclamation District 70-1660	185	456	114	755
SAC33	Meridian	138	2	61	201

Table 4-1. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – No Project (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC34	Reclamation District 1500 East	191	466	232	889
SAC35	Elkhorn	113	1,353	5	1,471
SAC36	Natomas	44,004	120	10,058	54,181
SAC37	Rio Linda	2,993	2	1,922	4,917
SAC38	West Sacramento	5,679	1	2,848	8,528
SAC39	Reclamation District 900	4,877	12	187	5,076
SAC40	Sacramento North	16,622	0	11,014	27,636
SAC41	Reclamation District 302	22	69	1	91
SAC42	Reclamation District 999	55	101	2	158
SAC43	Clarksburg	38	0	9	47
SAC44	Stone Lake	3,068	214	1,489	4,770
SAC45	Hood	561	0	2,092	2,653
SAC46	Merritt Island	77	133	0	210
SAC47	Reclamation District 551	174	1,111	731	2,016
SAC48	Courtland	264	3	320	587
SAC49	Sutter Island	18	774	0	792
SAC50	Grand Island	615	1,500	307	2,423
SAC51	Locke	24	4	65	93
SAC52	Walnut Grove	15	0	8	22
SAC53	Tyler Island	95	405	121	622
SAC54	Andrus Island	132	212	108	452
SAC55	Ryer Island	92	564	0	656
SAC56	Prospect Island	14	133	24	171
SAC57	Twitchell Island	0	0	0	0
SAC58	Sherman Island	180	219	605	1,004
SAC59	Moore	31	84	0	115
SAC60	Cache Slough	3	10	0	13
SAC61	Hastings	21	120	0	141
SAC62	Lindsey Slough	65	237	0	303
SAC63	Sacramento South	69,832	5	37,283	107,120
	Total	**206,158**	**16,062**	**82,257**	**304,476**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-2. HEC-FDA Expected Flooding Return Period in Years for the Sacramento River Basin – All Approaches

Damage Area	Description	No Project	SPFC	PHRC	EFSC	SSIA
SAC01	Woodson Bridge East	> 200	> 200	> 200	> 200	> 200
SAC02	Woodson Bridge West	> 200	> 200	> 200	> 200	> 200
SAC03	Hamilton City	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SAC04	Capay	<25	<25	<25	<25	<25
SAC05	Butte Basin	25 - 100	> 200	25 - 100	> 200	25 - 100
SAC06	Butte City	25 - 100	> 200	25 - 100	25 - 100	25 - 100
SAC07	Colusa Basin North	> 200	> 200	> 200	> 200	> 200
SAC08	Colusa	100 - 200	> 200	100 - 200	> 200	100 - 200
SAC09	Colusa Basin South	25 - 100	> 200	25 - 100	> 200	25 - 100
SAC10	Grimes	25 - 100	> 200	25 - 100	> 200	25 - 100
SAC11	Reclamation District 1500 West	25 - 100	> 200	25 - 100	> 200	25 - 100
SAC12	Sycamore Slough	100 - 200	> 200	100 - 200	> 200	> 200
SAC13	Knight's Landing	25 - 100	25 - 100	25 - 100	> 200	25 - 100
SAC14	Ridge Cut (North)	25 - 100	> 200	25 - 100	> 200	25 - 100
SAC15	Ridge Cut (South)	<25	> 200	<25	> 200	<25
SAC16	Reclamation District 2035	<25	> 200	<25	> 200	<25
SAC17	East of Davis	> 200	> 200	> 200	> 200	> 200
SAC18	Upper Honcut	> 200	> 200	> 200	> 200	> 200
SAC20	Gridley	25 - 100	> 200	25 - 100	> 200	100 - 200
SAC21	Sutter Buttes East	25 - 100	> 200	25 - 100	> 200	100 - 200
SAC22	Live Oak	25 - 100	> 200	25 - 100	> 200	100 - 200
SAC23	Lower Honcut	> 200	> 200	> 200	> 200	> 200
SAC24	Levee District No.1	<25	100 - 200	<25	> 200	<25
SAC25	Yuba City	<25	> 200	> 200	> 200	> 200
SAC26	Marysville	> 200	> 200	> 200	> 200	> 200
SAC27	Linda-Olivehurst	> 200	> 200	> 200	> 200	> 200
SAC28	Reclamation District 784	> 200	> 200	> 200	> 200	> 200
SAC29	Best Slough	<25	100 - 200	<25	<25	<25
SAC30	Reclamation District 1001	<25	> 200	<25	> 200	<25
SAC32	Reclamation District 70-1660	<25	> 200	<25	> 200	<25
SAC33	Meridian	<25	> 200	<25	> 200	<25

Table 4-2. HEC-FDA Expected Flooding Return Period in Years for the Sacramento River Basin – All Approaches (contd.)

Damage Area	Description	No Project	SPFC	PHRC	EFSC	SSIA
SAC34	Reclamation District 1500 East	25 - 100	> 200	25 - 100	> 200	25 - 100
SAC35	Elkhorn	<25	> 200	<25	<25	<25
SAC36	Natomas	<25	> 200	> 200	> 200	> 200
SAC37	Rio Linda	100 - 200	> 200	> 200	> 200	> 200
SAC38	West Sacramento	25 - 100	> 200	> 200	> 200	> 200
SAC39	Reclamation District 900	<25	> 200	> 200	> 200	> 200
SAC40	Sacramento North	25 - 100	100 - 200	> 200	> 200	> 200
SAC41	Reclamation District 302	<25	100 - 200	<25	> 200	<25
SAC42	Reclamation District 999	<25	100 - 200	<25	> 200	<25
SAC43	Clarksburg	25 - 100	100 - 200	25 - 100	> 200	25 - 100
SAC44	Stone Lake	<25	100 - 200	> 200	<25	> 200
SAC45	Hood	<25	100 - 200	> 200	> 200	> 200
SAC46	Merritt Island	25 - 100	100 - 200	25 - 100	> 200	25 - 100
SAC47	Reclamation District 551	<25	> 200	<25	> 200	<25
SAC48	Courtland	<25	> 200	<25	> 200	<25
SAC49	Sutter Island	<25	> 200	<25	> 200	<25
SAC50	Grand Island	<25	> 200	<25	> 200	<25
SAC51	Locke	100 - 200	> 200	100 - 200	> 200	> 200
SAC52	Walnut Grove	100 - 200	> 200	100 - 200	> 200	> 200
SAC53	Tyler Island	<25	> 200	<25	> 200	<25
SAC54	Andrus Island	25 - 100	100 - 200	25 - 100	> 200	25 - 100
SAC55	Ryer Island	<25	> 200	<25	> 200	<25
SAC56	Prospect Island	<25	> 200	<25	> 200	<25
SAC57	Twitchell Island	100 - 200	> 200	100 - 200	> 200	100 - 200
SAC58	Sherman Island	<25	> 200	<25	> 200	<25
SAC59	Moore	<25	25 - 100	<25	25 - 100	<25
SAC60	Cache Slough	<25	<25	<25	<25	<25
SAC61	Hastings	<25	25 - 100	<25	> 200	<25
SAC62	Lindsey Slough	<25	> 200	<25	> 200	<25
SAC63	Sacramento South	25 - 100	100 - 200	> 200	> 200	> 200

Note: The HEC-FDA expected flooding return period for each damage area is based on its corresponding levee performance curve and overall systemwide hydraulic performance upstream of the damage area. For the purposes of hydraulic modeling on a systemwide scale, a reconstructed levee is assumed to have zero probability of failure until it is overtopped.

Key:
EFSC = Enhance Flood System Capacity Approach
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis
PHRC = Protect High Risk Communities Approach
RD = Reclamation District
SPFC = Achieve SPFC Design Flow Capacity Approach
SSIA = State Systemwide Investment Approach

Table 4-3. HEC-FDA Expected Annual Damages for the San Joaquin River Basin and Stockton Area in 2010 October $1,000 – No Project

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ01	Fresno	76	3	7	86
SJ02	Fresno Slough East	94	364	5	463
SJ03	Fresno Slough West	6	80	0	86
SJ04	Mendota	27	0	0	28
SJ05	Chowchilla Bypass	41	728	0	769
SJ06	Lone Willow Slough	15	464	0	479
SJ07	Mendota North	1	10	0	10
SJ08	Firebaugh	22	0	0	22
SJ09	Salt Slough	909	2,092	84	3,085
SJ10	Dos Palos	235	18	4	256
SJ11	Fresno River	7	489	0	496
SJ12	Berenda Slough	271	3,436	10	3,716
SJ13	Ash Slough	25	724	6	754
SJ14	Sandy Mush	10	429	1	440
SJ15	Turner Island	46	2,500	0	2,546
SJ16	Bear Creek	12	29	1	42
SJ17	Deep Slough	6	27	0	33
SJ18	West Bear Creek	31	91	7	129
SJ19	Fremont Ford	3	4	0	8
SJ20	Merced River	142	842	27	1,011
SJ21	Merced River North	86	218	71	376
SJ22	Orestimba	25	30	13	68
SJ23	Tuolumne South	57	239	8	303
SJ24	Tuolumne River	247	18	70	335
SJ25	Modesto	237	1	192	431
SJ26	Three Amigos	18	221	6	245
SJ27	Stanislaus South	44	131	8	183
SJ28	Stanislaus North	277	346	33	656
SJ29	Banta Carbona	123	127	2	251
SJ30	Paradise Cut	33	183	2	218
SJ31	Stewart Tract	0	2	0	2
SJ32	East Lathrop	35	7	29	71

Table 4-3. HEC-FDA Expected Annual Damages for the San Joaquin River Basin and Stockton Area in 2010 October $1,000 – No Project (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ33	Lathrop/Sharpe	1,189	6	117	1,312
SJ34	French Camp	54	3	0	58
SJ35	Moss Tract	163	0	17	180
SJ36	Roberts Island	134	647	6	787
SJ37	Rough and Ready Island	0	1	1	2
SJ38	Drexler Tract	17	68	6	91
SJ39	Union Island	22	81	5	107
SJ40	Union Island Toe	10	15	0	25
SJ41	Fabian Tract	3	14	0	17
SJ42	Reclamation District 1007	8	9	0	17
SJ43	Grayson	28	0	1	29
STK01	Lower Roberts Island	108	537	72	716
STK06	Stockton East	124	8	32	163
STK07	Calaveras River	802	0	39	840
STK08	Bear Creek South	568	0	1	569
STK09	Bear Creek North	616	2	0	618
STK10	Central Stockton	1,786	1	79	1,866
	Total	**8,791**	**15,243**	**962**	**24,996**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-4. HEC-FDA Expected Flooding Return Period in Years for San Joaquin River Basin and Stockton Area – All Approaches

Damage Area	Description	No Project	SPFC	PHRC	EFSC	SSIA
SJ01	Fresno	> 200	> 200	> 200	> 200	> 200
SJ02	Fresno Slough East	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ03	Fresno Slough West	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ04	Mendota	25 - 100	25 - 100	25 - 100	100 - 200	25 - 100
SJ05	Chowchilla Bypass	<25	25 - 100	<25	100 - 200	<25
SJ06	Lone Willow Slough	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ07	Mendota North	> 200	> 200	> 200	> 200	> 200
SJ08	Firebaugh	> 200	> 200	> 200	> 200	> 200
SJ09	Salt Slough	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ10	Dos Palos	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ11	Fresno River	<25	> 200	<25	> 200	<25
SJ12	Berenda Slough	<25	> 200	<25	> 200	<25
SJ13	Ash Slough	<25	> 200	<25	> 200	<25
SJ14	Sandy Mush	<25	> 200	<25	100 - 200	<25
SJ15	Turner Island	<25	25 - 100	<25	25 - 100	<25
SJ16	Bear Creek	100 - 200	100 - 200	100 - 200	100 - 200	100 - 200
SJ17	Deep Slough	25 - 100	> 200	25 - 100	> 200	25 - 100
SJ18	West Bear Creek	<25	100 - 200	<25	> 200	<25
SJ19	Fremont Ford	> 200	> 200	> 200	> 200	> 200
SJ20	Merced River	<25	<25	<25	<25	<25
SJ21	Merced River North	25 - 100	> 200	25 - 100	> 200	25 - 100
SJ22	Orestimba	<25	> 200	<25	> 200	<25
SJ23	Tuolumne South	<25	<25	<25	<25	<25
SJ24	Tuolumne River	<25	<25	> 200	> 200	> 200
SJ25	Modesto	> 200	> 200	> 200	> 200	> 200
SJ26	Three Amigos	<25	> 200	<25	> 200	<25
SJ27	Stanislaus South	<25	100 - 200	<25	> 200	<25
SJ28	Stanislaus North	25 - 100	25 - 100	25 - 100	> 200	25 - 100
SJ29	Banta Carbona	<25	> 200	<25	> 200	<25
SJ30	Paradise Cut	<25	> 200	<25	> 200	<25
SJ31	Stewart Tract	> 200	> 200	> 200	> 200	> 200
SJ32	East Lathrop	> 200	> 200	> 200	> 200	> 200

Table 4-4. HEC-FDA Expected Flooding Return Period in Years for San Joaquin River Basin and Stockton Area – All Approaches (contd.)

Damage Area	Description	No Project	SPFC	PHRC	EFSC	SSIA
SJ33	Lathrop/Sharpe	100 - 200	> 200	> 200	> 200	> 200
SJ34	French Camp	> 200	> 200	> 200	> 200	> 200
SJ35	Moss Tract	100 - 200	> 200	> 200	> 200	> 200
SJ36	Roberts Island	<25	> 200	<25	> 200	<25
SJ37	Rough and Ready Island	> 200	> 200	> 200	> 200	> 200
SJ38	Drexler Tract	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ39	Union Island	25 - 100	25 - 100	25 - 100	25 - 100	25 - 100
SJ40	Union Island Toe	25 - 100	> 200	25 - 100	> 200	25 - 100
SJ41	Fabian Tract	100 - 200	100 - 200	100 - 200	> 200	100 - 200
SJ42	Reclamation District 1007	> 200	100 - 200	> 200	100 - 200	> 200
SJ43	Grayson	100 - 200	> 200	100 - 200	> 200	100 - 200
STK01	Lower Roberts Island	<25	> 200	> 200	> 200	> 200
STK06	Stockton East	25 - 100	100 - 200	100 - 200	100 - 200	100 - 200
STK07	Calaveras River	100 - 200	> 200	> 200	> 200	> 200
STK08	Bear Creek South	100 - 200	100 - 200	100 - 200	100 - 200	100 - 200
STK09	Bear Creek North	25 - 100	100 - 200	100 - 200	100 - 200	100 - 200
STK10	Central Stockton	<25	> 200	> 200	> 200	> 200

Note: The HEC-FDA expected flooding return period for each damage area is based on its corresponding levee performance curve and overall systemwide hydraulic performance upstream of the damage area. For the purposes of hydraulic modeling on a systemwide scale, a reconstructed levee is assumed to have zero probability of failure until it is overtopped.

Key:
EFSC = Enhance Flood System Capacity Approach
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis
PHRC = Protect High Risk Communities Approach
SPFC = Achieve SPFC Design Flow Capacity Approach
SSIA = State Systemwide Investment Approach

Table 4-5. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – Achieve SPFC Design Flow Capacity Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC01	Woodson Bridge East	27	213	8	247
SAC02	Woodson Bridge West	4	10	0	13
SAC03	Hamilton City	519	0	35	554
SAC04	Capay	46	735	76	857
SAC05	Butte Basin	38	130	23	191
SAC06	Butte City	2	0	0	2
SAC07	Colusa Basin North	47	28	10	85
SAC08	Colusa	87	1	4	92
SAC09	Colusa Basin South	42	61	6	110
SAC10	Grimes	5	0	0	5
SAC11	Reclamation District 1500 West	14	23	5	43
SAC12	Sycamore Slough	0	7	0	8
SAC13	Knight's Landing	622	2	205	829
SAC14	Ridge Cut (North)	1	13	0	14
SAC15	Ridge Cut (South)	1	2	0	3
SAC16	Reclamation District 2035	6	9	0	16
SAC17	East of Davis	87	3	10	101
SAC18	Upper Honcut	9	13	0	22
SAC20	Gridley	237	2	3	243
SAC21	Sutter Buttes East	232	68	16	316
SAC22	Live Oak	357	1	15	373
SAC23	Lower Honcut	98	88	31	217
SAC24	Levee District No.1	155	0	8	164
SAC25	Yuba City	4,694	12	698	5,404
SAC26	Marysville	271	0	80	350
SAC27	Linda-Olivehurst	1,678	18	470	2,166
SAC28	Reclamation District 784	956	95	28	1,079
SAC29	Best Slough	54	43	7	104
SAC30	Reclamation District 1001	30	35	5	71
SAC32	Reclamation District 70-1660	45	83	22	149
SAC33	Meridian	30	0	11	41

Table 4-5. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – Achieve SPFC Design Flow Capacity Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC34	Reclamation District 1500 East	21	19	18	58
SAC35	Elkhorn	35	194	1	230
SAC36	Natomas	15,551	67	4,333	19,951
SAC37	Rio Linda	3,568	3	2,311	5,882
SAC38	West Sacramento	3,280	0	1,581	4,862
SAC39	Reclamation District 900	2,094	7	81	2,182
SAC40	Sacramento North	11,665	0	7,553	19,219
SAC41	Reclamation District 302	13	62	0	76
SAC42	Reclamation District 999	90	114	2	206
SAC43	Clarksburg	73	0	16	90
SAC44	Stone Lake	6,310	155	402	6,868
SAC45	Hood	63	0	177	240
SAC46	Merritt Island	17	92	0	109
SAC47	Reclamation District 551	40	104	113	256
SAC48	Courtland	55	0	55	111
SAC49	Sutter Island	0	8	0	8
SAC50	Grand Island	1	1	0	2
SAC51	Locke	28	2	88	118
SAC52	Walnut Grove	0	0	0	0
SAC53	Tyler Island	0	0	0	0
SAC54	Andrus Island	225	91	124	441
SAC55	Ryer Island	0	0	0	0
SAC56	Prospect Island	1	2	1	4
SAC57	Twitchell Island	0	0	0	0
SAC58	Sherman Island	21	5	68	93
SAC59	Moore	34	27	0	61
SAC60	Cache Slough	18	24	0	42
SAC61	Hastings	8	29	0	37
SAC62	Lindsey Slough	3	6	0	9
SAC63	Sacramento South	66,184	5	34,860	101,049
	Total	**119,796**	**2,714**	**53,562**	**176,072**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis
SPFC = State Plan of Flood Control

Table 4-6. HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – Achieve SPFC Design Flow Capacity Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ01	Fresno	76	3	7	86
SJ02	Fresno Slough East	95	359	5	459
SJ03	Fresno Slough West	6	80	0	86
SJ04	Mendota	28	0	0	28
SJ05	Chowchilla Bypass	17	381	0	398
SJ06	Lone Willow Slough	110	481	0	591
SJ07	Mendota North	1	10	0	10
SJ08	Firebaugh	26	0	0	26
SJ09	Salt Slough	725	1,643	65	2,433
SJ10	Dos Palos	193	14	3	209
SJ11	Fresno River	1	36	0	37
SJ12	Berenda Slough	15	70	0	86
SJ13	Ash Slough	9	34	1	44
SJ14	Sandy Mush	2	6	0	9
SJ15	Turner Island	15	256	0	271
SJ16	Bear Creek	13	35	1	49
SJ17	Deep Slough	3	9	0	12
SJ18	West Bear Creek	19	20	2	40
SJ19	Fremont Ford	1	0	0	1
SJ20	Merced River	138	840	27	1,004
SJ21	Merced River North	28	15	8	51
SJ22	Orestimba	3	1	1	4
SJ23	Tuolumne South	89	328	11	428
SJ24	Tuolumne River	289	18	70	377
SJ25	Modesto	238	1	193	432
SJ26	Three Amigos	13	45	2	60
SJ27	Stanislaus South	26	40	3	69
SJ28	Stanislaus North	230	141	17	387
SJ29	Banta Carbona	207	37	2	247
SJ30	Paradise Cut	3	2	0	5
SJ31	Stewart Tract	0	2	0	2
SJ32	East Lathrop	30	5	22	57

Table 4-6 HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – Achieve SPFC Design Flow Capacity Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ33	Lathrop/Sharpe	598	2	32	631
SJ34	French Camp	1,125	16	0	1,142
SJ35	Moss Tract	3	0	0	3
SJ36	Roberts Island	23	42	1	67
SJ37	Rough and Ready Island	0	1	1	2
SJ38	Drexler Tract	32	93	10	135
SJ39	Union Island	28	205	7	241
SJ40	Union Island Toe	2	3	0	5
SJ41	Fabian Tract	5	24	1	29
SJ42	Reclamation District 1007	11	14	0	24
SJ43	Grayson	32	0	1	33
STK01	Lower Roberts Island	0	0	0	0
STK06	Stockton East	46	4	17	67
STK07	Calaveras River	15	0	0	15
STK08	Bear Creek South	27	0	0	27
STK09	Bear Creek North	22	0	0	22
STK10	Central Stockton	0	0	0	0
	Total	**4,615**	**5,315**	**511**	**10,441**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis
SPFC = State Plan of Flood Control

Table 4-7. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – Protect High Risk Communities Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC01	Woodson Bridge East	26	213	8	246
SAC02	Woodson Bridge West	4	9	0	13
SAC03	Hamilton City	488	0	32	521
SAC04	Capay	37	730	74	842
SAC05	Butte Basin	239	2,339	187	2,764
SAC06	Butte City	6	0	0	6
SAC07	Colusa Basin North	65	65	18	149
SAC08	Colusa	55	1	4	61
SAC09	Colusa Basin South	159	515	55	728
SAC10	Grimes	8	1	0	10
SAC11	Reclamation District 1500 West	109	190	56	356
SAC12	Sycamore Slough	1	45	0	45
SAC13	Knight's Landing	1,311	3	255	1,568
SAC14	Ridge Cut (North)	1	38	0	39
SAC15	Ridge Cut (South)	9	68	0	77
SAC16	Reclamation District 2035	3	265	1	269
SAC17	East of Davis	56	2	7	65
SAC18	Upper Honcut	24	60	0	83
SAC20	Gridley	410	17	9	437
SAC21	Sutter Buttes East	501	496	46	1,043
SAC22	Live Oak	781	8	40	828
SAC23	Lower Honcut	181	161	62	405
SAC24	Levee District No.1	1,424	2,238	498	4,159
SAC25	Yuba City	3,919	10	583	4,511
SAC26	Marysville	282	0	83	365
SAC27	Linda-Olivehurst	1,683	18	470	2,171
SAC28	Reclamation District 784	783	80	24	887
SAC29	Best Slough	388	323	29	740
SAC30	Reclamation District 1001	218	1,540	35	1,793
SAC32	Reclamation District 70-1660	185	456	114	755
SAC33	Meridian	138	2	61	201

Table 4-7. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – Protect High Risk Communities Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC34	Reclamation District 1500 East	192	467	233	893
SAC35	Elkhorn	113	1,357	5	1,476
SAC36	Natomas	3,671	15	1,192	4,878
SAC37	Rio Linda	1,813	1	1,088	2,902
SAC38	West Sacramento	2,135	0	987	3,122
SAC39	Reclamation District 900	660	2	23	685
SAC40	Sacramento North	5,454	0	3,082	8,536
SAC41	Reclamation District 302	24	79	1	104
SAC42	Reclamation District 999	82	112	2	196
SAC43	Clarksburg	55	0	13	68
SAC44	Stone Lake	380	11	26	417
SAC45	Hood	4	0	12	17
SAC46	Merritt Island	81	124	0	205
SAC47	Reclamation District 551	172	1,089	703	1,964
SAC48	Courtland	257	3	306	566
SAC49	Sutter Island	18	767	0	785
SAC50	Grand Island	570	1,490	300	2,361
SAC51	Locke	22	4	59	85
SAC52	Walnut Grove	15	0	7	22
SAC53	Tyler Island	92	400	116	608
SAC54	Andrus Island	120	203	92	416
SAC55	Ryer Island	96	565	0	661
SAC56	Prospect Island	14	133	24	171
SAC57	Twitchell Island	3	0	0	3
SAC58	Sherman Island	178	211	585	975
SAC59	Moore	32	84	0	115
SAC60	Cache Slough	3	10	0	13
SAC61	Hastings	22	121	0	143
SAC62	Lindsey Slough	66	237	0	304
SAC63	Sacramento South	29,655	2	13,488	43,145
	Total	**59,496**	**17,381**	**101,972**	**25,095**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-8. HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – Protect High Risk Communities Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ01	Fresno	76	3	7	86
SJ02	Fresno Slough East	94	364	5	463
SJ03	Fresno Slough West	6	80	0	86
SJ04	Mendota	27	0	0	28
SJ05	Chowchilla Bypass	41	728	0	769
SJ06	Lone Willow Slough	15	464	0	479
SJ07	Mendota North	1	10	0	10
SJ08	Firebaugh	24	0	0	24
SJ09	Salt Slough	899	2,062	83	3,044
SJ10	Dos Palos	235	18	4	256
SJ11	Fresno River	7	489	0	496
SJ12	Berenda Slough	271	3,436	10	3,716
SJ13	Ash Slough	25	724	6	754
SJ14	Sandy Mush	12	429	1	442
SJ15	Turner Island	46	2,500	0	2,546
SJ16	Bear Creek	12	29	1	42
SJ17	Deep Slough	6	27	0	33
SJ18	West Bear Creek	31	91	7	129
SJ19	Fremont Ford	3	4	0	8
SJ20	Merced River	142	842	27	1,011
SJ21	Merced River North	87	219	72	378
SJ22	Orestimba	24	31	13	69
SJ23	Tuolumne South	71	278	9	357
SJ24	Tuolumne River	147	9	30	186
SJ25	Modesto	238	1	193	432
SJ26	Three Amigos	22	247	7	276
SJ27	Stanislaus South	45	133	8	186
SJ28	Stanislaus North	274	342	33	649
SJ29	Banta Carbona	121	125	2	248
SJ30	Paradise Cut	33	182	2	217
SJ31	Stewart Tract	0	2	0	2
SJ32	East Lathrop	24	3	16	43

Table 4-8. HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – Protect High Risk Communities Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ33	Lathrop/Sharpe	169	1	10	180
SJ34	French Camp	0	0	0	0
SJ35	Moss Tract	0	0	0	0
SJ36	Roberts Island	126	625	6	756
SJ37	Rough and Ready Island	0	0	0	0
SJ38	Drexler Tract	18	68	6	92
SJ39	Union Island	21	76	4	101
SJ40	Union Island Toe	10	14	0	24
SJ41	Fabian Tract	3	14	0	17
SJ42	Reclamation District 1007	8	9	0	17
SJ43	Grayson	32	0	1	33
STK01	Lower Roberts Island	0	0	0	0
STK06	Stockton East	46	4	17	67
STK07	Calaveras River	15	0	0	15
STK08	Bear Creek South	27	0	0	27
STK09	Bear Creek North	22	0	0	22
STK10	Central Stockton	0	0	0	0
	Total	**3,553**	**14,684**	**582**	**18,819**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-9. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – Enhance Flood System Capacity Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC01	Woodson Bridge East	26	213	8	246
SAC02	Woodson Bridge West	4	9	0	13
SAC03	Hamilton City	492	0	34	526
SAC04	Capay	38	731	75	844
SAC05	Butte Basin	15	49	8	72
SAC06	Butte City	1	0	0	1
SAC07	Colusa Basin North	37	23	8	67
SAC08	Colusa	33	0	2	35
SAC09	Colusa Basin South	0	1	0	2
SAC10	Grimes	0	0	0	0
SAC11	Reclamation District 1500 West	5	10	2	17
SAC12	Sycamore Slough	0	27	0	28
SAC13	Knight's Landing	171	0	56	227
SAC14	Ridge Cut (North)	0	5	0	5
SAC15	Ridge Cut (South)	1.5	6	0	7
SAC16	Reclamation District 2035	7	7	0	15
SAC17	East of Davis	101	4	12	117
SAC18	Upper Honcut	7	10	0	18
SAC20	Gridley	168	2	2	172
SAC21	Sutter Buttes East	161	44	11	216
SAC22	Live Oak	245	1	10	255
SAC23	Lower Honcut	69	0	0	69
SAC24	Levee District No.1	0	0	0	0
SAC25	Yuba City	3,361	8	488	3,857
SAC26	Marysville	343	0	102	445
SAC27	Linda-Olivehurst	1,645	18	453	2,116
SAC28	Reclamation District 784	335	30	9	375
SAC29	Best Slough	105	43	7	155
SAC30	Reclamation District 1001	29	35	5	69
SAC32	Reclamation District 70-1660	2	3	1	6
SAC33	Meridian	1	0	0	1

Table 4-9. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – Enhance Flood System Capacity Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC34	Reclamation District 1500 East	16	15	14	46
SAC35	Elkhorn	16	91	1	108
SAC36	Natomas	2,086	8	641	2,735
SAC37	Rio Linda	1,434	1	809	2,244
SAC38	West Sacramento	1,356	0	597	1,954
SAC39	Reclamation District 900	452	1	15	469
SAC40	Sacramento North	5,410	0	3,101	8,511
SAC41	Reclamation District 302	6	0	0	6
SAC42	Reclamation District 999	47	57	1	105
SAC43	Clarksburg	2	0	0	3
SAC44	Stone Lake	308	4	10	321
SAC45	Hood	2	0	4	6
SAC46	Merritt Island	16	48	0	64
SAC47	Reclamation District 551	18	54	58	130
SAC48	Courtland	28	0	0	28
SAC49	Sutter Island	0	8	0	8
SAC50	Grand Island	29	27	12	69
SAC51	Locke	19	1	61	82
SAC52	Walnut Grove	2	0	1	3
SAC53	Tyler Island	0	1	0	2
SAC54	Andrus Island	120	55	74	248
SAC55	Ryer Island	1	2	0	3
SAC56	Prospect Island	1	2	1	4
SAC57	Twitchell Island	0	0	0	0
SAC58	Sherman Island	144	189	412	745
SAC59	Moore	17	15	0	32
SAC60	Cache Slough	15	14	0	29
SAC61	Hastings	3	12	0	15
SAC62	Lindsey Slough	3	6	0	8
SAC63	Sacramento South	20,620	1	9,338	29,959
	Total	**39,575**	**1,891**	**57,911**	**16,446**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-10. HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – Enhance Flood System Capacity Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ01	Fresno	49	2	5	56
SJ02	Fresno Slough East	48	181	3	232
SJ03	Fresno Slough West	5	59	0	64
SJ04	Mendota	25	0	0	25
SJ05	Chowchilla Bypass	5	51	0	56
SJ06	Lone Willow Slough	74	304	0	378
SJ07	Mendota North	0	6	0	6
SJ08	Firebaugh	24	0	0	24
SJ09	Salt Slough	395	947	33	1,375
SJ10	Dos Palos	105	8	1	114
SJ11	Fresno River	1	36	0	37
SJ12	Berenda Slough	15	70	0	85
SJ13	Ash Slough	9	34	1	44
SJ14	Sandy Mush	3	8	0	12
SJ15	Turner Island	9	158	0	167
SJ16	Bear Creek	13	33	1	47
SJ17	Deep Slough	3	8	0	11
SJ18	West Bear Creek	1	1	0	2
SJ19	Fremont Ford	1	1	0	2
SJ20	Merced River	113	842	27	982
SJ21	Merced River North	0	0	0	0
SJ22	Orestimba	0	0	0	0
SJ23	Tuolumne South	44	152	5	202
SJ24	Tuolumne River	11	1	5	17
SJ25	Modesto	170	1	146	316
SJ26	Three Amigos	5	16	1	22
SJ27	Stanislaus South	8	11	1	20
SJ28	Stanislaus North	105	37	4	146
SJ29	Banta Carbona	92	16	1	110
SJ30	Paradise Cut	2	1	0	3
SJ31	Stewart Tract	0	0	0	0
SJ32	East Lathrop	14	2	10	27

Table 4-10. HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – Enhance Flood System Capacity Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ33	Lathrop/Sharpe	231	1	12	244
SJ34	French Camp	0	4	0	4
SJ35	Moss Tract	0	0	0	0
SJ36	Roberts Island	5	16	0	22
SJ37	Rough and Ready Island	0	0	0	0
SJ38	Drexler Tract	1	73	7	81
SJ39	Union Island	14	58	3	75
SJ40	Union Island Toe	0	1	0	2
SJ41	Fabian Tract	2	11	0	13
SJ42	Reclamation District 1007	9	10	0	20
SJ43	Grayson	4	0	0	4
STK01	Lower Roberts Island	0	0	0	0
STK06	Stockton East	46	4	17	67
STK07	Calaveras River	15	0	0	15
STK08	Bear Creek South	27	0	0	27
STK09	Bear Creek North	22	0	0	22
STK10	Central Stockton	0	0	0	0
	Total	**1,726**	**3,165**	**285**	**5,176**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-11. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – State Systemwide Investment Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC01	Woodson Bridge East	26	213	8	246
SAC02	Woodson Bridge West	4	9	0	13
SAC03	Hamilton City	489	0	32	521
SAC04	Capay	37	729	74	840
SAC05	Butte Basin	252	2,403	198	2,854
SAC06	Butte City	6	0	0	6
SAC07	Colusa Basin North	65	65	18	149
SAC08	Colusa	61	1	5	66
SAC09	Colusa Basin South	143	453	49	644
SAC10	Grimes	7	1	0	8
SAC11	Reclamation District 1500 West	64	101	33	198
SAC12	Sycamore Slough	0	27	0	28
SAC13	Knight's Landing	382	2	203	586
SAC14	Ridge Cut (North)	1	25	0	26
SAC15	Ridge Cut (South)	10	79	0	89
SAC16	Reclamation District 2035	11	267	1	280
SAC17	East of Davis	62	2	7	72
SAC18	Upper Honcut	26	61	0	88
SAC20	Gridley	345	8	6	359
SAC21	Sutter Buttes East	481	211	28	720
SAC22	Live Oak	807	3	25	835
SAC23	Lower Honcut	136	118	46	299
SAC24	Levee District No.1	296	0	25	321
SAC25	Yuba City	3,480	8	512	4,000
SAC26	Marysville	298	0	88	386
SAC27	Linda-Olivehurst	1,657	18	462	2,137
SAC28	Reclamation District 784	706	73	21	800
SAC29	Best Slough	388	323	29	740
SAC30	Reclamation District 1001	306	1,380	29	1,715
SAC32	Reclamation District 70-1660	226	640	159	1,025
SAC33	Meridian	200	3	84	286

Table 4-11. HEC-FDA Expected Annual Damages for Sacramento River Basin in 2010 October $1,000 – State Systemwide Investment Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SAC34	Reclamation District 1500 East	121	360	152	633
SAC35	Elkhorn	99	1,387	6	1,491
SAC36	Natomas	3,966	16	1,287	5,269
SAC37	Rio Linda	1,796	1	1,076	2,874
SAC38	West Sacramento	2,165	0	997	3,162
SAC39	Reclamation District 900	654	2	23	679
SAC40	Sacramento North	5,496	0	3,105	8,601
SAC41	Reclamation District 302	21	71	1	93
SAC42	Reclamation District 999	84	109	2	195
SAC43	Clarksburg	59	0	14	73
SAC44	Stone Lake	224	7	15	246
SAC45	Hood	3	0	7	10
SAC46	Merritt Island	55	84	0	139
SAC47	Reclamation District 551	156	912	526	1,594
SAC48	Courtland	247	3	228	479
SAC49	Sutter Island	15	620	0	635
SAC50	Grand Island	457	1,279	224	1,959
SAC51	Locke	16	3	37	56
SAC52	Walnut Grove	13	0	5	18
SAC53	Tyler Island	86	358	88	532
SAC54	Andrus Island	63	172	58	293
SAC55	Ryer Island	76	486	0	562
SAC56	Prospect Island	13	105	20	137
SAC57	Twitchell Island	0	0	0	0
SAC58	Sherman Island	166	210	508	884
SAC59	Moore	34	84	0	118
SAC60	Cache Slough	3	9	0	12
SAC61	Hastings	16	96	0	112
SAC62	Lindsey Slough	49	191	0	240
SAC63	Sacramento South	27,371	2	12,525	39,897
	Total	**54,497**	**13,791**	**23,044**	**91,332**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

Table 4-12. HEC-FDA Expected Annual Damages for San Joaquin River Basin and Stockton Area in 2010 October $1,000 – State Systemwide Investment Approach

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ01	Fresno	76	3	7	86
SJ02	Fresno Slough East	94	364	5	463
SJ03	Fresno Slough West	6	80	0	86
SJ04	Mendota	27	0	0	28
SJ05	Chowchilla Bypass	41	728	0	769
SJ06	Lone Willow Slough	15	464	0	479
SJ07	Mendota North	1	10	0	10
SJ08	Firebaugh	24	0	0	24
SJ09	Salt Slough	899	2,062	83	3,044
SJ10	Dos Palos	235	18	4	256
SJ11	Fresno River	7	489	0	496
SJ12	Berenda Slough	271	3,436	10	3,716
SJ13	Ash Slough	25	724	6	754
SJ14	Sandy Mush	12	429	1	442
SJ15	Turner Island	46	2,500	0	2,546
SJ16	Bear Creek	12	29	1	42
SJ17	Deep Slough	6	27	0	33
SJ18	West Bear Creek	31	91	7	129
SJ19	Fremont Ford	3	4	0	8
SJ20	Merced River	142	842	27	1,011
SJ21	Merced River North	87	219	72	378
SJ22	Orestimba	24	31	13	69
SJ23	Tuolumne South	71	278	9	357
SJ24	Tuolumne River	147	9	30	186
SJ25	Modesto	238	1	193	432
SJ26	Three Amigos	22	247	7	276
SJ27	Stanislaus South	45	133	8	186
SJ28	Stanislaus North	274	342	33	649
SJ29	Banta Carbona	121	125	2	248
SJ30	Paradise Cut	33	182	2	217
SJ31	Stewart Tract	0	2	0	2
SJ32	East Lathrop	24	3	16	43

Table 4-12. HEC-FDA Expected Annual Damages for the San Joaquin River Basin and Stockton Area in 2010 October $1,000 – State Systemwide Investment Approach (contd.)

Damage Area	Description	Structure and Contents	Crop	Business Loss	Total
SJ33	Lathrop/Sharpe	169	1	10	180
SJ34	French Camp	0	0	0	0
SJ35	Moss Tract	0	0	0	0
SJ36	Roberts Island	126	625	6	757
SJ37	Rough and Ready Island	0	0	0	0
SJ38	Drexler Tract	19	70	6	95
SJ39	Union Island	21	73	4	98
SJ40	Union Island Toe	10	14	0	24
SJ41	Fabian Tract	3	14	0	17
SJ42	Reclamation District 1007	8	9	0	17
SJ43	Grayson	32	0	1	33
STK01	Lower Roberts Island	0	0	0	0
STK06	Stockton East	46	4	17	67
STK07	Calaveras River	15	0	0	15
STK08	Bear Creek South	27	0	0	27
STK09	Bear Creek North	22	0	0	22
STK10	Central Stockton	0	0	0	0
	Total	**3,554**	**14,683**	**582**	**18,819**

Key:
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis

4.6 Structures and Population at Risk

Structures and population at risk were determined for both river basins.

4.6.1 Structures at Risk

HAZUS-MH is a computer program developed by FEMA, under contract with the National Institute of Building Sciences, to assess potential losses from floods, hurricane winds, and earthquakes. HAZUS-MH comes bundled with a wide range of spatial and tabular data and uses GIS software (ArcGIS), to map and display hazard data. Figure 4-1 and Table 4-13 summarize core data from HAZUS-MH regarding at-risk structures inside the Systemwide Planning Area that CVFPP could apply to evaluate emergency cost. There are 2,861 at-risk facilities in the Systemwide Planning Area, including more than 1,500 highway bridges and about 700 schools, also, there are 1,847 miles of transportation segments in the Systemwide Planning Area; two-thirds are highways (FEMA, 2010).

In Figure 4-1, the following definitions of at-risk facilities are used:

- Transportation – airports, bus stations, ferries, highway bridges, light rail facilities, port facilities, railway facilities, railway bridges, and runway facilities
- High Potential Loss – dams and facilities with hazardous materials
- Emergency Facilities – care facilities, emergency centers, fire stations, police stations, and schools
- Utilities – telecommunication facilities, electric power facilities, oil facilities, potable water facilities, and wastewater treatment facilities

4.6.1 Population at Risk

Using the 2000 Census population data in HAZUS-MH, census blocks inside the Systemwide Planning Area were first identified; then, population in the Systemwide Planning Area was prorated based on block area inside the Systemwide Planning Area (U.S. Census Bureau, 2000). It was estimated that the total population inside the Systemwide Planning Area is 1,525,142. The same approach was applied to estimate the population inside each CVFPP HEC-FDA damage area; these numbers are summarized in Table 4-14 for the Sacramento River Basin and Table 4-15 for the San Joaquin River Basin (FEMA, 2010).

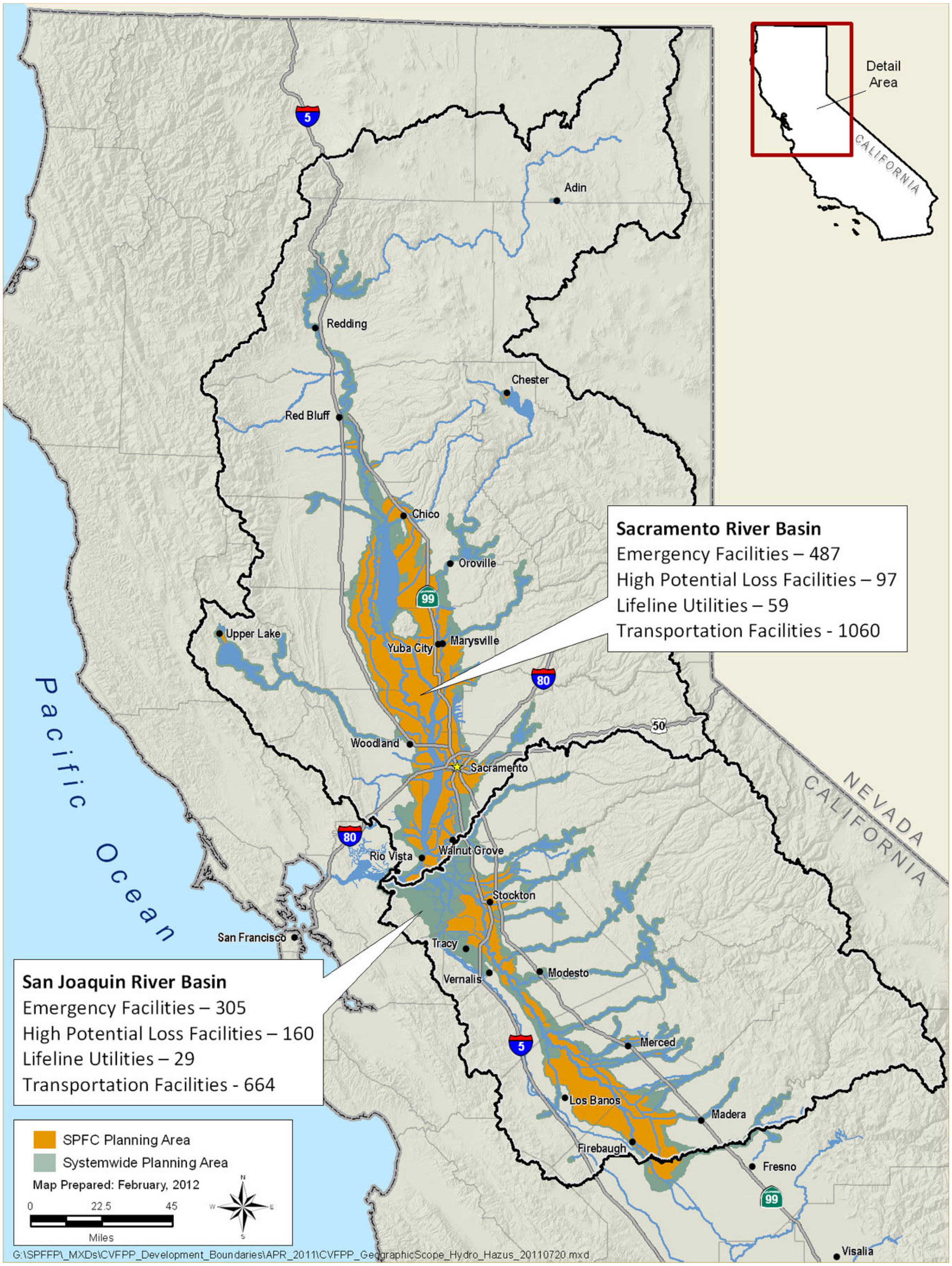

Figure 4-1. At-Risk Facilities in the Systemwide Planning Area

In the Sacramento River Basin, SAC63 (Sacramento South) has the largest population (413,736), followed by SAC40 (Sacramento North – 60,314) and SAC25 (Yuba City – 58,020). In the San Joaquin River Basin, STK10 (Central Stockton) has the largest population of 124,857, followed by STK07 (Calaveras River) – 52,026, STK08 (Bear Creek South) – 37,058, SJ25 (Modesto) - 16,344, SJ34 (French Camp - 13,245), SJ35 (Moss Tract - 10,501), and SJ33 (Lathrop/Sharpe – 10,342).

Table 4-13. Lengths of At-Risk Transportation Segments Inside Systemwide Planning Area

Segments	Total Miles
Highway	1,270
Light Rail	39
Railway	537
Total	**1,847**

Table 4-14. Population for CVFPP HEC-FDA Damage Areas – Sacramento River Basin

Damage Area	Description	Population	Damage Area	Description	Population
SAC01	Woodson Bridge East	714	SAC33	Meridian	214
SAC02	Woodson Bridge West	129	SAC34	RD 1500 East	329
SAC03	Hamilton City	2,068	SAC35	Elkhorn	170
SAC04	Capay	140	SAC36	Natomas	41,141
SAC05	Butte Basin	755	SAC37	Rio Linda	26,173
SAC06	Butte City	55	SAC38	West Sacramento	25,605
SAC07	Colusa Basin North	1,616	SAC39	RD 900	6,018
SAC08	Colusa	5,933	SAC40	Sacramento North	60,314
SAC09	Colusa Basin South	1,286	SAC41	RD 302	144
SAC10	Grimes	292	SAC42	RD 999	751
SAC11	RD 1500 West	578	SAC43	Clarksburg	292
SAC12	Sycamore Slough	64	SAC44	Stone Lake	39,386
SAC13	Knight's Landing	951	SAC45	Hood	182
SAC14	Ridge Cut (North)	156	SAC46	Merritt Island	214
SAC15	Ridge Cut (South)	65	SAC47	RD 551	597
SAC16	RD 2035	205	SAC48	Courtland	70
SAC17	East of Davis	1,785	SAC49	Sutter Island	121
SAC18	Upper Honcut	719	SAC50	Grand Island	1,174
SAC20	Gridley	6,859	SAC51	Locke	149
SAC21	Sutter Buttes East	5,465	SAC52	Walnut Grove	471
SAC22	Live Oak	6,328	SAC53	Tyler Island	62
SAC23	Lower Honcut	1,323	SAC54	Andrus Island	1,824
SAC24	Levee District. No.1	4,109	SAC55	Ryer Island	287
SAC25	Yuba City	58,020	SAC56	Prospect Island	2
SAC26	Marysville	12,320	SAC57	Twitchell Island	112
SAC27	Linda-Olivehurst	25,516	SAC58	Sherman Island	182
SAC28	RD 784	1,062	SAC59	Moore	140
SAC29	Best Slough	361	SAC60	Cache Slough	84
SAC30	RD 1001	1,272	SAC61	Hastings	48
SAC32	RD 70-1660	495	SAC62	Lindsey Slough	1,087
			SAC63	Sacramento South	413,736
					Grand Total Population = 761,717

Source: FEMA, 2010
Key:
CVFPP = Central Valley Flood Protection Plan
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis
RD = Reclamation District

Table 4-15. Population for CVFPP HEC-FDA Damage Areas – San Joaquin River Basin, Including Stockton Area

Damage Area	Description	Population	Damage Area	Description	Population
SJ01	Fresno	2,624	SJ26	Three Amigos	569
SJ02	Fresno Slough East	782	SJ27	Stanislaus South	156
SJ03	Fresno Slough West	58	SJ28	Stanislaus North	1,794
SJ04	Mendota	1,918	SJ29	Banta Carbona	4,840
SJ05	Chowchilla Bypass	359	SJ30	Paradise Cut	622
SJ06	Lone Willow Slough	812	SJ31	Stewart Tract	199
SJ07	Mendota North	71	SJ32	East Lathrop	333
SJ08	Firebaugh	6,181	SJ33	Lathrop/Sharpe	10,342
SJ09	Salt Slough	4,093	SJ34	French Camp	13,245
SJ10	Dos Palos	5,528	SJ35	Moss Tract	10,501
SJ11	Fresno River	66	SJ36	Roberts Island	488
SJ12	Berenda Slough	874	SJ37	Rough and Ready Island	1
SJ13	Ash Slough	359	SJ38	Drexler Tract	64
SJ14	Sandy Mush	11	SJ39	Union Island	519
SJ15	Turner Island	95	SJ40	Union Island Toe	12
SJ16	Bear Creek	257	SJ41	Fabian Tract	172
SJ17	Deep Slough	4	SJ42	RD 1007	1,066
SJ18	West Bear Creek	7	SJ43	Grayson	661
SJ19	Fremont Ford	846	STK01	Lower Roberts Island	321
SJ20	Merced River	830	STK06	Stockton East	465
SJ21	Merced River North	1,170	STK07	Calaveras River	52,026
SJ22	Orestimba	902	STK08	Bear Creek South	37,058
SJ23	Tuolumne South	414	STK09	Bear Creek North	4,220
SJ24	Tuolumne River	2,799	STK10	Central Stockton	124,857
SJ25	Modesto	16,344			
					Grand total population = 311,933

Source: FEMA, 2010

Key:
CVFPP = Central Valley Flood Protection Plan
HEC-FDA = Hydrologic Engineering Center Flood Damage Analysis
RD = Reclamation District

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6.0 Acronyms and Abbreviations

AEP	annual exceedence probability
Ag damage spreadsheet	Comprehensive Study Agricultural Damage Spreadsheet
APN	Assessor Parcel Number
Board	The Reclamation Board or Central Valley Flood Protection Board
Breach	levee failure
CDFA	California Department of Food and Agriculture
cfs	cubic feet per second
Comprehensive Study	Sacramento and San Joaquin River Basins Comprehensive Study
CPI	Consumer Price Index
CVFPP	Central Valley Flood Protection Plan
DDF	depth-damage function
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EAD	expected annual damages
EFSC	Enhance Flood System Capacity
EIA	Energy Information Administration
FEMA	Federal Emergency Management Agency
FloodSAFE	DWR FloodSAFE California
F-RAM	Flood Rapid Assessment Model
GIS	geographic information system
HEC-FDA	Hydrologic Engineering Center Flood Damage Analysis
HEC-RAS	Hydrologic Engineering Center River Analysis System
IMPLAN	IMPact Analysis for PLANning
LFPZ	Levee Flood Protection Zones
NED	national economic development
NFIP	National Flood Insurance Program

NRCS	Natural Resources Conservation Service
NULE	Non-Urban Levee Evaluation
OES	State Office of Emergency Services
P&G	Principles and Guidelines
PHRC	Protect High Risk Communities
RD	Reclamation District
Reclamation	U.S. Department of Interior, Bureau of Reclamation
SAFCA	Sacramento Area Flood Control Agency
SJAFCA	San Joaquin Area Flood Control Agency
SPFC	State Plan of Flood Control
SSIA	State Systemwide Investment Approach
Stage	maximum water surface elevation
State	State of California
TRLIA	Three Rivers Levee Improvement Authority
UC Davis	University of California, Davis
ULE	Urban Levee Evaluation
UNET	Unsteady flow through a NETwork of open channels
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture

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