CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

# Public Draft

## 2012 Central Valley Flood Protection Plan

# Attachment 8E: Levee Performance Curves

## January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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# 1.0 Introduction

This section provides the purpose of this attachment, background information (including planning areas, goals, and approaches), an overview levee performance curves, and report organization.

## 1.1 Purpose of this Attachment

The hydraulic and economic analysis of the State Plan of Flood Control (SPFC) facilities for the Central Valley Flood Protection Plan (CVFPP) is based on analysis methodologies and computer models developed for the 2002 Sacramento-San Joaquin River Basins Comprehensive Study (Comprehensive Study) conducted by the U.S. Army Corps of Engineers (USACE) and the California Department of Water Resources (DWR) between 1998 and 2002 (2002). In that study, levee performance curves[1] were used to describe the ability of a given levee segment to withstand specified water surface elevations without breaching.

To reflect the most current levee conditions, new levee performance curves were developed using the recently generated data and preliminary evaluations from DWR's Urban Levee Evaluation (ULE) and Non-Urban Levee Evaluation (NULE) levee segments/reaches in the Sacramento River (North) and San Joaquin River (South) basins, in lieu of the Comprehensive Study levee performance curves. The new levee performance curves were based on geotechnical data and evaluations performed through summer 2011.

This attachment first describes the expert consultation process that resulted in equations and techniques for using ULE and NULE data/preliminary evaluations to develop levee performance curves. Next, the methodology used to develop the levee performance curves is described and applied using the ULE and NULE data/preliminary evaluations.

## 1.2 Background

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, DWR has prepared a sustainable, integrated flood management plan called the CVFPP, for adoption by the Central Valley

[1] The term levee performance curves and fragility curves are synonymous.

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).

The DWR Levee Evaluations Program includes the ULE Project, covering State-federal Project (project) and appurtenant non-project levees in highly populated areas, and the NULE Project, which covers the remaining project and appurtenant non-project levees. The ULE Project includes approximately 470 miles of project and non-project levees protecting populations of 10,000 people or more, and the NULE Project includes 1,620 miles of project and non-project levees protecting populations of fewer than 10,000 people. Non-project levees are considered appurtenant and are included in the DWR Levee Evaluations Program when these levees protect part of an overflow basin partially protected by project levees or may impact the performance of project levees.

## 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.

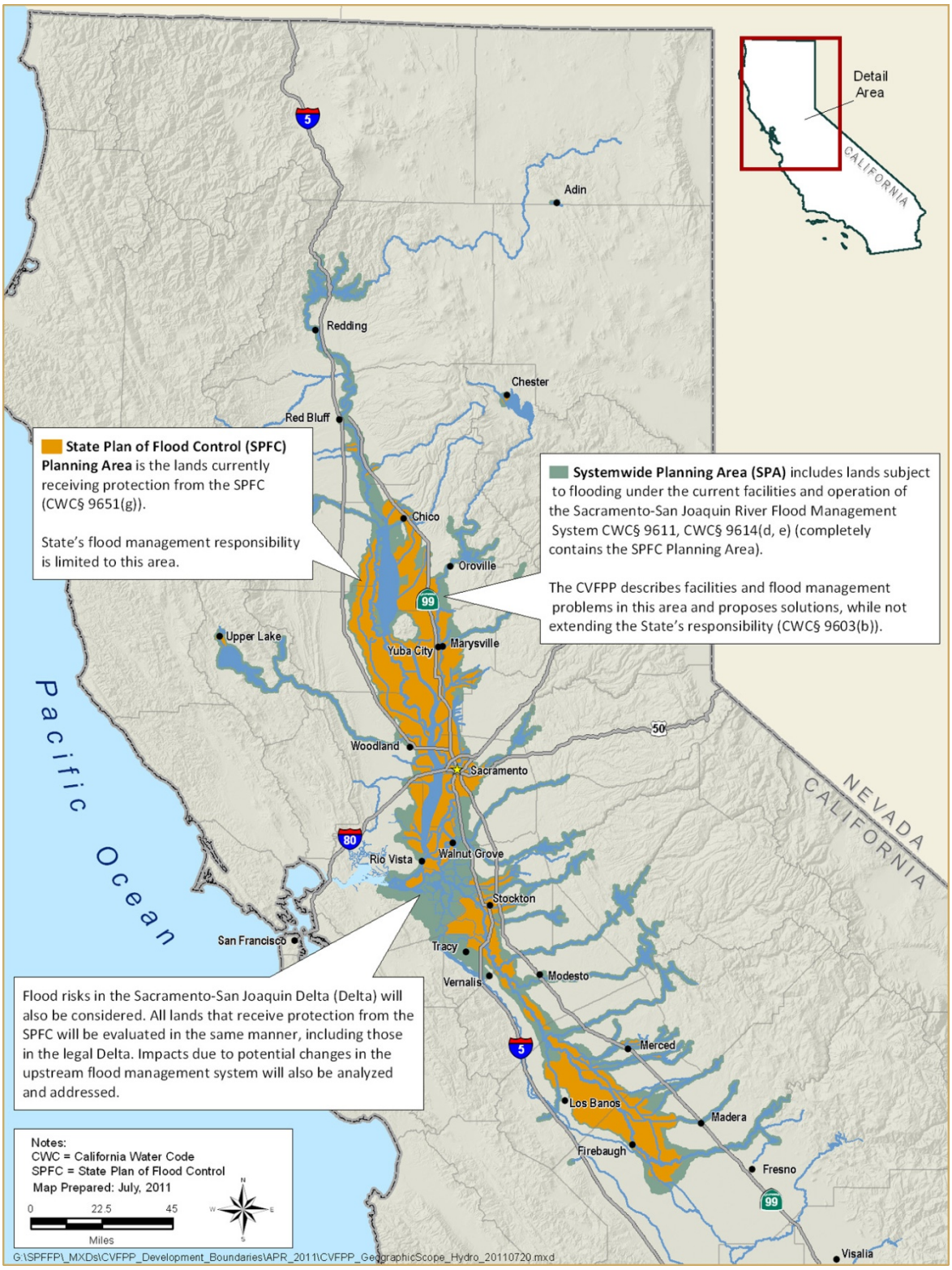



**Figure 1-1. Central Valley Flood Protection Plan Planning Areas**

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.

The newly developed levee performance curves are used to support geotechnical levee reliability for hydraulic models of the Sacramento and San Joaquin rivers and major tributaries contained within the SPFC Planning Area. Levee performance curves located within the Stockton Area are discussed in Attachment 8C: Riverine Channel Evaluations.

## 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

The work described in this attachment is related to the primary goal of improving flood risk management. The levee performance curves help to understand and model the way SPFC levees react to floodwaters and what improvements to the levees may be required to provide desired levels of protection.

## 1.5 2012 CVFPP Planning Approaches

In addition to **No Project**, three fundamentally different approaches to flood management were initially compared to explore potential improvements in the Central Valley. These approaches are not alternatives; rather, they bracket a range of potential actions and help explore tradeoffs 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.

The levee performance curves developed from the ULE and NULE data describe the No Project condition of the levees. Each of the approaches described above would require modifications or improvements to levees with levee performance curves that result in levels of protection lower than desired for a given location in the particular approach.

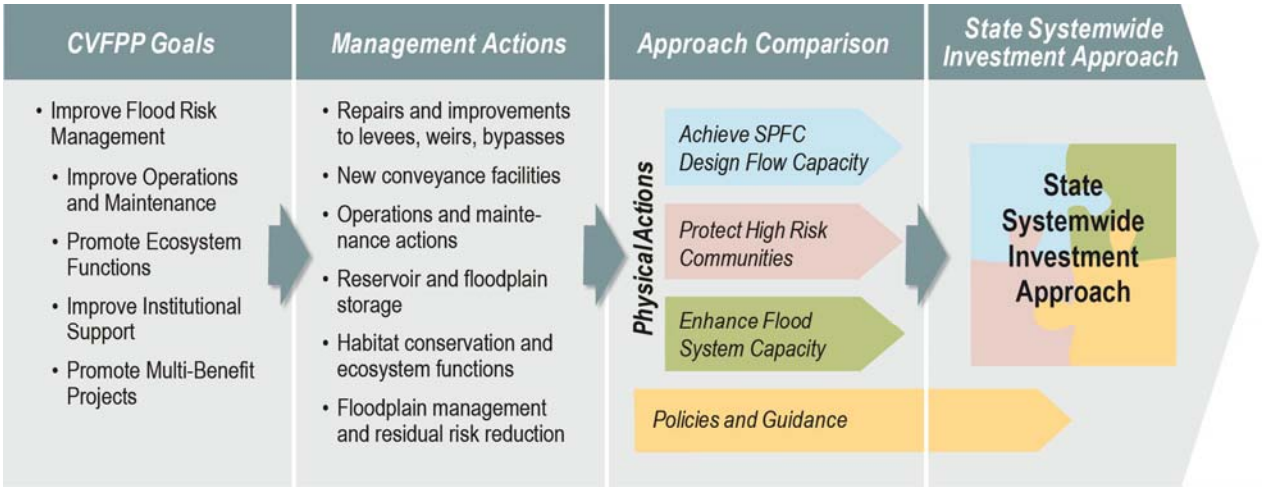



**Figure 1-2. Formulation Process for State Systemwide Investment Approach**

## 1.6 Levee Performance Curves

Levee performance curves developed for the CVFPP provide relationships between river water surface elevation (stage) and the probability that the levee segment will fail when exposed to that water surface elevation without human intervention (floodfighting). In this application, "failure" is defined as a levee breach in which water from the waterside of the levee is allowed to flow in an uncontrolled manner to the landside of the levee, potentially resulting in loss of life, personal injury, property damage, and economic loss. The approach used to develop levee performance curves herein generally follows a process similar to that described in the USACE Manual ETL 1102-2-556 (USACE, 1999).

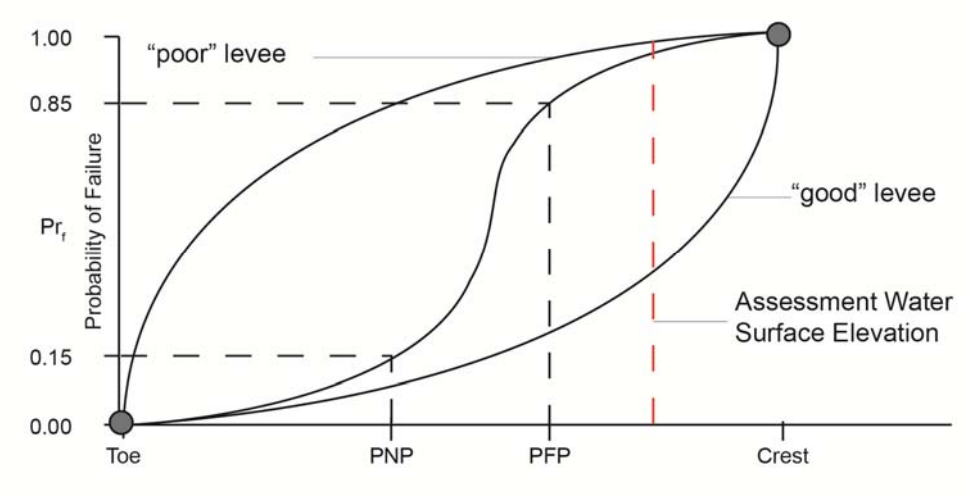
Figure 1-3 provides three example levee performance curves. The probability of failure is plotted on the vertical (dependent) axis and water surface elevation is plotted on the horizontal (independent) axis. Probability of failure is shown on the vertical or dependent axis because probability of failure is a function the channel stage. The range of water surface elevations of interest begin at the landside toe of a levee, below which the probability of failure is assumed to be zero, to the levee crest, where the probability of failure is assumed to be 100 percent because of overtopping.

The three example levee performance curves shown in Figure 1-3 represent the performance of a "poor" levee, a "good" levee, and a "generic" levee. The performance for the good levee shows a low probability of failure until higher water levels are reached and is concave upward, while the performance curve for the poor levee shows a high probability of failure even at low water surface elevations, and is concave downward (convex). The performance curve for the generic levee includes elements of both the poor and the good levees and follows a characteristic levee performance curve "s" shape.

An assessment water surface elevation is also shown in Figure 1-3. The ULE Project has performed geotechnical evaluations for a number of water surface elevations (e.g., 100- and 200-year flood levels). For the NULE Project, geotechnical assessments have been completed that consider likely levee performance at only a single design or assessment water surface elevation (typically the 1955/1957 water surface profile) (Kleinfelder, 2010 and URS, 2010b). For areas that require further study, additional NULE Project work may include geotechnical evaluations as for those areas as needed.

Figure 1-3 also shows the probable non-failure point (PNP) and probable failure point (PFP), representing 15 percent and 85 percent probabilities of

failure, respectively. Previous studies developing levee performance curves for Central Valley levees (e.g., Comprehensive Study, USACE, 2002) have made use of these terms, but they are not used in developing the levee performance curves for the CVFPP. The PFP, or 85 percent probability of failure, however, is used to set the levee failure elevation for use in the hydraulic models.




Key:
Crest = levee crest
PFP = probable failure point
PNP = probable nonfailure point
Toe = levee toe

**Figure 1-3. Conceptual Levee Performance Curve Examples**

## 1.7 Report Organization

Organization of this document is as follows:

- Section 1 introduces and describes the purpose of this attachment. It also provides an overview of levee performance curves.
- Section 2 provides a summary of results and findings.
- Section 3 describes the methodology used to develop the levee performance curves.
- Section 4 describes the results in more detail.
- Section 5 contains references for the sources cited in this document.
- Section 6 lists acronyms and abbreviations used in this document.

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# 2.0 Levee Performance Curve Locations

A total of 307 new levee performance curves were developed using ULE and NULE data and methodologies described in Section 3. Levee performance curves were grouped according their location within the SPFC Planning Area. The SPFC Planning Area is separated into different impact areas. An impact area is a unique, contiguous floodplain located along a stream or waterway. Most impact areas in the SPFC Planning Area are protected by levees. At least one levee performance curve was developed for each of the impact areas, where levees are present, in the SPFC Planning Area. Many of the impact areas have more than one levee. Tables 2-1 and 2-2 show the number of levee performance curves developed for each impact area and the methodology used (ULE/NULE), and Figures 2-1 and 2-2 map the locations of the levee performance curves for the Sacramento River Basin and San Joaquin River Basin, respectively.

**Table 2-1. Levee Performance Curve Summary for Sacramento River Basin**

| Impact Area | Name | Number of Levee Performance Curves | Methodology |
|---|---|---|---|
| SAC01 | Woodson Bridge East | 0 | N/A |
| SAC02 | Woodson Bridge West | 0 | N/A |
| SAC03 | Hamilton City | 1 | NULE[1] |
| SAC04 | Capay | 1 | NULE[1] |
| SAC05 | Butte Basin | 10 | NULE |
| SAC06 | Butte City | 1 | NULE |
| SAC07 | Colusa Basin North | 5 | NULE Anomalous[2] |
| SAC08 | Colusa | 1 | NULE |
| SAC09 | Colusa Basin South | 4 | NULE Anomalous[2] |
| SAC10 | Grimes | 1 | NULE |
| SAC11 | RD 1500 West | 2 | NULE |
| SAC12 | Sycamore Slough | 1 | NULE[1] |
| SAC13 | Knight's Landing | 1 | NULE[1] |
| SAC14 | Ridge Cut (North) | 3 | NULE |
| SAC15 | Ridge Cut (South) | 3 | NULE |
| SAC16 | RD 2035 | 6 | ULE |
| SAC17 | East of Davis | 3 | ULE |

**Table 2-1 Levee Performance Curve Summary for Sacramento River Basin (contd.)**

| Impact Area | Name | Number of Levee Performance Curves | Methodology |
|---|---|---|---|
| SAC18 | Upper Honcut | 1 | NULE[1] |
| SAC20 | Gridley | 1 | ULE |
| SAC21 | Sutter Buttes East | 3 | NULE[1] |
| SAC22 | Live Oak | 1 | ULE |
| SAC23 | Lower Honcut | 2 | NULE[1] |
| SAC24 | Levee District No. 1 | 6 | NULE |
| SAC25 | Yuba City | 2 | ULE Anomalous Hazard[2] |
| SAC26 | Marysville | 3 | ULE Anomalous Hazard[2] |
| SAC27 | Linda-Olivehurst | 3 | NULE Anomalous Hazard[1,2] |
| SAC28 | RD 384 | 2 | ULE |
| SAC29 | Best Slough | 8 | NULE Anomalous Hazard [2] |
| SAC30 | RD 1001 | 5 | NULE |
| SAC32 | RD 70-1660 | 5 | NULE |
| SAC33 | Meridian | 1 | NULE |
| SAC34 | RD 1500 East | 1 | NULE |
| SAC35 | Elkhorn | 7 | NULE |
| SAC36 | Natomas | 4 | NULE Anomalous Hazard[2] |
| SAC37 | Rio Linda | 1 | NULE[1] |
| SAC38 | West Sacramento | 1 | ULE |
| SAC39 | RD 900 | 1 | ULE |
| SAC40 | Sacramento North | 2 | ULE |
| SAC41 | RD 302 | 1 | NULE |
| SAC42 | RD 999 | 3 | NULE |
| SAC43 | Clarksburg | 1 | NULE |
| SAC44 | Stone Lake | 3 | NULE Anomalous Hazard[2] |
| SAC45 | Hood | 1 | NULE |
| SAC46 | Merritt Island | 2 | NULE |
| SAC47 | RD 551 | 2 | NULE |
| SAC48 | Courtland | 1 | NULE |
| SAC49 | Sutter Island | 3 | NULE |
| SAC51 | Locke | 2 | NULE |
| SAC52 | Walnut Grove | 1 | NULE |
| SAC53 | Tyler Island | 1 | NULE |
| SAC54 | Andrus Island | 8 | NULE Anomalous Hazard[2] |

**Table 2-1 Levee Performance Curve Summary for Sacramento River Basin (contd.)**

| Impact Area | Name | Number of Levee Performance Curves | Methodology |
|---|---|---|---|
| SAC55 | Ryer Island | 5 | NULE Anomalous Hazard[2] |
| SAC56 | Prospect Island | N/A | TOL |
| SAC57 | Twitchell Island | 1 | NULE |
| SAC58 | Sherman Island | 8 | NULE Anomalous Hazard[2] |
| SAC59 | Moore | 6 | NULE Anomalous Hazard[2] |
| SAC60 | Cache Slough | 1 | NULE |
| SAC61 | Hastings | 1 | NULE |
| SAC62 | Lindsey Slough | 3 | NULE |
| SAC63 | Sacramento South | 1 | ULE |

Notes:
[1] Additional evaluations were required; initial ULE/NULE Project evaluations did not evaluate/assess levees in this impact area.
[2] A short anomalous section within the impact area had a lower levee performance curve than surrounding levees. Used data that resulted in the most conservative (highest hazard) levee performance curve.
Key:
N/A = not applicable – no levee
No. = number
NULE = Non-Urban Levee Evaluations
RD = Reclamation District
TOL = top of levee
ULE = Urban Levee Evaluations

**Table 2-2. Levee Performance Curve Summary for San Joaquin River Basin**

| Impact Area | Name | Number of Levee Performance Curves | Methodology |
|---|---|---|---|
| SJ01 | Fresno | 0 | N/A |
| SJ02 | Fresno Slough East | 3 | NULE |
| SJ03 | Fresno Slough West | 1 | NULE[1] |
| SJ04 | Mendota | 1 | NULE[1] |
| SJ05 | Chowchilla Bypass | 2 | NULE |
| SJ06 | Lone Willow Slough | 6 | NULE |
| SJ07 | Mendota North | 1 | NULE |
| SJ08 | Firebaugh | 1 | NULE[1] |
| SJ09 | Salt Slough | 3 | NULE |
| SJ10 | Dos Palos | Used SJ09[3] | NULE |
| SJ11 | Fresno River | 5 | NULE |
| SJ12 | Berenda Slough | 6 | NULE |
| SJ13 | Ash Slough | 2 | NULE |
| SJ14 | Sandy Mush | 6 | NULE |

**Table 2-2. Levee Performance Curve Summary for San Joaquin River Basin (contd.)**

| Impact Area | Name | Number of Levee Performance Curves | Methodology |
|---|---|---|---|
| SJ15 | Turner Island | 3 | NULE |
| SJ16 | Bear Creek | 2 | NULE |
| SJ17 | Deep Slough | 4 | NULE |
| SJ18 | West Bear Creek | 2 | NULE |
| SJ19 | Fremont Ford | 1 | NULE |
| SJ20 | Merced River | 0 | N/A |
| SJ21 | Merced River North | 3 | NULE Anomalous Hazard[2] |
| SJ22 | Orestimba | 2 | NULE Anomalous Hazard[2] |
| SJ23 | Tuolumne South | 2 | NULE |
| SJ24 | Tuolumne River | 1 | NULE |
| SJ25 | Modesto | 0 | N/A |
| SJ26 | 3 Amigos | 3 | NULE |
| SJ27 | Stanislaus South | 2 | NULE |
| SJ28 | Stanislaus North | 4 | NULE |
| SJ29 | Banta Carbona | 4 | NULE |
| SJ30 | Paradise Cut | 1 | NULE |
| SJ31 | Stewart Tract | 6 | NULE Anomalous Hazard[2] |
| SJ32 | East Lathrop | 1 | NULE[1] |
| SJ33 | Lathrop/ Sharpe | 1 | NULE[1] |
| SJ34 | French Camp | 1 | NULE[1] |
| SJ35 | Moss Tract | 1 | NULE[1] |
| SJ36 | Roberts Island | 5 | NULE |
| SJ37 | Rough and Ready Island | 1 | ULE |
| SJ38 | Drexler Tract | 2 | NULE[1] |
| SJ39 | Union Island | 1 | NULE |
| SJ40 | Southeast Union Island | 3 | NULE |
| SJ41 | Fabian Tract | 1 | NULE |
| SJ42 | RD 1007 | 1 | NULE[1] |
| SJ43 | Grayson | 1 | NULE |

Notes:
[1] Additional evaluations were required; initial ULE/NULE Project evaluations did not evaluate/assess levees in this impact area.
[2] A short anomalous section within the impact area had a lower levee performance curve than surrounding levees. Used data that resulted in the most conservative (highest hazard) levee performance curve.
[3] SJ10 is part of SJ09; therefore, SJ10 used the same levee performance curve as SJ09.

Key:
N/A = not applicable – no levee
NULE = Non-Urban Levee Evaluation
RD = Reclamation District
ULE = Urban Levee Evaluations

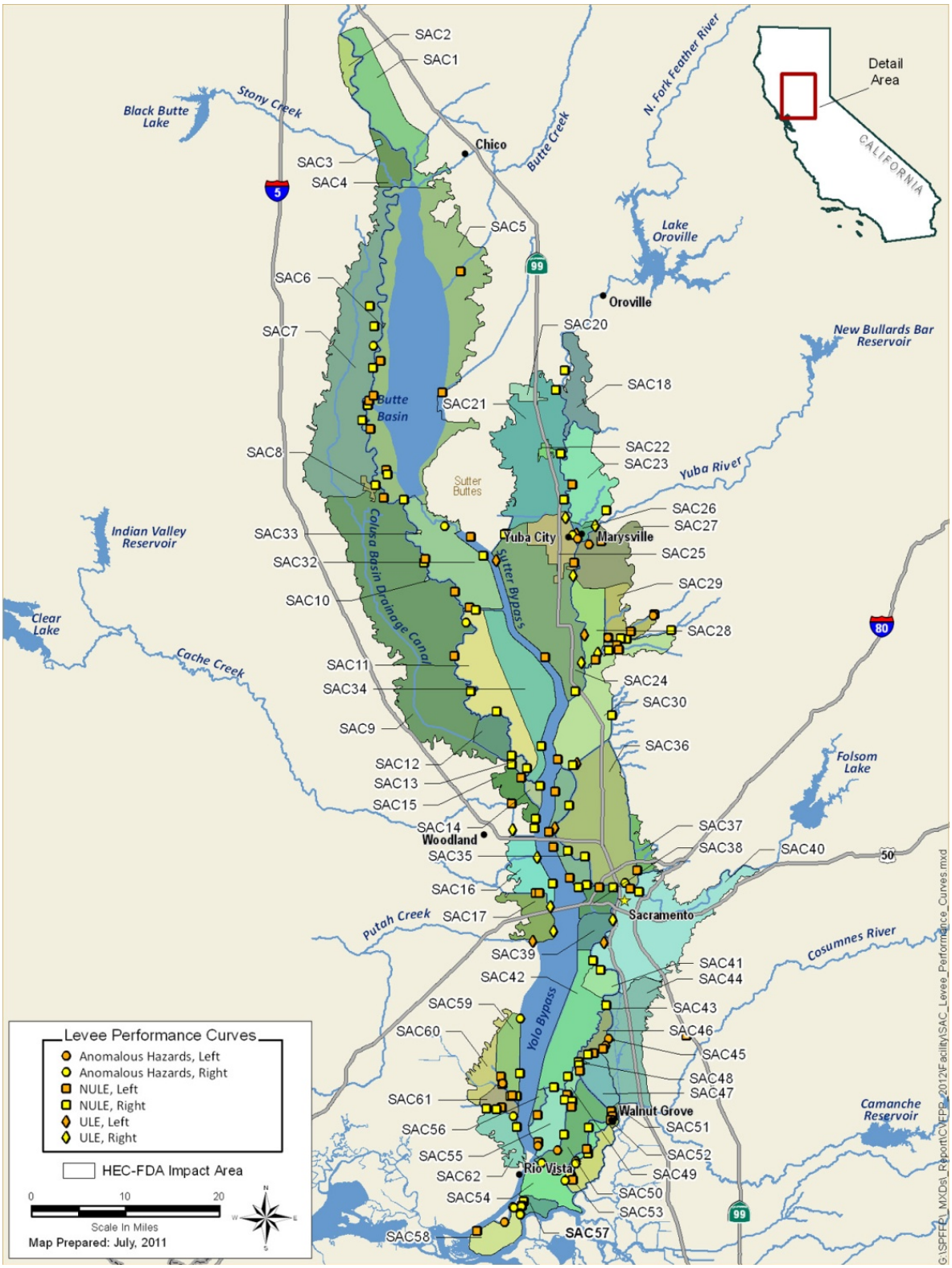



**Figure 2-1. Levee Performance Curve Locations, Sacramento River Basin**

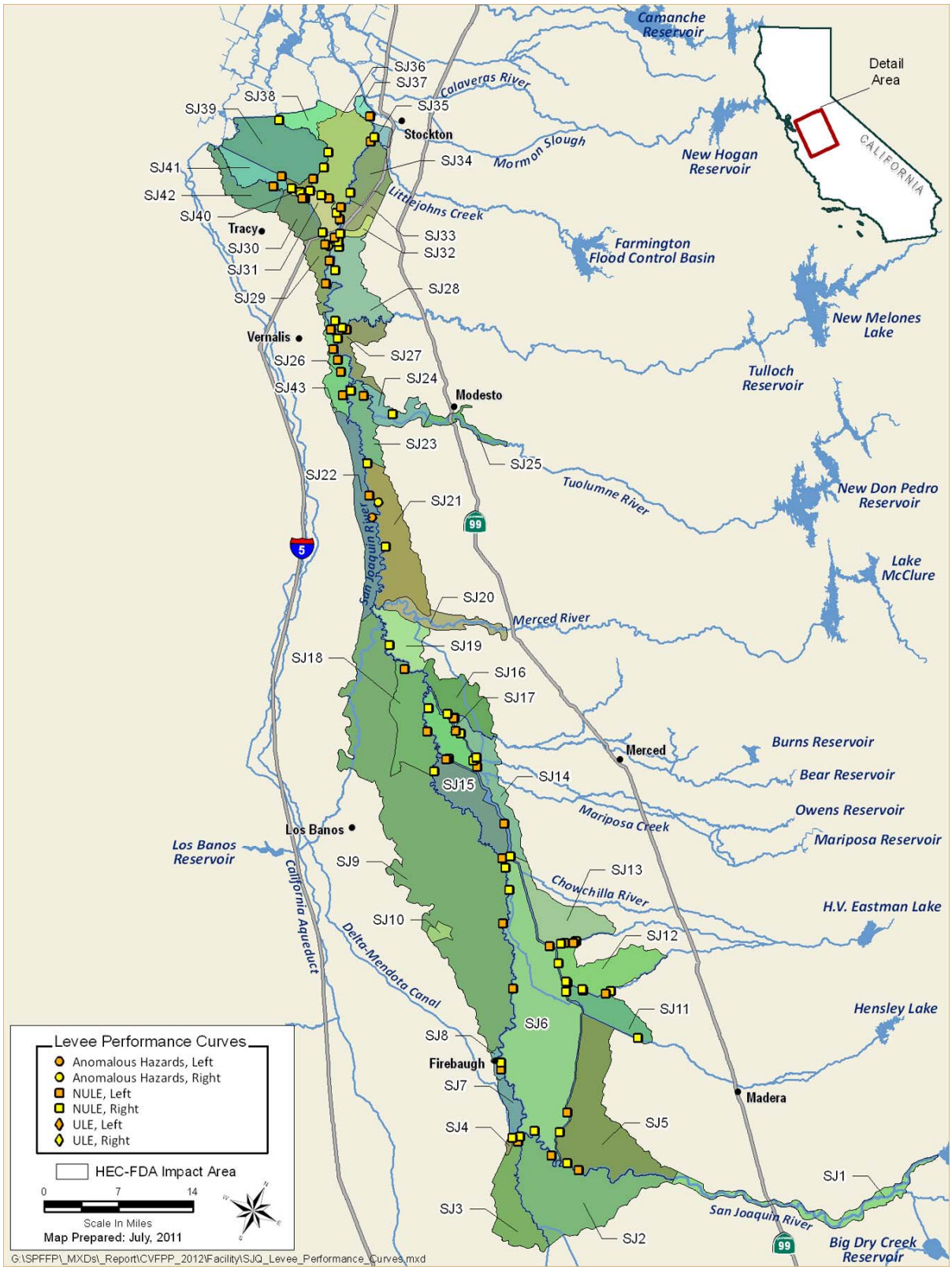



**Figure 2-2. Levee Performance Curve Locations, San Joaquin River Basin**

# 3.0 Methodology

This section describes the methodology used to develop levee performance curves, a description of the sources of the data, and a detailed description of the process for developing levee performance curves for both ULE and NULE Project segments.

Note that the detailed description of the process for developing levee performance curves is first described for NULE Project segments. This is because some of the data developed for the NULE levee performance curves were used in the ULE assessment, as additional ULE work has yet to be completed.

## 3.1 Developing Levee Performance Curve Methodology Overview

The methodology used to develop levee performance curves included review of the data, formulation of a levee expert panel, and a sensitivity analysis.

### 3.1.1 Data Review

To begin the task of developing levee performance curves, two levee evaluation teams, one in the north study area and one in the south study area, were formed. These teams reviewed the data collected and conclusions drawn during preparation of the NULE Geotechnical Assessment Report (GAR), and the hazard maps developed to support the ULE study areas in the *Flood Control System Status Report* (FCSSR) (DWR, 2011) (URS, 2010a). Each team compiled and summarized key performance events relevant to preparation of levee performance curves, such as information related to historical levee failures and estimates of the water surface elevation during these events, using readily available records.

Based on review and compilation of this information, a standard set of levee performance curves was developed for application to ULE and NULE levee segments. The approach used to develop levee performance curves generally follows a process similar to that described in *USACE Manual Engineering Technical Letter (ETL) 1102-2-556* (USACE, 1999).

### 3.1.2 Levee Expert Panel

A levee Expert Panel was formed to provide technical expertise, advice, and review (Table 3-1). This panel met multiple times, from fall 2010 through spring 2011, during the development of the levee performance curve methodology. The comments and suggestions of the levee Expert Panel were incorporated in the development of two separate levee performance curve tools (Excel workbooks), one for ULE levees and one for NULE levees. These tools incorporated and made use of data generated during earlier ULE and NULE work, and provided the user options for generating levee performance curves.

**Table 3-1. Levee Expert Panel**

| Name | Organization |
|---|---|
| David Ford (facilitator) | David Ford Consulting Engineers |
| Ray Costa | Consultant to DWR |
| Mike Inamine | DWR |
| Steve Verigen | GEI |
| Les Harder | HDR |
| Scott Anderson | Kleinfelder |
| Pat Dell | Neil O. Anderson and Associates |
| Ram Kulkarni | URS Corporation |
| Michael Ramsbotham | USACE |
| Ed Ketchum | USACE |

Key:
DWR = California Department of Water Resources
USACE = U.S. Army Corps of Engineers

### 3.1.3 Sensitivity Analysis

A sensitivity analysis was performed to evaluate the effect on estimated damage from varying parameters in the levee performance curve tool. Additionally, preliminary hydraulic modeling was conducted using a complete set of preliminary levee performance curves to evaluate (1) how these draft levee performance curves worked in the context of the existing hydraulic model, and (2) the number of levee failures predicted using the model and preliminary levee performance curves. These results were used to assess how well the results from the models approximated general historical flood conditions. Refinement of the preliminary ULE and NULE levee performance curve tools followed the sensitivity analysis and preliminary hydraulic modeling.

## 3.2 Sources of Levee Performance Data

The ULE Project has subdivided levees into reaches that are typically on the order of thousands of feet long. The NULE Project has assessed individual levee segments, which are generally two to five miles long, but were as long as 25 miles at some locations. Results of the ULE and NULE projects are summarized in the FCSSR (DWR, 2011).

### 3.2.1 Urban Levee Evaluations Project

The ULE Project evaluated 470 miles of levees. Based on an initial phase of field explorations, laboratory testing, and subsequent geotechnical analysis, levees in each urban study area were subdivided into reaches, typically 1,000 feet to 3,000 feet long. For the ULE study areas, the ULE teams reviewed data and analysis results from the ULE Technical Review Memoranda; Phase 1 Geotechnical Data Reports; Phase 1 Geotechnical Evaluation Reports; and where already prepared, Supplemental Geotechnical Data Reports. Each team compiled and summarized key performance events relevant to preparation of levee performance curves, such as information related to historical levee failures and estimates of the water surface elevation during these events, using readily available records.

### 3.2.2 Non-Urban Levee Evaluations Project

During the geotechnical assessment for the NULE Project, existing data were assessed to assign hazard categories to 1,620 mile of levees and results were provided in the GARs (URS, 2010b; Kleinfelder, 2010), as follows:

- **Low (A)** – When water reaches the assessment water surface elevation, there is a low likelihood of either levee failure or the need to floodfight to prevent levee failure.

- **Moderate (B)** – When water reaches the assessment water surface elevation, there is a moderate likelihood of either levee failure or the need to floodfight to prevent levee failure.

- **High (C)** – When water reaches the assessment water surface elevation, there is a high likelihood of either levee failure or the need to floodfight to prevent levee failure.

- **Lacking Sufficient Data (LD)** – Currently lacking sufficient data regarding past performance or hazard indicators.

Floodfight refers to actions taken to prevent geotechnical levee failure, not actions to prevent overtopping.

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

The categorization was done for each of four failure modes: under-seepage, stability, through-seepage, and erosion.

## 3.3 Levee Performance Curves for NULE Levee Segments

During the geotechnical assessment for the NULE Project, existing data were collected and used to categorize the levees. As described above, each levee segment was categorized as Low (A), Moderate (B), High (C), or Lacking Sufficient Data (LD), and the levee was cumulatively categorized as a whole. The categorization was done for each of four failure modes: under-seepage, stability, through-seepage, and erosion. It is important to note that the categorization was performed for only one water level, the assessment water surface elevation, which, where available, was the 1955/1957 water surface. All NULE categorizations and results are, therefore, for the single assessment water surface elevation. To produce levee performance curves for each NULE segment, levee performance curves were developed for each failure mode. These independent failure mode levee performance curves were then mathematically combined to produce the cumulative or overall levee performance curve for the segment or reach. Thus, two levees with similar failure mode categorizations and similar topographic profiles had very similar levee performance curves.

Topographic information necessary for levee performance curve development included levee crest elevation, levee toe elevation, and assessment water surface elevation. Topographic data used for developing levee performance curves were based on two sources: levee center line survey data obtained from the California Levee Database (CLD), and project-specific light detection and ranging (LiDAR) surveys.

Few additional data were used to generate the NULE levee performance curves; however, abundant data on past performance and past floodwater levels collected during the geotechnical assessment were used to calibrate and review the parameters selected in developing the levee performance curves.

To make use of the failure mode categorizations assigned in NULE to each segment, it was necessary to assign a probability of failure at the assessment water surface elevation for the Low (A), Moderate (B), and High (C) categories. These probability of failure values were not explicitly included in the NULE GAR (URS, 2010b), and part of the efforts expended in this task involved discussions and sensitivity analyses to constrain the values used for each category. Based on review of the sensitivity analysis and input from the levee Expert Panel, the values for each category, at the assessment water surface elevation, were Low (A), 0.5 percent; Moderate (B), 2 percent; and High (C), 16 percent. These points, which define the levee performance curve at the assessment water surface elevation, are called the "pin points." Figure 3-1 shows an example of three schematic levee performance curves for each hazard category (Low (A), Moderate (B) and High (C) curves) for a single failure mode. The pin points are where each curve intersects the assessment water surface elevation and represents the probability of failure at the assessment water surface elevation for each category. It is important to note that the values used here for the pin-point probabilities are for the purposes of this levee performance curve effort; they should not be retroactively imposed on the NULE GAR.

Thus, for NULE levee performance curves, three water surface elevations were used to define the levee performance curves: (1) the levee toe elevation, at which the probability of failure is assumed to be zero, (2) the levee crest elevation, at which overtopping would occur and the probability of failure is set to 100 percent, and (3) the pin-point at the assessment water surface elevation (Figure 3-1). The NULE levee performance curve Excel tool fitted a simple curve through these three points for each failure mode using the assigned probability of failure at the assessment water surface elevation. Below the assessment water surface elevation, the curve was fitted using a "concavity factor" that ranges between zero and 1, with zero yielding a curve of constant slope of no concavity, and 1 yielding a curve that is concave upward and very steep at the assessment water surface elevation. For this analysis, a concavity factor of 0.5 was used for all levee performance curves based on the results of the sensitivity analyses. The levee performance curves are extended above the assessment water surface elevation based on their slope as they approach the assessment water level. Low (A) and Moderate (B) curves extend at constant slope (although the example in Figure 3-1 shows a curving line), and High (C) curves roughly mirror the shape of the curve below the assessment water surface elevation. The same probability values are used for every Low (A), Moderate (B), or High (C) pin-point (e.g., all Moderate (B) levee performance curves were assigned a probability of failure of 2 percent at the assessment water surface elevation, independent of the failure mode, the size of the levee, or other differences in levees). For levee segments categorized LD, pin-point values between those of Low (A) and Moderate (B), or Moderate (B) and

High (C) were used, depending on the nature of the LD categorization (e.g., LD (Low (A) or Moderate(B)) vs. LD (Moderate(B) or High(C))).

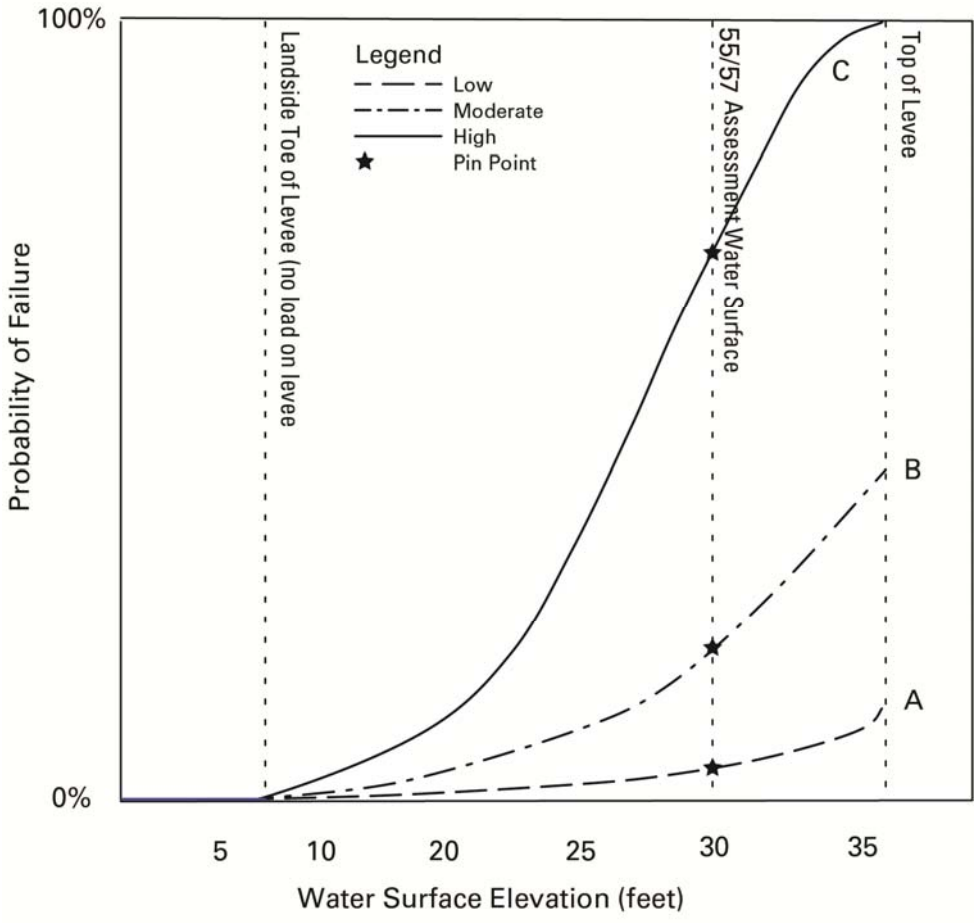


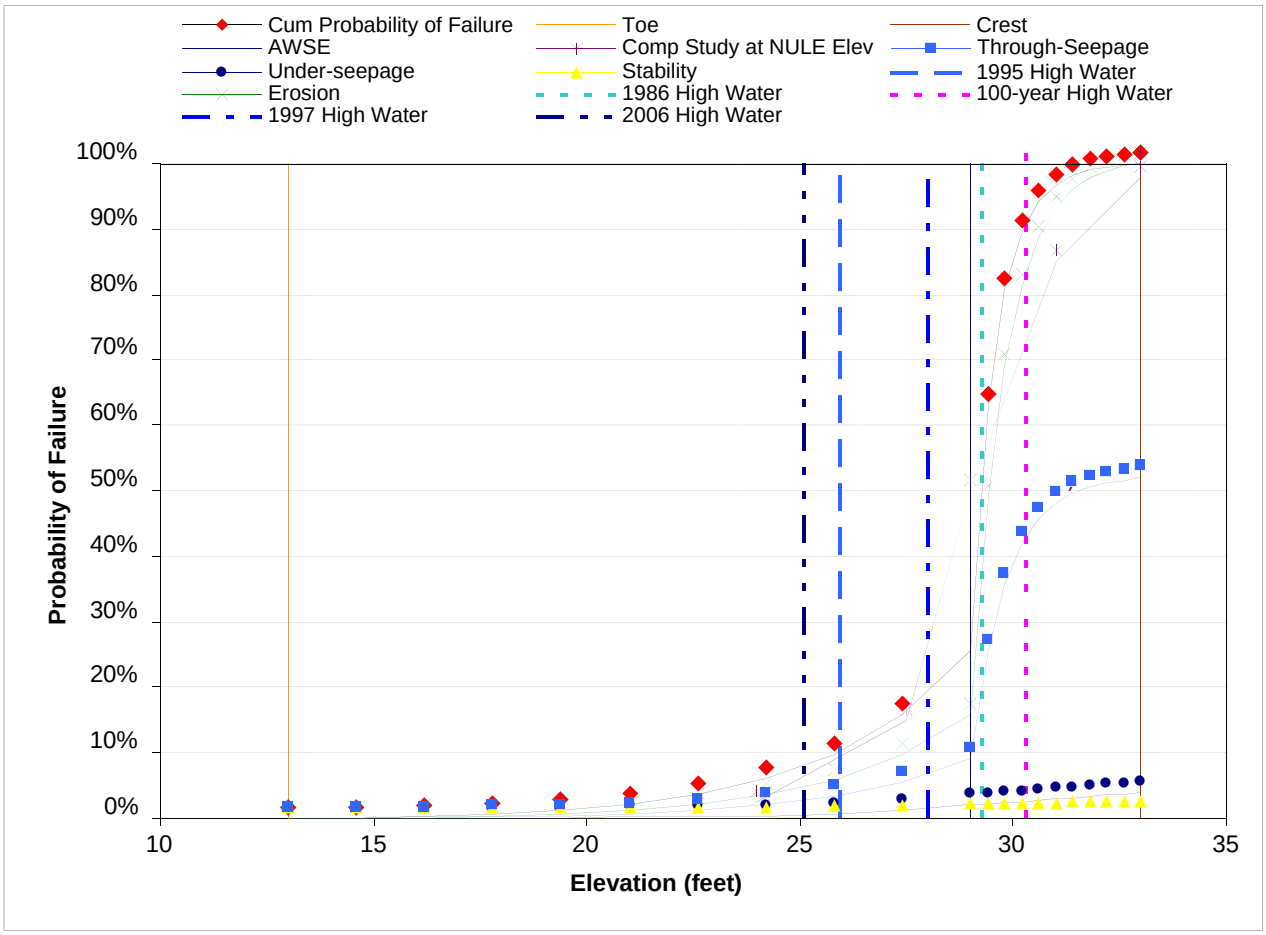

**Figure 3-1. Conceptual NULE Levee Performance Curves for Hazard Categories Low (A), Moderate (B), and High (C)**

Past flood information (water surface elevation and record of performance) can be used to calibrate or validate levee performance curves for individual segments. Basin-wide compilations of past performance were used as guidance in constraining the chosen pin-point probability values. The four individual failure mode levee performance curves were mathematically combined using the conventional probabilistic summing expression:

$$Cumulative\ Pf = 1 - (1 - Pf(underseepage)) * (1 - Pf(stability)) * (1 - Pf(through\ seepage)) * (1 - Pf(erosion)) \qquad \text{Equation 1}$$

Figure 3-2 shows an example of output generated by the NULE levee performance curve Excel tool. Individual failure modes for this example levee segment were categorized as Moderate (B) for under-seepage; Low (A) for stability; LD (Moderate (B) or High (C)) for through-seepage; and High (C) for erosion in the GAR. The example levee's landside toe is at elevation 13 feet, the crest is at elevation 33 feet, and the assessment water surface was at elevation 29 feet, or 4 feet below the levee crest. The dark blue line with circles shows the levee performance curve for under-seepage, the yellow line is stability, the light blue line with squares is through-seepage, and the green line is erosion. The black line shows the combined or cumulative levee performance curve when the failure mode levee performance curves are summed using the expression above. Also shown are vertical lines depicting the assessment water surface elevation and water surface elevations for a number of historical high-water events. The magenta lines show the levee performance curves used in the Comprehensive Study (USACE, 2002). The solid line shows the Comprehensive Study curve at the levee crest elevation used in the NULE Program, which was estimated based on LiDAR and CLD information. The dashed magenta curve shows the Comprehensive Study curve tied to the elevation used in the Comprehensive Study.

When levee locations were identified where elevations used in the Comprehensive Study hydraulic models were different from the top-of-levee elevations used in the ULE and NULE projects, which are based on more recent and better constrained topographic data, the ULE and NULE elevations were used.




Note: These curves represent a levee segment with the following hazard categories from the GAR: Moderate (B) for under-seepage, Low (A) for stability, LD (Moderate (B) or High (C)) for through-seepage, and High (C) for erosion.
Key:
AWSE = assessment water surface elevation
Cum = cumulative
Elev = elevation
NULE = Non-Urban Levee Evaluations

**Figure 3-2. Example NULE Levee Performance Curve**

Note that the levee performance curves for the failure modes categorized A (stability) and B (under-seepage) extend above the assessment water surface to the elevation of the levee crest at nearly a constant slope. This means that this example levee is not expected to fail because of either of these failure modes, even when the water surface reaches the levee crest. The failure mode levee performance curves for through-seepage and erosion have the more classic “s”-shaped curves, as does the combined or cumulative levee performance curve. This example levee performance curve shows that there is little probability of the levee failing at low water

levels, and that the cumulative probability of failure at the assessment water surface elevation is about 25 percent.

## 3.4 Levee Performance Curves for ULE Levee Segments

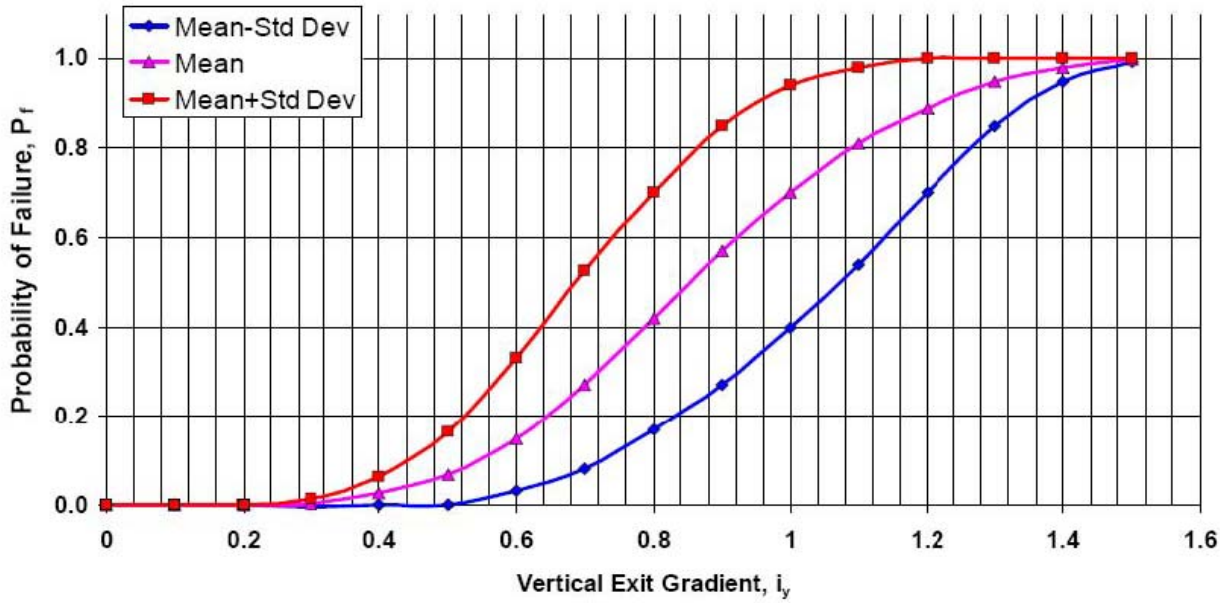
To support the 2012 CVFPP modeling, representative reaches and corresponding cross sections within individual urban study areas were selected for development of levee performance curves. A cumulative ULE levee performance curve for each of these selected cross sections was prepared based on the individual curves for the same four failure modes: assessed in the NULE program (under-seepage, stability, through-seepage, and erosion).

For steady-state under-seepage and steady-state stability, historical data and field and laboratory geotechnical data collected in the initial phase of the ULE Project were used as input to calculate average vertical exit gradients (i) and stability factors of safety (FS) for various flood elevations for each respective cross-section location.

To establish the relationships between i and probability of failure ($P_f$) and between stability FS and $P_f$, input from the levee Expert Panel and program-specific information were used to generate classic “s”-shaped curves (see Figure 3-3) (note that Figure 3-3 is a generic example). For this study, the following control points were used to develop the applicable “s” curves:

- Under-seepage i=0.5, $P_f$ =1 percent and i=0.9, $P_f$ =50 percent
- Stability FS=1.4, $P_f$ =1 percent and FS=1.0, $P_f$ =50 percent

Using these relationships for under-seepage and stability, and correlating them to specific results at various river water surface elevations, levee performance curves for under-seepage and stability were then developed using the same concavity factor (0.5) used in development of the NULE levee performance curves. Figures 3-4 and 3-5 show examples of ULE levee performance curves for the under-seepage and stability failure modes.




*Source: DWR, 2007*

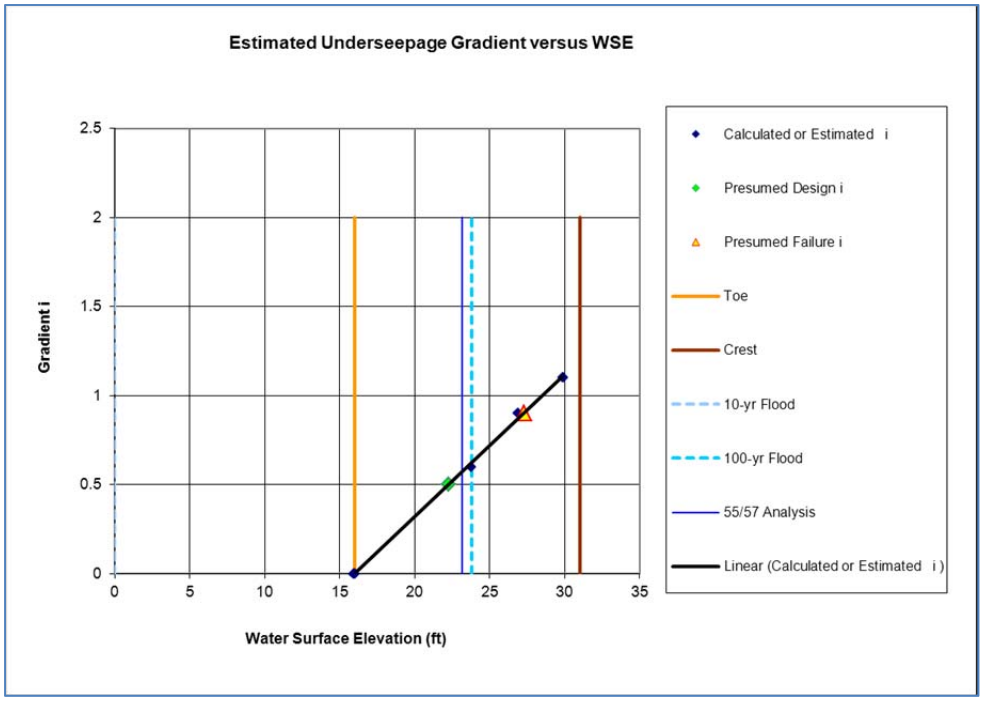
**Figure 3-3. Relationship Between Vertical Exit Gradient and Probability of Failure**

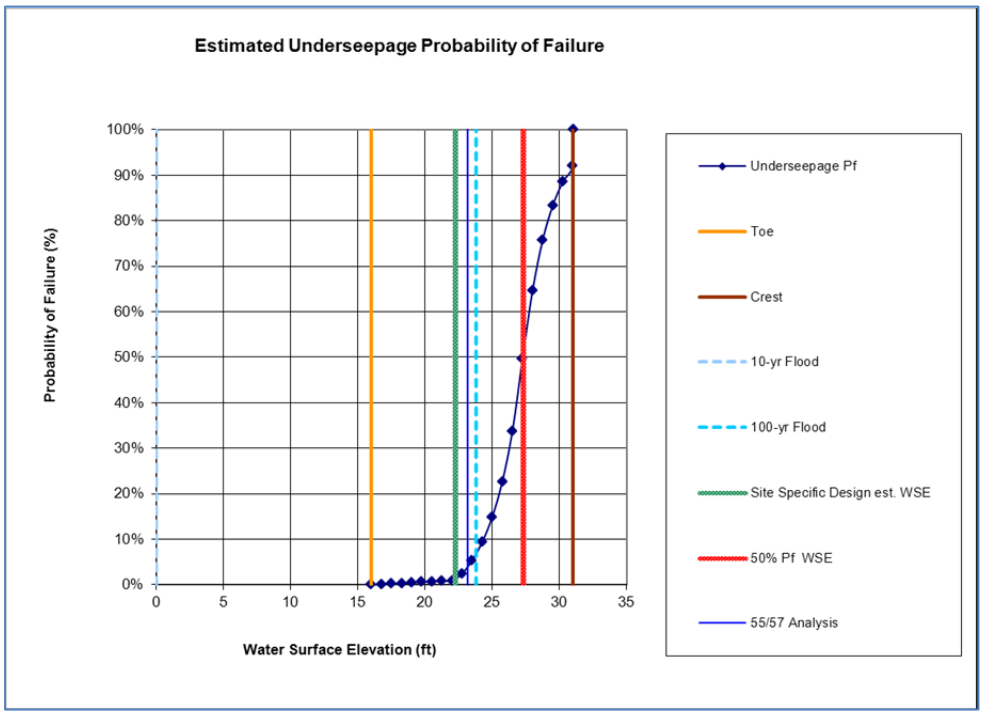
To develop ULE levee performance curves for through seepage, a failure model was developed for landside levee slopes that are composed of erodible materials, typically silts and sands. If these soils are present, then a failure assessment based on the height of seepage "breakout" above the landside toe of the levee was used. The height of seepage breakout above the landside toe was identified from the seepage analyses, which therefore relates the height of seepage breakout to the water surface elevation (flood elevation). The levee performance curve model relates the probability of failure to the height of seepage breakout where erodible materials are present – the higher the breakout, the higher the probability of failure. Figure 3-6 shows the relationship used relating breakout probability of failure versus flood elevation.

For the erosion failure mode, because a formal erosion analysis is not yet available (this work is planned for the final ULE Geotechnical Evaluation Reports), a more qualitative assessment was performed resulting in an erosion A, B, or C classification for each ULE reach for which a levee performance curve was developed. The erosion levee performance curve developed in NULE described in Section 3.3 was then used in the ULE assessment.

The final step was to mathematically combine (using Equation 1) the four failure modes into one cumulative levee performance curve for each selected cross section. Figure 3-7 provides an example cumulative ULE levee performance curve.

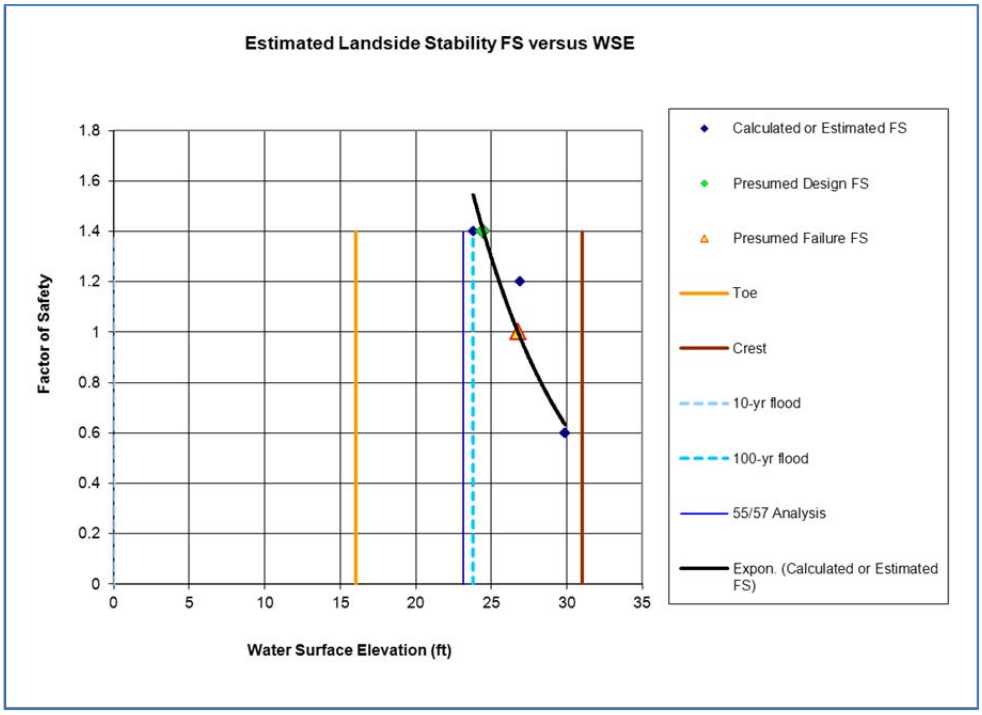
An informal review of ULE levee performance curves was provided by some ULE team Task Managers who were responsible for the ULE study area in question where each cross section is located.

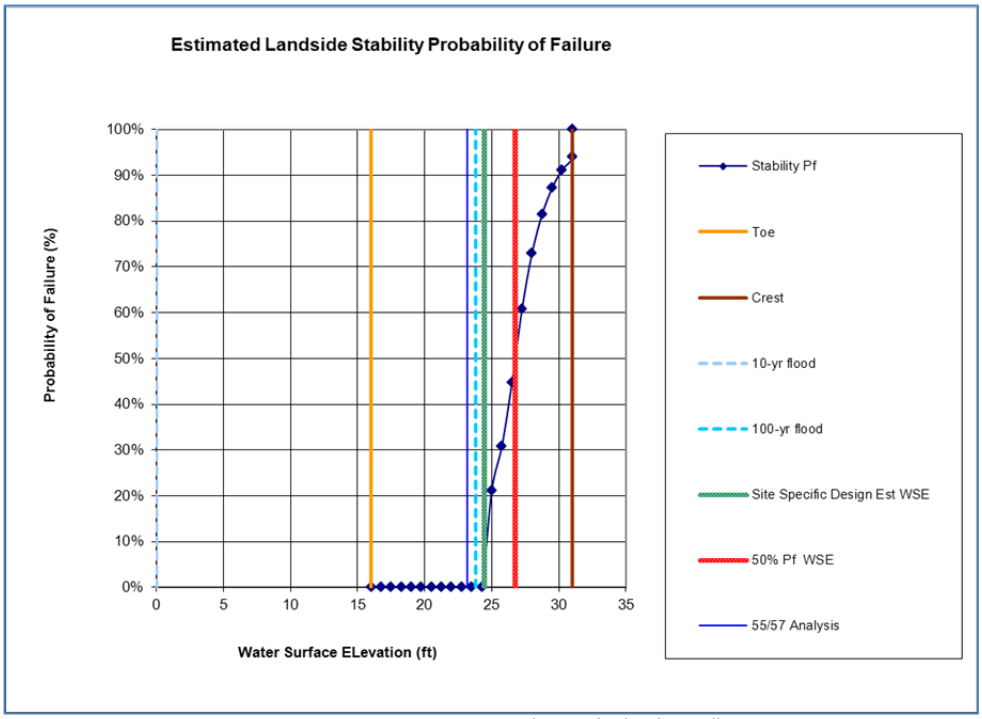



Key:
55/57 = 55/57 assessment water surface elevation
ft = feet
i = vertical exit gradient
$P_f$ = probability of failure
WSE = water surface elevation
yr = year

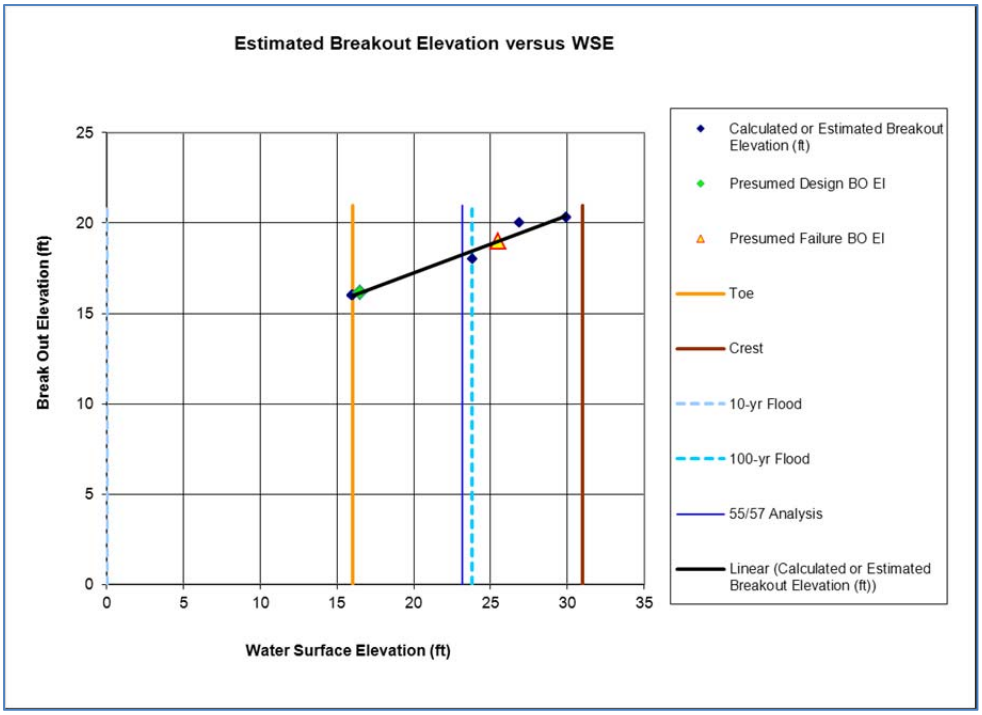
**Figure 3-4. Example ULE Under-Seepage Levee Performance Curves**

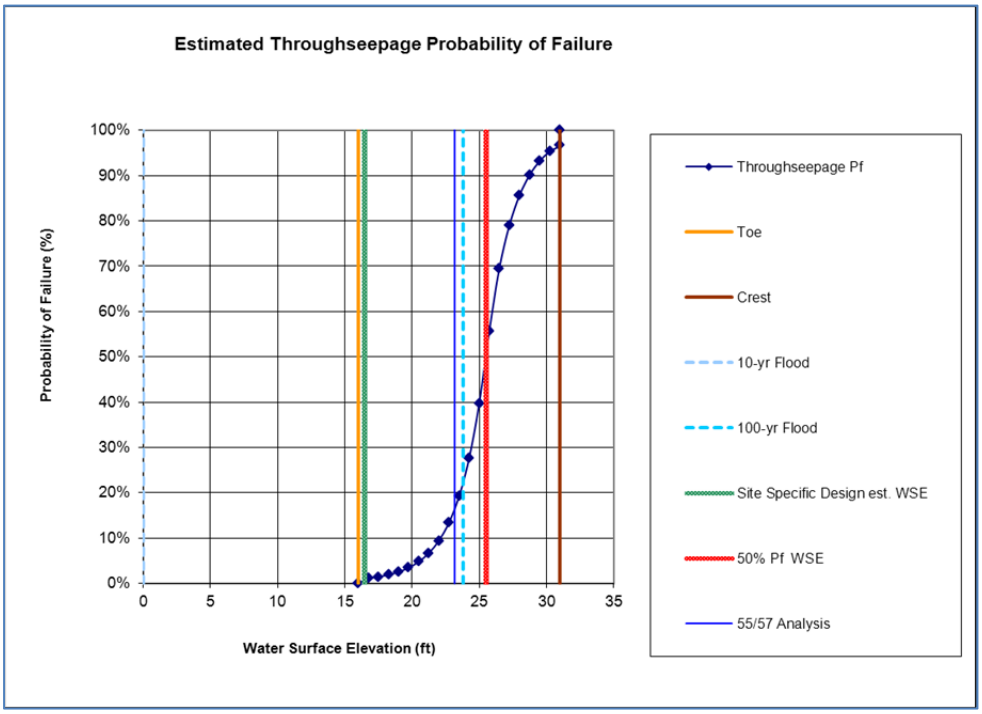



Key:
55/57 = 55/57 assessment water surface elevation
FS = factor of safety
ft = feet
i = vertical exit gradient
$P_f$ = probability of failure
WSE = water surface elevation
yr = year

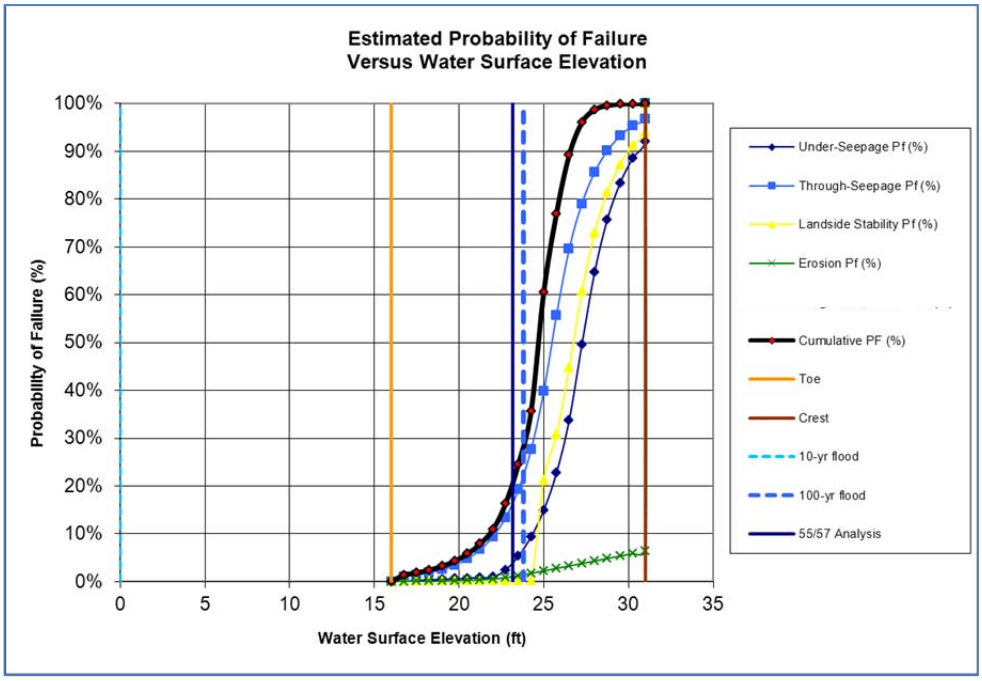
**Figure 3-5. Example ULE Stability Levee Performance Curves**




Key:
55/57 = 55/57 assessment water surface elevation
BO = breakout
El = failure elevation
ft = feet
i = vertical exit gradient
$P_f$ = probability of failure
WSE = water surface elevation
yr = year

**Figure 3-6. Example ULE Through-Seepage Levee Performance Curves**




Key:
55/57 = 55/57 assessment water surface elevation
ft = feet
$P_f$ = probability of failure
yr = year

**Figure 3-7. Example ULE Levee Performance Curves (with failure mode and combined curves)**

## 3.5 Anomalous Hazards

Levee performance curves for anomalous hazards were also developed. Anomalous hazards were identified in the preliminary ULE analysis and NULE GAR as isolated locations distinct from the overall levee segment for which the following apply:

- Geotechnical conditions are different from the remainder of the segment (reach).
- The current scope of levee assessment approaches used in ULE and NULE Phase 1 do not lend themselves to further detailed analyses of the hazard at these sites (e.g., analyses of structures, penetrations, encroachments).
- In many cases, the anomalous conditions are associated with observations of past poor performance.
- Available information in the area with anomalous conditions suggests that the levee may be susceptible to failing in one of the four failure

modes assessed in NULE Phase 1 (under-seepage, instability, through-seepage, or erosion).

Anomalous hazards are not related to the potential for overtopping (e.g., low spots in a levee crown at a bridge or ramp) as overtopping is not included as a failure mode in ULE and NULE.

As mentioned, additional levee performance curves were developed for anomalous hazard locations identified by the ULE teams and in the NULE GAR. Groups of anomalous hazards and suggested modifications to parent segment category ratings for NULE are listed in Table 3-2. Anomalous conditions for ULE generally followed the methods described in Section 3.4 above.

In some cases, the anomalous hazard rating and parent segment category rating are identical. The anomalous hazard will still impact the hydraulic and damage models by adding an additional potential breakout location within the segment.

**Table 3-2. Anomalous Hazard Groups and Suggested Modifications to Parent Segment Category Ratings**

| Anomalous Hazard Group | Suggested Modifications to Rating |
|---|---|
| Erosion coincident with constructed features | Increase erosion rating to C |
| Poor past performance coincident with a penetration (usually through-seepage) | Increase through-seepage rating to C |
| Large siphon | Increase under-seepage rating to C |
| Site of past breach that has been repaired and has had either (1) poor performance since repair, or (2) an adjacent landside hole (e.g., scour pool, which shortens flow path) | Increase under-seepage and through-seepage ratings to C |
| Soft foundations resulting from buried sloughs or the like, with associated indicators of stability problems | Increase stability rating to C |
| Landside holes (adjacent or near to levee) associated with boils or other poor performance | Increase under-seepage rating to C |
| Permanent unrepaired breach | Use new topography and assign all failure modes a category of C |
| Significant encroachment/transition in levee geometry | Increase impacted failure mode to C |
| Documented geotechnical conditions at specific anomalous hazard locations | Increase other failure mode ratings |

Note:
C = When water reaches assessment water surface elevation, there is a high likelihood of either levee failure or the need to floodfight to prevent levee failure.

## 3.6 Capabilities of HEC-FDA

The risk analysis capabilities provided by the USACE Hydrologic Engineering Center Flood Damage Assessment (HEC-FDA) program are used in the CVFPP, and as described in Attachment 8F: Flood Damage Analysis. Because the levee performance curves are important input data for the HEC-FDA model, this section briefly describes the capabilities and uses of HEC-FDA.

The HEC-FDA program can be used to perform an integrated hydrologic engineering, risk, and economic analysis during formulation and evaluation of flood risk management plans.

The use of risk analysis procedures for formulating and evaluating flood damage reduction measures is described in USACE Engineer Manual 1110-2-1619 (1996) and Engineer Regulation 1105-2-101 (2006). These documents describe how to quantify uncertainty in discharge-exceedence probability, stage-discharge relationships, and stage-damage functions and incorporate uncertainty into economic and engineering performance analyses. The program applies Monte Carlo simulation, a numerical analysis procedure that computes the expected value of damage while explicitly accounting for uncertainty in the basic parameters used to determine flood inundation damage. One of those basic parameters is the levee performance curve.

HEC-FDA assists in formulating and evaluating flood risk management plans using these procedures to calculate damage-stage-uncertainty information at damage reach index locations. Expected annual damage and flood risk are computed in the evaluation portion of the program.

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# 4.0 Results

This section presents the levee performance curves and describes the limitations in using these curves.

## 4.1 Summary

This section presents the levee performance curves developed using the techniques described above for use in systemwide SPFC hydraulic and economic damage modeling and for preparing the 2012 CVFPP. Table 4-1 contains levee performance curves for the Sacramento River Basin and Table 4-2 contains the levee performance curves for the San Joaquin River Basin.

The ULE Excel tool for developing levee performance curves should only be used on a reach-by-reach basis. The NULE Excel tool allows the user to modify certain parameters and rapidly generate a new set of levee performance curves for all NULE segments.

**Table 4-1. Sacramento River Basin Levee Performance Curves**

| ID | | SA1 | SA2 | SA3 | | SA4 | | SA5 | | SA6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Woodson Bridge East | Woodson Bridge West | Hamilton City | | Capay | | Butte Basin | | Butte City | |
| Toe Elevation[3] | | 1 | 1 | 145.5 | | 135.4 | | 52.6 | | 52.6 | |
| AWSE | | | | 151.0 | | 142.1 | | 66.1 | | 66.1 | |
| Crest Elevation[3] | | | | 154.0 | | 145.1 | | 69.1 | | 69.1 | |
| Type of Project (ULE or NULE) | | | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 2 | 2 | 145.47 | 0 | 135.38 | 0 | 52.59 | 0 | 52.59 | 0 |
| | | | | 146.02 | 0 | 136.05 | 0 | 53.94 | 0 | 53.94 | 0 |
| | | | | 146.57 | 0 | 136.72 | 0 | 55.29 | 0 | 55.29 | 0 |
| | | | | 147.12 | 1 | 137.38 | 1 | 56.64 | 1 | 56.64 | 1 |
| | | | | 147.67 | 1 | 138.05 | 1 | 57.99 | 1 | 57.99 | 1 |
| | | | | 148.22 | 2 | 138.72 | 2 | 59.34 | 2 | 59.34 | 2 |
| | | | | 148.77 | 4 | 139.39 | 4 | 60.69 | 3 | 60.69 | 3 |
| | | | | 149.32 | 6 | 140.06 | 6 | 62.04 | 6 | 62.04 | 6 |
| | | | | 149.87 | 10 | 140.72 | 10 | 63.39 | 9 | 63.39 | 9 |
| | | | | 150.42 | 16 | 141.39 | 16 | 64.74 | 15 | 64.74 | 15 |
| | | | | 150.97 | 25 | 142.06 | 25 | 66.09 | 24 | 66.09 | 24 |
| | | | | 151.27 | 63 | 142.36 | 63 | 66.39 | 63 | 66.39 | 63 |
| | | | | 151.57 | 81 | 142.66 | 81 | 66.69 | 80 | 66.69 | 80 |
| | | | | 151.87 | 90 | 142.96 | 90 | 66.99 | 89 | 66.99 | 89 |
| | | | | 152.17 | 94 | 143.26 | 94 | 67.29 | 94 | 67.29 | 94 |
| | | | | 152.47 | 97 | 143.56 | 97 | 67.59 | 97 | 67.59 | 97 |
| | | | | 152.77 | 98 | 143.86 | 98 | 67.89 | 98 | 67.89 | 98 |
| | | | | 153.07 | 99 | 144.16 | 99 | 68.19 | 99 | 68.19 | 99 |
| | | | | 153.37 | 100 | 144.46 | 100 | 68.49 | 99 | 68.49 | 99 |
| | | | | 153.67 | 100 | 144.76 | 100 | 68.79 | 100 | 68.79 | 100 |
| | | | | 153.97 | 100 | 145.06 | 100 | 69.09 | 100 | 69.09 | 100 |
| | | | | - | - | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA7 | | SA8 | | SA9 | | SA10 | | SA11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Colusa Basin North | | Colusa | | Colusa Basin South | | Grimes | | RD 1500 West | |
| Toe Elevation[3] | | 84.6 | | 58.6 | | 46.6 | | 46.6 | | 36.6 | |
| AWSE | | 97.6 | | 67.6 | | 57.4 | | 57.4 | | 48.2 | |
| Crest Elevation[3] | | 101.6 | | 70.6 | | 61.4 | | 61.4 | | 53.7 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 84.61 | 0 | 58.58 | 0 | 46.60 | 0 | 46.60 | 0 | 36.63 | 0 |
| | | 85.91 | 0 | 59.48 | 0 | 47.68 | 0 | 47.68 | 0 | 37.79 | 0 |
| | | 87.21 | 0 | 60.38 | 0 | 48.76 | 0 | 48.76 | 0 | 38.95 | 0 |
| | | 88.51 | 0 | 61.28 | 0 | 49.84 | 1 | 49.84 | 1 | 40.11 | 1 |
| | | 89.81 | 0 | 62.18 | 0 | 50.92 | 2 | 50.92 | 2 | 41.27 | 1 |
| | | 91.11 | 0 | 63.08 | 0 | 52.00 | 3 | 52.00 | 3 | 42.43 | 2 |
| | | 92.41 | 1 | 63.98 | 1 | 53.08 | 5 | 53.08 | 5 | 43.59 | 3 |
| | | 93.71 | 1 | 64.88 | 1 | 54.16 | 8 | 54.16 | 8 | 44.75 | 4 |
| | | 95.01 | 2 | 65.78 | 2 | 55.24 | 13 | 55.24 | 13 | 45.91 | 7 |
| | | 96.31 | 3 | 66.68 | 3 | 56.32 | 20 | 56.32 | 20 | 47.07 | 12 |
| | | 97.61 | 6 | 67.58 | 4 | 57.40 | 32 | 57.40 | 32 | 48.23 | 20 |
| | | 98.01 | 6 | 67.88 | 5 | 57.80 | 73 | 57.80 | 73 | 48.78 | 52 |
| | | 98.41 | 7 | 68.18 | 5 | 58.20 | 88 | 58.20 | 88 | 49.33 | 71 |
| | | 98.81 | 8 | 68.48 | 6 | 58.60 | 94 | 58.60 | 94 | 49.88 | 83 |
| | | 99.21 | 8 | 68.78 | 6 | 59.00 | 97 | 59.00 | 97 | 50.43 | 90 |
| | | 99.61 | 9 | 69.08 | 7 | 59.40 | 98 | 59.40 | 98 | 50.98 | 94 |
| | | 100.01 | 10 | 69.38 | 7 | 59.80 | 99 | 59.80 | 99 | 51.53 | 97 |
| | | 100.41 | 10 | 69.68 | 8 | 60.20 | 100 | 60.20 | 100 | 52.08 | 98 |
| | | 100.81 | 11 | 69.98 | 8 | 60.60 | 100 | 60.60 | 100 | 52.63 | 99 |
| | | 101.21 | 12 | 70.28 | 9 | 61.00 | 100 | 61.00 | 100 | 53.18 | 100 |
| | | 101.61 | 100 | 70.58 | 100 | 61.40 | 100 | 61.40 | 100 | 53.73 | 100 |
| | | - | - | - | - | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA12 | | SA13 | | SA14 | | SA15 | | SA16 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Sycamore Slough | | Knights Landing | | Ridge Cut (North) | | Ridge Cut (South) | | RD 2035 | |
| Toe Elevation[3] | | 33.2 | | 30.3 | | 29.6 | | 15.5 | | 13.0 | |
| AWSE | | 42.2 | | 39.3 | | 38.6 | | 33.5 | | 25.0 | |
| Crest Elevation[3] | | 47.2 | | 42.3 | | 43.6 | | 39.5 | | 30.0 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Breach (percent) | 33.16 | 0 | 30.35 | 0 | 29.56 | 0 | 15.51 | 0 | 12.97 | 0 |
| | | 34.06 | 0 | 31.25 | 0 | 30.46 | 0 | 17.31 | 0 | 14.17 | 0 |
| | | 34.96 | 0 | 32.15 | 0 | 31.36 | 0 | 19.11 | 0 | 15.37 | 0 |
| | | 35.86 | 0 | 33.05 | 0 | 32.26 | 0 | 20.91 | 1 | 16.57 | 1 |
| | | 36.76 | 0 | 33.95 | 0 | 33.16 | 0 | 22.71 | 1 | 17.77 | 2 |
| | | 37.66 | 1 | 34.85 | 1 | 34.06 | 1 | 24.51 | 2 | 18.97 | 3 |
| | | 38.56 | 1 | 35.75 | 1 | 34.96 | 1 | 26.31 | 3 | 20.17 | 5 |
| | | 39.46 | 2 | 36.65 | 2 | 35.86 | 2 | 28.11 | 4 | 21.37 | 8 |
| | | 40.36 | 3 | 37.55 | 3 | 36.76 | 3 | 29.91 | 7 | 22.57 | 13 |
| | | 41.26 | 4 | 38.45 | 4 | 37.66 | 4 | 31.71 | 12 | 23.77 | 20 |
| | | 42.16 | 7 | 39.35 | 7 | 38.56 | 7 | 33.51 | 20 | 24.97 | 32 |
| | | 42.66 | 9 | 39.64 | 8 | 39.06 | 9 | 34.11 | 52 | 25.42 | 73 |
| | | 43.16 | 10 | 39.94 | 9 | 39.56 | 10 | 34.71 | 71 | 25.87 | 88 |
| | | 43.66 | 11 | 40.23 | 10 | 40.06 | 11 | 35.31 | 83 | 26.32 | 94 |
| | | 44.16 | 13 | 40.52 | 11 | 40.56 | 13 | 35.91 | 90 | 26.77 | 97 |
| | | 44.66 | 14 | 40.82 | 11 | 41.06 | 14 | 36.51 | 94 | 27.22 | 98 |
| | | 45.16 | 16 | 41.11 | 12 | 41.56 | 16 | 37.11 | 96 | 27.67 | 99 |
| | | 45.66 | 17 | 41.41 | 13 | 42.06 | 17 | 37.71 | 98 | 28.12 | 100 |
| | | 46.16 | 19 | 41.70 | 14 | 42.56 | 19 | 38.31 | 99 | 28.57 | 100 |
| | | 46.66 | 20 | 41.99 | 15 | 43.06 | 20 | 38.91 | 100 | 29.02 | 100 |
| | | 47.16 | 100 | 42.29 | 100 | 43.56 | 100 | 39.51 | 100 | 29.47 | 100 |
| | | - | - | - | - | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA17 | | SA18 | | SA20 | | SA21 | | SA22 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | East of Davis | | Upper Honcut | | Gridley | | Sutter Buttes East | | Live Oak | |
| Toe Elevation[3] | | 26.0 | | 0.00 | | 77.7 | | 77.7 | | 77.7 | |
| AWSE | | 31.6 | | 0.00 | | 83.2 | | 83.2 | | 83.2 | |
| Crest Elevation[3] | | 37.2 | | 0.00 | | 88.7 | | 88.7 | | 88.7 | |
| Type of Project (ULE or NULE) | | ULE | | NULE | | ULE | | ULE | | ULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 25.97 | 0 | 96.57 | 0 | 77.73 | 0 | 77.73 | 0 | 77.73 | 0 |
| | | 26.53 | 0 | 97.00 | 0 | 78.28 | 17 | 78.28 | 17 | 78.28 | 17 |
| | | 27.09 | 0 | 97.42 | 0 | 78.83 | 24 | 78.83 | 24 | 78.83 | 24 |
| | | 27.65 | 0 | 97.84 | 1 | 79.38 | 33 | 79.38 | 33 | 79.38 | 33 |
| | | 28.22 | 1 | 98.26 | 2 | 79.93 | 44 | 79.93 | 44 | 79.93 | 44 |
| | | 28.78 | 1 | 98.68 | 3 | 80.48 | 57 | 80.48 | 57 | 80.48 | 57 |
| | | 29.34 | 1 | 99.11 | 4 | 81.03 | 70 | 81.03 | 70 | 81.03 | 70 |
| | | 29.90 | 1 | 99.53 | 7 | 81.58 | 82 | 81.58 | 82 | 81.58 | 82 |
| | | 30.47 | 1 | 99.95 | 12 | 82.13 | 90 | 82.13 | 90 | 82.13 | 90 |
| | | 31.03 | 1 | 100.37 | 19 | 82.68 | 95 | 82.68 | 95 | 82.68 | 95 |
| | | 31.59 | 1 | 100.79 | 30 | 83.23 | 97 | 83.23 | 97 | 83.23 | 97 |
| | | 32.15 | 2 | 101.09 | 74 | 83.78 | 99 | 83.78 | 99 | 83.78 | 99 |
| | | 32.72 | 3 | 101.39 | 91 | 84.33 | 99 | 84.33 | 99 | 84.33 | 99 |
| | | 33.28 | 4 | 101.69 | 97 | 84.88 | 100 | 84.88 | 100 | 84.88 | 100 |
| | | 33.84 | 6 | 101.99 | 99 | 85.43 | 100 | 85.43 | 100 | 85.43 | 100 |
| | | 34.40 | 9 | 102.29 | 100 | 85.98 | 100 | 85.98 | 100 | 85.98 | 100 |
| | | 34.97 | 12 | 102.59 | 100 | 86.53 | 100 | 86.53 | 100 | 86.53 | 100 |
| | | 35.53 | 16 | 102.89 | 100 | 87.08 | 100 | 87.08 | 100 | 87.08 | 100 |
| | | 36.09 | 21 | 103.19 | 100 | 87.63 | 100 | 87.63 | 100 | 87.63 | 100 |
| | | 36.65 | 28 | 103.49 | 100 | 88.18 | 100 | 88.18 | 100 | 88.18 | 100 |
| | | 37.22 | 35 | 103.79 | 100 | 88.73 | 100 | 88.73 | 100 | 88.73 | 100 |
| | | 37.23 | 100 | | | 88.74 | 100 | 88.74 | 100 | 88.74 | 100 |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA23 | | SA24 | | SA25 | | SA26 | | SA27 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Lower Honcut | | Levee Dist. #1 | | Yuba City | | Marysville | | Linda-Olivehurst | |
| Toe Elevation[3] | | 68.7 | | 49.2 | | 63.7 | | 65.7 | | 67.7 | |
| AWSE | | 81.7 | | 53.7 | | 74.0 | | 77.7 | | 75.2 | |
| Crest Elevation[3] | | 85.7 | | 56.7 | | 84.2 | | 89.7 | | 82.7 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | ULE | | ULE | | ULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 68.73 | 0 | 49.16 | 0 | 63.72 | 0 | 65.73 | 0 | 67.73 | 0 |
| | | 70.03 | 0 | 49.61 | 0 | 64.74 | 0 | 66.93 | 1 | 68.48 | 0 |
| | | 71.33 | 0 | 50.06 | 0 | 65.77 | 1 | 68.13 | 1 | 69.23 | 0 |
| | | 72.63 | 1 | 50.51 | 0 | 66.79 | 1 | 69.33 | 2 | 69.98 | 0 |
| | | 73.93 | 2 | 50.96 | 0 | 67.82 | 1 | 70.53 | 2 | 70.73 | 0 |
| | | 75.23 | 3 | 51.41 | 0 | 68.84 | 3 | 71.73 | 2 | 71.48 | 0 |
| | | 76.53 | 4 | 51.86 | 1 | 69.87 | 11 | 72.93 | 2 | 72.23 | 0 |
| | | 77.83 | 7 | 52.31 | 1 | 70.89 | 22 | 74.13 | 2 | 72.98 | 0 |
| | | 79.13 | 12 | 52.76 | 2 | 71.92 | 55 | 75.33 | 4 | 73.73 | 0 |
| | | 80.43 | 19 | 53.21 | 3 | 72.94 | 77 | 76.53 | 7 | 74.48 | 0 |
| | | 81.73 | 30 | 53.66 | 4 | 73.97 | 91 | 77.73 | 12 | 75.23 | 0 |
| | | 82.13 | 74 | 53.96 | 5 | 74.99 | 97 | 78.93 | 21 | 75.98 | 0 |
| | | 82.53 | 91 | 54.26 | 6 | 76.02 | 99 | 80.13 | 36 | 76.73 | 0 |
| | | 82.93 | 97 | 54.56 | 7 | 77.04 | 100 | 81.33 | 60 | 77.48 | 1 |
| | | 83.33 | 99 | 54.86 | 8 | 78.07 | 100 | 82.53 | 81 | 78.23 | 1 |
| | | 83.73 | 100 | 55.16 | 10 | 79.09 | 100 | 83.73 | 92 | 78.98 | 1 |
| | | 84.13 | 100 | 55.46 | 11 | 80.12 | 100 | 84.93 | 97 | 79.73 | 1 |
| | | 84.53 | 100 | 55.76 | 12 | 81.14 | 100 | 86.13 | 99 | 80.48 | 2 |
| | | 84.93 | 100 | 56.06 | 13 | 82.17 | 100 | 87.33 | 100 | 81.23 | 2 |
| | | 85.33 | 100 | 56.36 | 14 | 83.19 | 100 | 88.53 | 100 | 81.98 | 2 |
| | | 85.73 | 100 | 56.66 | (100) | 84.22 | 100 | 89.73 | 100 | 82.73 | 3 |
| | | - | - | - | - | 84.23 | 100 | 89.74 | 100 | 82.74 | 100 |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA28 | | SA29 | | SA30 | | SA32 | | SA33 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | RD 384 | | Best Slough | | RD 1001 | | RD 70-1660 | | Meridian | |
| Toe Elevation[3] | | 44.7 | | 70.3 | | 35.7 | | 42.6 | | 42.6 | |
| AWSE | | 54.7 | | 77.8 | | 55.7 | | 57.2 | | 57.2 | |
| Crest Elevation[3] | | 64.7 | | 80.8 | | 62.7 | | 61.8 | | 61.8 | |
| Type of Project (UULE or NULE) | | ULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 44.70 | 0 | 70.29 | 0 | 35.69 | 0 | 42.60 | 0 | 42.60 | 0 |
| | | 45.70 | 0 | 71.04 | 0 | 37.69 | 0 | 44.07 | 0 | 44.07 | 0 |
| | | 46.70 | 0 | 71.79 | 0 | 39.69 | 1 | 45.53 | 0 | 45.53 | 0 |
| | | 47.70 | 0 | 72.54 | 1 | 41.69 | 1 | 47.00 | 1 | 47.00 | 1 |
| | | 48.70 | 0 | 73.29 | 2 | 43.69 | 2 | 48.46 | 2 | 48.46 | 2 |
| | | 49.70 | 0 | 74.04 | 3 | 45.69 | 4 | 49.93 | 3 | 49.93 | 3 |
| | | 50.70 | 0 | 74.79 | 5 | 47.69 | 6 | 51.39 | 4 | 51.39 | 4 |
| | | 51.70 | 1 | 75.54 | 7 | 49.69 | 11 | 52.86 | 7 | 52.86 | 7 |
| | | 52.70 | 1 | 76.29 | 12 | 51.69 | 17 | 54.32 | 12 | 54.32 | 12 |
| | | 53.70 | 1 | 77.04 | 20 | 53.69 | 27 | 55.79 | 19 | 55.79 | 19 |
| | | 54.70 | 1 | 77.79 | 31 | 55.69 | 42 | 57.25 | 30 | 57.25 | 30 |
| | | 55.70 | 1 | 78.09 | 72 | 56.39 | 86 | 57.71 | 74 | 57.71 | 74 |
| | | 56.70 | 1 | 78.39 | 87 | 57.09 | 96 | 58.17 | 91 | 58.17 | 91 |
| | | 57.70 | 1 | 78.69 | 94 | 57.79 | 99 | 58.63 | 97 | 58.63 | 97 |
| | | 58.70 | 1 | 78.99 | 97 | 58.49 | 100 | 59.08 | 99 | 59.08 | 99 |
| | | 59.70 | 1 | 79.29 | 98 | 59.19 | 100 | 59.54 | 100 | 59.54 | 100 |
| | | 60.70 | 2 | 79.59 | 99 | 59.89 | 100 | 60.00 | 100 | 60.00 | 100 |
| | | 61.70 | 2 | 79.89 | 99 | 60.59 | 100 | 60.46 | 100 | 60.46 | 100 |
| | | 62.70 | 2 | 80.19 | 100 | 61.29 | 100 | 60.91 | 100 | 60.91 | 100 |
| | | 63.70 | 3 | 80.49 | 100 | 61.99 | 100 | 61.37 | 100 | 61.37 | 100 |
| | | 64.70 | 4 | 80.79 | 100 | 62.69 | 100 | 61.83 | 100 | 61.83 | 100 |
| | | 64.71 | 100 | - | - | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA34 | | SA35 | | SA36 | | SA37 | | SA38 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | RD 1500 East | | Elkhorn | | Natomas | | Rio Linda | | West Sacramento | |
| Toe Elevation[3] | | 18.6 | | 8.5 | | 23.3 | | 19.5 | | 24.5 | |
| AWSE | | 42.8 | | 28.0 | | 32.9 | | 30.4 | | 32.5 | |
| Crest Elevation[3] | | 48.1 | | 31.5 | | 38.9 | | 41.4 | | 40.5 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | ULE | | ULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 18.59 | 0 | 8.47 | 0 | 23.26 | 0 | 19.47 | 0 | 24.46 | 0 |
| | | 21.01 | 0 | 10.42 | 0 | 24.23 | 0 | 20.56 | 0 | 25.26 | 0 |
| | | 23.43 | 0 | 12.37 | 0 | 25.20 | 0 | 21.66 | 0 | 26.06 | 0 |
| | | 25.85 | 1 | 14.32 | 1 | 26.16 | 1 | 22.75 | 0 | 26.86 | 0 |
| | | 28.27 | 1 | 16.27 | 2 | 27.13 | 1 | 23.85 | 0 | 27.66 | 1 |
| | | 30.69 | 2 | 18.22 | 3 | 28.10 | 2 | 24.94 | 0 | 28.46 | 1 |
| | | 33.11 | 3 | 20.17 | 4 | 29.07 | 3 | 26.04 | 0 | 29.26 | 1 |
| | | 35.53 | 5 | 22.12 | 7 | 30.04 | 4 | 27.13 | 0 | 30.06 | 1 |
| | | 37.95 | 8 | 24.07 | 12 | 31.00 | 7 | 28.23 | 0 | 30.86 | 1 |
| | | 40.37 | 13 | 26.02 | 19 | 31.97 | 12 | 29.32 | 0 | 31.66 | 2 |
| | | 42.79 | 21 | 27.97 | 30 | 32.94 | 20 | 30.42 | 0 | 32.46 | 2 |
| | | 43.32 | 52 | 28.32 | 74 | 33.54 | 52 | 31.51 | 0 | 33.26 | 2 |
| | | 43.85 | 71 | 28.67 | 91 | 34.14 | 71 | 32.61 | 1 | 34.06 | 8 |
| | | 44.38 | 83 | 29.02 | 97 | 34.75 | 83 | 33.70 | 1 | 34.86 | 11 |
| | | 44.91 | 90 | 29.37 | 99 | 35.35 | 90 | 34.80 | 1 | 35.66 | 15 |
| | | 45.44 | 94 | 29.72 | 100 | 35.95 | 94 | 35.89 | 1 | 36.46 | 21 |
| | | 45.97 | 96 | 30.07 | 100 | 36.55 | 97 | 36.99 | 2 | 37.26 | 29 |
| | | 46.50 | 98 | 30.42 | 100 | 37.15 | 98 | 38.08 | 2 | 38.06 | 41 |
| | | 47.03 | 99 | 30.77 | 100 | 37.76 | 99 | 39.18 | 3 | 38.86 | 57 |
| | | 47.56 | 100 | 31.12 | 100 | 38.36 | 100 | 40.27 | 3 | 39.66 | 72 |
| | | 48.09 | 100 | 31.47 | 100 | 38.96 | 100 | 41.37 | 3 | 40.46 | 81 |
| | | - | - | - | - | - | - | 41.38 | 100 | 40.47 | 100 |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA39 | | SA40 | | SA41 | | SA42 | | SA43 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | RD 900 | | Sacramento North | | RD 302 | | RD 999 | | Clarksburg | |
| Toe Elevation[3] | | 17.5 | | 25.5 | | 10.5 | | 12.5 | | 11.5 | |
| AWSE | | 27.5 | | 34.0 | | 26.5 | | 27.5 | | 23.0 | |
| Crest Elevation[3] | | 37.5 | | 42.5 | | 30.5 | | 31.5 | | 28.5 | |
| Type of Project (ULE or NULE) | | ULE | | ULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 17.46 | 0 | 25.46 | 0 | 10.50 | 0 | 12.49 | 0 | 11.53 | 0 |
| | | 18.46 | 1 | 26.31 | 0 | 12.10 | 0 | 13.99 | 0 | 12.68 | 0 |
| | | 19.46 | 1 | 27.16 | 0 | 13.70 | 0 | 15.49 | 0 | 13.83 | 0 |
| | | 20.46 | 2 | 28.01 | 0 | 15.30 | 1 | 16.99 | 1 | 14.98 | 0 |
| | | 21.46 | 2 | 28.86 | 0 | 16.90 | 1 | 18.49 | 1 | 16.13 | 0 |
| | | 22.46 | 2 | 29.71 | 0 | 18.50 | 2 | 19.99 | 2 | 17.28 | 0 |
| | | 23.46 | 3 | 30.56 | 1 | 20.10 | 4 | 21.49 | 3 | 18.43 | 1 |
| | | 24.46 | 4 | 31.41 | 1 | 21.70 | 6 | 22.99 | 4 | 19.58 | 1 |
| | | 25.46 | 6 | 32.26 | 1 | 23.30 | 10 | 24.49 | 7 | 20.73 | 2 |
| | | 26.46 | 10 | 33.11 | 1 | 24.90 | 16 | 25.99 | 12 | 21.88 | 3 |
| | | 27.46 | 18 | 33.96 | 5 | 26.50 | 25 | 27.49 | 19 | 23.03 | 5 |
| | | 28.46 | 28 | 34.81 | 7 | 26.90 | 63 | 27.89 | 46 | 23.58 | 6 |
| | | 29.46 | 43 | 35.66 | 10 | 27.30 | 81 | 28.29 | 60 | 24.13 | 7 |
| | | 30.46 | 63 | 36.51 | 14 | 27.70 | 90 | 28.69 | 67 | 24.68 | 8 |
| | | 31.46 | 82 | 37.36 | 19 | 28.10 | 94 | 29.09 | 72 | 25.23 | 9 |
| | | 32.46 | 93 | 38.21 | 27 | 28.50 | 97 | 29.49 | 74 | 25.78 | 9 |
| | | 33.46 | 98 | 39.06 | 39 | 28.90 | 98 | 29.89 | 76 | 26.33 | 10 |
| | | 34.46 | 100 | 39.91 | 55 | 29.30 | 99 | 30.29 | 77 | 26.88 | 11 |
| | | 35.46 | 100 | 40.76 | 70 | 29.70 | 99 | 30.69 | 77 | 27.43 | 12 |
| | | 36.46 | 100 | 41.61 | 81 | 30.10 | 100 | 31.09 | 78 | 27.98 | 13 |
| | | 37.46 | 100 | 42.46 | 88 | 30.50 | 100 | 31.49 | 100 | 28.53 | 100 |
| | | 37.47 | 100 | 42.47 | 100 | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA44 | | SA45 | | SA46 | | SA47 | | SA48 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Stone Lake | | Hood | | Merritt Island | | RD 551 | | Courtland | |
| Toe Elevation[3] | | 15.6 | | 15.6 | | 10.5 | | 5.6 | | 5.6 | |
| AWSE | | 20.5 | | 20.6 | | 21.1 | | 21.6 | | 21.6 | |
| Crest Elevation[3] | | 26.4 | | 26.4 | | 23.6 | | 25.6 | | 25.6 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 15.56 | 0 | 15.56 | 0 | 10.55 | 0 | 5.56 | 0 | 5.56 | 0 |
| | | 16.06 | 0 | 16.06 | 0 | 11.60 | 0 | 7.16 | 0 | 7.16 | 0 |
| | | 16.56 | 0 | 16.56 | 0 | 12.65 | 0 | 8.76 | 0 | 8.76 | 0 |
| | | 17.06 | 1 | 17.06 | 1 | 13.70 | 1 | 10.36 | 1 | 10.36 | 1 |
| | | 17.56 | 2 | 17.56 | 2 | 14.75 | 1 | 11.96 | 1 | 11.96 | 1 |
| | | 18.05 | 3 | 18.05 | 3 | 15.80 | 2 | 13.56 | 2 | 13.56 | 2 |
| | | 18.55 | 5 | 18.55 | 5 | 16.85 | 4 | 15.16 | 4 | 15.16 | 4 |
| | | 19.05 | 8 | 19.05 | 8 | 17.90 | 6 | 16.76 | 6 | 16.76 | 6 |
| | | 19.55 | 13 | 19.55 | 13 | 18.95 | 10 | 18.36 | 10 | 18.36 | 10 |
| | | 20.05 | 20 | 20.05 | 20 | 20.00 | 16 | 19.96 | 16 | 19.96 | 16 |
| | | 20.55 | 32 | 20.55 | 32 | 21.05 | 25 | 21.56 | 25 | 21.56 | 25 |
| | | 21.13 | 76 | 21.13 | 76 | 21.30 | 63 | 21.96 | 63 | 21.96 | 63 |
| | | 21.72 | 91 | 21.72 | 91 | 21.55 | 81 | 22.36 | 81 | 22.36 | 81 |
| | | 22.30 | 97 | 22.30 | 97 | 21.80 | 90 | 22.76 | 90 | 22.76 | 90 |
| | | 22.88 | 99 | 22.88 | 99 | 22.05 | 94 | 23.16 | 94 | 23.16 | 94 |
| | | 23.46 | 100 | 23.46 | 100 | 22.30 | 97 | 23.56 | 97 | 23.56 | 97 |
| | | 24.04 | 100 | 24.04 | 100 | 22.55 | 98 | 23.96 | 98 | 23.96 | 98 |
| | | 24.62 | 100 | 24.62 | 100 | 22.80 | 99 | 24.36 | 99 | 24.36 | 99 |
| | | 25.20 | 100 | 25.20 | 100 | 23.05 | 99 | 24.76 | 99 | 24.76 | 99 |
| | | 25.79 | 100 | 25.79 | 100 | 23.30 | 100 | 25.16 | 100 | 25.16 | 100 |
| | | 26.37 | 100 | 26.37 | 100 | 23.55 | 100 | 25.56 | 100 | 25.56 | 100 |
| | | - | - | - | - | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA49 | | SA50 | | SA51 | | SA52 | | SA53 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Sutter Island | | Grand Island | | Locke | | Walnut Grove | | Tyler Island | |
| Toe Elevation[3] | | 4.6 | | -0.4 | | 7.6 | | 9.6 | | -2.4 | |
| AWSE | | 16.1 | | 12.4 | | 15.0 | | 14.5 | | 9.6 | |
| Crest Elevation[3] | | 22.6 | | 17.8 | | 20.1 | | 22.6 | | 11.6 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 4.58 | 0 | -0.42 | 0 | 7.61 | 0 | 9.61 | 0 | -2.38 | 0 |
| | | 5.73 | 0 | 0.87 | 0 | 8.35 | 0 | 10.10 | 0 | -1.18 | 0 |
| | | 6.88 | 0 | 2.15 | 1 | 9.09 | 0 | 10.59 | 0 | 0.02 | 0 |
| | | 8.03 | 1 | 3.44 | 1 | 9.83 | 0 | 11.08 | 0 | 1.22 | 1 |
| | | 9.18 | 2 | 4.73 | 2 | 10.57 | 0 | 11.57 | 0 | 2.42 | 2 |
| | | 10.33 | 3 | 6.01 | 3 | 11.31 | 0 | 12.06 | 0 | 3.62 | 3 |
| | | 11.48 | 5 | 7.30 | 6 | 12.05 | 0 | 12.55 | 0 | 4.82 | 5 |
| | | 12.63 | 8 | 8.59 | 9 | 12.79 | 0 | 13.04 | 0 | 6.02 | 8 |
| | | 13.78 | 13 | 9.87 | 15 | 13.53 | 1 | 13.53 | 1 | 7.22 | 13 |
| | | 14.93 | 20 | 11.16 | 24 | 14.27 | 1 | 14.02 | 1 | 8.42 | 20 |
| | | 16.08 | 32 | 12.45 | 37 | 15.01 | 2 | 14.51 | 2 | 9.62 | 32 |
| | | 16.73 | 73 | 12.98 | 81 | 15.52 | 3 | 15.32 | 3 | 9.82 | 75 |
| | | 17.38 | 88 | 13.52 | 94 | 16.03 | 3 | 16.13 | 5 | 10.02 | 91 |
| | | 18.03 | 94 | 14.06 | 98 | 16.54 | 4 | 16.94 | 6 | 10.22 | 97 |
| | | 18.68 | 97 | 14.60 | 99 | 17.05 | 4 | 17.75 | 7 | 10.42 | 99 |
| | | 19.33 | 98 | 15.13 | 100 | 17.56 | 5 | 18.56 | 8 | 10.62 | 100 |
| | | 19.98 | 99 | 15.67 | 100 | 18.07 | 5 | 19.37 | 9 | 10.82 | 100 |
| | | 20.63 | 100 | 16.21 | 100 | 18.58 | 6 | 20.18 | 11 | 11.02 | 100 |
| | | 21.28 | 100 | 16.75 | 100 | 19.09 | 6 | 20.99 | 12 | 11.22 | 100 |
| | | 21.93 | 100 | 17.28 | 100 | 19.60 | 7 | 21.80 | 13 | 11.42 | 100 |
| | | 22.58 | 100 | 17.82 | 100 | 20.11 | 100 | 22.61 | 100 | 11.62 | 100 |
| | | - | - | - | - | - | - | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA54 | | SA55 | | SA56 | | SA57 | | SA58 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Andrus Island | | Ryer Island | | Prospect Island | | Twitchell Island | | Sherman Island | |
| Toe Elevation[3] | | -2.4 | | -1.4 | | 0.00 | | -1.4 | | -12.4 | |
| AWSE | | 11.6 | | 11.8 | | 0.00 | | 9.1 | | 8.6 | |
| Crest Elevation[3] | | 13.6 | | 20.8 | | 0.00 | | 13.6 | | 10.6 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | -2.39 | 0 | -1.42 | 0 | | | -1.40 | 0 | -12.43 | 0 |
| | | -0.99 | 0 | -0.10 | 0 | | | -0.35 | 0 | -10.33 | 0 |
| | | 0.41 | 0 | 1.22 | 0 | | | 0.70 | 0 | -8.23 | 0 |
| | | 1.81 | 0 | 2.55 | 1 | | | 1.75 | 0 | -6.13 | 1 |
| | | 3.21 | 0 | 3.87 | 2 | | | 2.80 | 0 | -4.03 | 2 |
| | | 4.61 | 1 | 5.20 | 3 | | | 3.85 | 1 | -1.93 | 3 |
| | | 6.01 | 1 | 6.52 | 5 | | | 4.90 | 1 | 0.17 | 5 |
| | | 7.41 | 2 | 7.84 | 8 | | | 5.95 | 2 | 2.27 | 8 |
| | | 8.81 | 3 | 9.17 | 13 | | | 7.00 | 3 | 4.37 | 13 |
| | | 10.21 | 4 | 10.49 | 20 | | | 8.05 | 5 | 6.47 | 20 |
| | | 11.61 | 7 | 11.82 | 32 | | | 9.10 | 8 | 8.57 | 32 |
| | | 11.81 | 7 | 12.72 | 75 | | | 9.55 | 9 | 8.77 | 75 |
| | | 12.01 | 8 | 13.62 | 91 | | | 10.00 | 10 | 8.97 | 91 |
| | | 12.21 | 8 | 14.52 | 97 | | | 10.45 | 12 | 9.17 | 97 |
| | | 12.41 | 9 | 15.42 | 99 | | | 10.90 | 13 | 9.37 | 99 |
| | | 12.61 | 9 | 16.33 | 100 | | | 11.35 | 14 | 9.57 | 100 |
| | | 12.81 | 9 | 17.23 | 100 | | | 11.80 | 15 | 9.77 | 100 |
| | | 13.01 | 10 | 18.13 | 100 | | | 12.25 | 16 | 9.97 | 100 |
| | | 13.21 | 10 | 19.03 | 100 | | | 12.70 | 18 | 10.17 | 100 |
| | | 13.41 | 10 | 19.94 | 100 | | | 13.15 | 19 | 10.37 | 100 |
| | | 13.61 | 100 | 20.84 | 100 | | 100 | 13.60 | 100 | 10.57 | 100 |
| | | - | - | - | - | | | - | - | - | - |

**Table 4-1. Sacramento River Basin Levee Performance Curves (contd.)**

| ID | | SA59 | | SA60 | | SA61 | | SA62 | | SA63 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Moore | | Cache Slough | | Hastings | | Lindsey Slough | | Sacramento South | |
| Toe Elevation[3] | | 2.0 | | 2.5 | | 1.5 | | 3.5 | | 27.5 | |
| AWSE | | 15.5 | | 15.5 | | 14.3 | | 14.3 | | 33.3 | |
| Crest Elevation[3] | | 19.5 | | 18.0 | | 16.7 | | 18.5 | | 39.1 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | ULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 2.04 | 0 | 2.52 | 0 | 1.53 | 0 | 3.53 | 0 | 27.46 | 0 |
| | | 3.39 | 0 | 3.82 | 0 | 2.81 | 0 | 4.60 | 0 | 28.04 | 0 |
| | | 4.74 | 0 | 5.12 | 0 | 4.09 | 0 | 5.68 | 1 | 28.62 | 0 |
| | | 6.09 | 1 | 6.42 | 0 | 5.36 | 1 | 6.75 | 1 | 29.20 | 0 |
| | | 7.44 | 1 | 7.72 | 0 | 6.64 | 1 | 7.83 | 2 | 29.78 | 1 |
| | | 8.79 | 2 | 9.02 | 0 | 7.92 | 2 | 8.90 | 4 | 30.36 | 1 |
| | | 10.14 | 4 | 10.32 | 0 | 9.19 | 3 | 9.98 | 6 | 30.94 | 1 |
| | | 11.49 | 6 | 11.62 | 1 | 10.47 | 5 | 11.06 | 11 | 31.52 | 1 |
| | | 12.84 | 10 | 12.92 | 1 | 11.75 | 8 | 12.13 | 17 | 32.10 | 2 |
| | | 14.19 | 16 | 14.22 | 2 | 13.02 | 13 | 13.21 | 27 | 32.68 | 2 |
| | | 15.54 | 25 | 15.52 | 3 | 14.30 | 21 | 14.28 | 42 | 33.26 | 3 |
| | | 15.94 | 63 | 15.77 | 3 | 14.54 | 52 | 14.71 | 86 | 33.84 | 4 |
| | | 16.34 | 81 | 16.02 | 3 | 14.79 | 71 | 15.13 | 96 | 34.42 | 5 |
| | | 16.74 | 90 | 16.27 | 3 | 15.03 | 83 | 15.55 | 99 | 35.00 | 6 |
| | | 17.14 | 94 | 16.52 | 4 | 15.27 | 90 | 15.97 | 100 | 35.58 | 7 |
| | | 17.54 | 97 | 16.77 | 4 | 15.52 | 94 | 16.40 | 100 | 36.16 | 8 |
| | | 17.94 | 98 | 17.02 | 4 | 15.76 | 96 | 16.82 | 100 | 36.74 | 8 |
| | | 18.34 | 99 | 17.27 | 4 | 16.00 | 98 | 17.24 | 100 | 37.32 | 9 |
| | | 18.74 | 99 | 17.52 | 4 | 16.25 | 99 | 17.66 | 100 | 37.90 | 10 |
| | | 19.14 | 100 | 17.77 | 5 | 16.49 | 100 | 18.09 | 100 | 38.48 | 12 |
| | | 19.54 | 100 | 18.02 | 100 | 16.73 | 100 | 18.51 | 100 | 39.06 | 13 |
| | | - | - | - | - | - | - | - | - | 39.07 | 100 |

Notes:
[1] No State-federal project levees found within the impact area
[2] Assume overbank flow
[3] Elevations in feet, NGVD29

Key:
- = not applicable
AWSE = Assessment Water Surface Elevation
NGVD29 = National Geodetic vertical Datum of 1929
NULE = Non-Urban Levee Evaluations
RD = Reclamation District
ULE = Urban Levee Evaluations

**Table 4-2. San Joaquin River Basin Levee Performance Curves**

| ID | | SJ1 | SJ2 | | SJ3 | | SJ4 | | SJ5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Fresno | Fresno Slough East | | Fresno Slough West | | Mendota | | Chowchilla Bypass | |
| Toe Elevation[3] | | 1 | 159.6 | | 150.9 | | 151.6 | | 157.8 | |
| AWSE | | | 163.8 | | 155.9 | | 153.6 | | 166.8 | |
| Crest Elevation[3] | | | 166.8 | | 158.9 | | 156.6 | | 170.8 | |
| Type of Project (ULE or NULE) | | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 2 | 159.59 | 0 | 150.90 | 0 | 151.61 | 0 | 157.82 | 0 |
| | | | 160.01 | 0 | 151.40 | 0 | 151.81 | 0 | 158.72 | 0 |
| | | | 160.43 | 0 | 151.90 | 0 | 152.01 | 0 | 159.62 | 0 |
| | | | 160.85 | 1 | 152.40 | 0 | 152.21 | 0 | 160.52 | 1 |
| | | | 161.27 | 2 | 152.90 | 1 | 152.41 | 0 | 161.42 | 2 |
| | | | 161.69 | 3 | 153.40 | 1 | 152.61 | 0 | 162.32 | 3 |
| | | | 162.11 | 5 | 153.90 | 3 | 152.81 | 0 | 163.22 | 4 |
| | | | 162.53 | 7 | 154.40 | 4 | 153.01 | 0 | 164.12 | 7 |
| | | | 162.95 | 12 | 154.90 | 7 | 153.21 | 1 | 165.02 | 12 |
| | | | 163.37 | 20 | 155.40 | 11 | 153.41 | 1 | 165.92 | 19 |
| | | | 163.79 | 31 | 155.90 | 18 | 153.61 | 2 | 166.82 | 30 |
| | | | 164.09 | 75 | 156.20 | 46 | 153.91 | 3 | 167.22 | 74 |
| | | | 164.39 | 91 | 156.50 | 60 | 154.21 | 4 | 167.62 | 91 |
| | | | 164.69 | 97 | 156.80 | 67 | 154.51 | 5 | 168.02 | 97 |
| | | | 164.99 | 99 | 157.10 | 72 | 154.81 | 7 | 168.42 | 99 |
| | | | 165.29 | 100 | 157.40 | 74 | 155.11 | 8 | 168.82 | 100 |
| | | | 165.59 | 100 | 157.70 | 76 | 155.41 | 9 | 169.22 | 100 |
| | | | 165.89 | 100 | 158.00 | 77 | 155.71 | 10 | 169.62 | 100 |
| | | | 166.19 | 100 | 158.30 | 78 | 156.01 | 11 | 170.02 | 100 |
| | | | 166.49 | 100 | 158.60 | 79 | 156.31 | 12 | 170.42 | 100 |
| | | | 166.79 | 100 | 158.90 | 100 | 156.61 | 100 | 170.82 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ6 | | SJ7 | SJ8 | | SJ9 | | SJ10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Lone Willow Slough | | Mendota North | Firebaugh | | Salt Slough | | Dos Palos | |
| Toe Elevation[3] | | 152.2 | | 1 | 141.2 | | 114.8 | | 114.8 | |
| AWSE | | 157.4 | | | 143.1 | | 117.5 | | 117.5 | |
| Crest Elevation[3] | | 160.4 | | | 146.1 | | 120.5 | | 120.5 | |
| Type of Project (ULE or NULE) | | NULE | | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 152.22 | 0 | 2 | 141.17 | 0 | 114.83 | 0 | 114.83 | 0 |
| | | 152.74 | 0 | | 141.37 | 0 | 115.10 | 0 | 115.10 | 0 |
| | | 153.26 | 0 | | 141.56 | 0 | 115.37 | 0 | 115.37 | 0 |
| | | 153.78 | 0 | | 141.76 | 0 | 115.64 | 0 | 115.64 | 0 |
| | | 154.30 | 1 | | 141.95 | 0 | 115.91 | 0 | 115.91 | 0 |
| | | 154.82 | 1 | | 142.14 | 0 | 116.18 | 0 | 116.18 | 0 |
| | | 155.34 | 2 | | 142.34 | 0 | 116.45 | 0 | 116.45 | 0 |
| | | 155.86 | 3 | | 142.53 | 1 | 116.72 | 1 | 116.72 | 1 |
| | | 156.38 | 4 | | 142.73 | 1 | 116.99 | 1 | 116.99 | 1 |
| | | 156.90 | 7 | | 142.92 | 2 | 117.26 | 2 | 117.26 | 2 |
| | | 157.42 | 12 | | 143.11 | 3 | 117.53 | 3 | 117.53 | 3 |
| | | 157.72 | 28 | | 143.41 | 4 | 117.83 | 4 | 117.83 | 4 |
| | | 158.02 | 39 | | 143.71 | 6 | 118.13 | 5 | 118.13 | 5 |
| | | 158.32 | 45 | | 144.01 | 8 | 118.43 | 6 | 118.43 | 6 |
| | | 158.62 | 49 | | 144.31 | 9 | 118.73 | 7 | 118.73 | 7 |
| | | 158.92 | 52 | | 144.61 | 11 | 119.03 | 9 | 119.03 | 9 |
| | | 159.22 | 54 | | 144.91 | 12 | 119.33 | 10 | 119.33 | 10 |
| | | 159.52 | 55 | | 145.21 | 14 | 119.63 | 11 | 119.63 | 11 |
| | | 159.82 | 56 | | 145.51 | 15 | 119.93 | 12 | 119.93 | 12 |
| | | 160.12 | 57 | | 145.81 | 17 | 120.23 | 13 | 120.23 | 13 |
| | | 160.42 | 100 | | 146.11 | 100 | 120.53 | 100 | 120.53 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ11 | | SJ12 | | SJ13 | | SJ14 | | SJ15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Fresno River | | Berenda Slough | | Ash Slough | | Sandy Mush | | Turner Island | |
| Toe Elevation[3] | | 184.1 | | 148.2 | | 139.1 | | 98.6 | | 96.5 | |
| AWSE | | 189.2 | | 150.9 | | 142.6 | | 105.8 | | 105.7 | |
| Crest Elevation[3] | | 192.2 | | 153.9 | | 145.6 | | 109.8 | | 109.7 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 184.14 | 0 | 148.17 | 0 | 139.06 | 0 | 98.61 | 0 | 96.49 | 0 |
| | | 184.65 | 0 | 148.44 | 0 | 139.41 | 0 | 99.33 | 0 | 97.41 | 0 |
| | | 185.16 | 0 | 148.71 | 0 | 139.76 | 0 | 100.05 | 0 | 98.33 | 0 |
| | | 185.67 | 0 | 148.98 | 0 | 140.11 | 0 | 100.77 | 1 | 99.25 | 1 |
| | | 186.18 | 1 | 149.25 | 0 | 140.46 | 0 | 101.49 | 2 | 100.17 | 2 |
| | | 186.69 | 1 | 149.52 | 0 | 140.81 | 0 | 102.21 | 3 | 101.09 | 3 |
| | | 187.20 | 3 | 149.79 | 0 | 141.16 | 1 | 102.93 | 4 | 102.01 | 4 |
| | | 187.71 | 4 | 150.06 | 0 | 141.51 | 1 | 103.65 | 7 | 102.93 | 7 |
| | | 188.22 | 7 | 150.33 | 1 | 141.86 | 2 | 104.37 | 12 | 103.85 | 12 |
| | | 188.73 | 11 | 150.60 | 1 | 142.21 | 3 | 105.09 | 19 | 104.77 | 19 |
| | | 189.24 | 19 | 150.87 | 2 | 142.56 | 5 | 105.81 | 30 | 105.69 | 30 |
| | | 189.54 | 51 | 151.17 | 3 | 142.86 | 7 | 106.21 | 74 | 106.09 | 74 |
| | | 189.84 | 71 | 151.47 | 4 | 143.16 | 8 | 106.61 | 91 | 106.49 | 91 |
| | | 190.14 | 82 | 151.77 | 5 | 143.46 | 10 | 107.01 | 97 | 106.89 | 97 |
| | | 190.44 | 89 | 152.07 | 5 | 143.76 | 11 | 107.41 | 99 | 107.29 | 99 |
| | | 190.74 | 94 | 152.37 | 6 | 144.06 | 13 | 107.81 | 100 | 107.69 | 100 |
| | | 191.04 | 96 | 152.67 | 7 | 144.36 | 14 | 108.21 | 100 | 108.09 | 100 |
| | | 191.34 | 98 | 152.97 | 8 | 144.66 | 16 | 108.61 | 100 | 108.49 | 100 |
| | | 191.64 | 99 | 153.27 | 9 | 144.96 | 17 | 109.01 | 100 | 108.89 | 100 |
| | | 191.94 | 100 | 153.57 | 10 | 145.26 | 19 | 109.41 | 100 | 109.29 | 100 |
| | | 192.24 | 100 | 153.87 | 100 | 145.56 | 100 | 109.81 | 100 | 109.69 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ16 | | SJ17 | | SJ18 | | SJ19 | | SJ20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Bear Creek | | Deep Slough | | West Bear Creek | | Fremont Ford | | Merced River |
| Toe Elevation[3] | | 84.4 | | 84.2 | | 81.3 | | 64.0 | | 1 |
| AWSE | | 89.1 | | 89.9 | | 85.8 | | 70.9 | | |
| Crest Elevation[3] | | 92.1 | | 92.9 | | 88.8 | | 73.5 | | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 84.39 | 0 | 84.20 | 0 | 81.27 | 0 | 63.97 | 0 | 2 |
| | | 84.86 | 0 | 84.77 | 0 | 81.72 | 0 | 64.66 | 0 | |
| | | 85.33 | 0 | 85.34 | 0 | 82.17 | 0 | 65.35 | 0 | |
| | | 85.80 | 0 | 85.91 | 0 | 82.62 | 0 | 66.04 | 0 | |
| | | 86.27 | 0 | 86.48 | 1 | 83.07 | 1 | 66.73 | 0 | |
| | | 86.74 | 0 | 87.05 | 1 | 83.52 | 1 | 67.42 | 0 | |
| | | 87.21 | 0 | 87.62 | 3 | 83.97 | 3 | 68.11 | 1 | |
| | | 87.68 | 1 | 88.19 | 4 | 84.42 | 4 | 68.80 | 1 | |
| | | 88.15 | 1 | 88.76 | 7 | 84.87 | 7 | 69.49 | 2 | |
| | | 88.62 | 2 | 89.33 | 11 | 85.32 | 11 | 70.18 | 3 | |
| | | 89.09 | 3 | 89.90 | 19 | 85.77 | 19 | 70.87 | 4 | |
| | | 89.39 | 4 | 90.20 | 51 | 86.07 | 51 | 71.13 | 5 | |
| | | 89.69 | 5 | 90.50 | 71 | 86.37 | 71 | 71.39 | 5 | |
| | | 89.99 | 6 | 90.80 | 82 | 86.67 | 82 | 71.65 | 6 | |
| | | 90.29 | 7 | 91.10 | 89 | 86.97 | 90 | 71.91 | 7 | |
| | | 90.59 | 8 | 91.40 | 94 | 87.27 | 94 | 72.17 | 7 | |
| | | 90.89 | 9 | 91.70 | 96 | 87.57 | 96 | 72.43 | 8 | |
| | | 91.19 | 9 | 92.00 | 98 | 87.87 | 98 | 72.69 | 8 | |
| | | 91.49 | 10 | 92.30 | 99 | 88.17 | 99 | 72.95 | 9 | |
| | | 91.79 | 11 | 92.60 | 100 | 88.47 | 100 | 73.21 | 10 | |
| | | 92.09 | 100 | 92.90 | 100 | 88.77 | 100 | 73.47 | 100 | |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ21 | | SJ22 | | SJ23 | | SJ24 | | SJ25 |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Merced River North | | Orestimba | | Tuolumne South | | Tuolumne River | | Modesto |
| Toe Elevation[3] | | 42.0 | | 48.6 | | 33.0 | | 40.1 | | 1 |
| AWSE | | 52.6 | | 57.0 | | 38.6 | | 47.0 | | |
| Crest Elevation[3] | | 54.9 | | 57.0 | | 38.6 | | 50.4 | | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 41.98 | 0 | 48.59 | 0 | 33.01 | 0 | 40.09 | 0 | 2 |
| | | 43.04 | 0 | 49.43 | 0 | 33.57 | 0 | 40.79 | 0 | |
| | | 44.10 | 0 | 50.27 | 0 | 34.13 | 0 | 41.48 | 1 | |
| | | 45.16 | 1 | 51.11 | 1 | 34.69 | 1 | 42.17 | 1 | |
| | | 46.22 | 2 | 51.95 | 2 | 35.25 | 2 | 42.86 | 2 | |
| | | 47.28 | 3 | 52.79 | 3 | 35.81 | 3 | 43.56 | 4 | |
| | | 48.34 | 4 | 53.63 | 4 | 36.37 | 4 | 44.25 | 6 | |
| | | 49.40 | 7 | 54.47 | 7 | 36.93 | 7 | 44.94 | 10 | |
| | | 50.46 | 12 | 55.31 | 12 | 37.49 | 12 | 45.64 | 17 | |
| | | 51.52 | 19 | 56.15 | 19 | 38.05 | 19 | 46.33 | 27 | |
| | | 52.58 | 30 | 56.99 | 30 | 38.61 | 31 | 47.02 | 41 | |
| | | 52.81 | 74 | 57.29 | 74 | 38.61 | 75 | 47.36 | 87 | |
| | | 53.04 | 91 | 57.59 | 91 | 38.61 | 91 | 47.70 | 97 | |
| | | 53.27 | 97 | 57.89 | 97 | 38.61 | 97 | 48.05 | 99 | |
| | | 53.50 | 99 | 58.19 | 99 | 38.61 | 99 | 48.39 | 100 | |
| | | 53.73 | 100 | 58.49 | 100 | 38.61 | 100 | 48.73 | 100 | |
| | | 53.96 | 100 | 58.79 | 100 | 38.61 | 100 | 49.07 | 100 | |
| | | 54.19 | 100 | 59.09 | 100 | 38.61 | 100 | 49.41 | 100 | |
| | | 54.42 | 100 | 59.39 | 100 | 38.61 | 100 | 49.75 | 100 | |
| | | 54.65 | 100 | 59.69 | 100 | 38.61 | 100 | 50.09 | 100 | |
| | | 54.88 | 100 | 59.99 | 100 | 38.61 | 100 | 50.43 | 100 | |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ26 | | SJ27 | | SJ28 | | SJ29 | | SJ30 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | 3 Amigos | | Stanislaus South | | Stanislaus North | | Banta Carbona | | Paradise Cut | |
| Toe Elevation[3] | | 28.4 | | 23.5 | | 27.9 | | 19.5 | | 0.6 | |
| AWSE | | 38.7 | | 36.6 | | 35.5 | | 28.4 | | 14.7 | |
| Crest Elevation[3] | | 41.7 | | 40.0 | | 38.5 | | 32.1 | | 22.4 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 28.41 | 0 | 23.52 | 0 | 27.93 | 0 | 19.49 | 0 | 0.58 | 0 |
| | | 29.44 | 0 | 24.83 | 0 | 28.69 | 0 | 20.39 | 0 | 1.99 | 0 |
| | | 30.47 | 0 | 26.14 | 1 | 29.45 | 1 | 21.28 | 0 | 3.40 | 1 |
| | | 31.50 | 1 | 27.45 | 1 | 30.21 | 1 | 22.17 | 1 | 4.81 | 1 |
| | | 32.53 | 2 | 28.76 | 2 | 30.97 | 2 | 23.07 | 2 | 6.22 | 2 |
| | | 33.56 | 3 | 30.07 | 4 | 31.73 | 4 | 23.96 | 3 | 7.63 | 4 |
| | | 34.59 | 5 | 31.38 | 6 | 32.49 | 6 | 24.86 | 5 | 9.04 | 6 |
| | | 35.62 | 7 | 32.69 | 10 | 33.25 | 10 | 25.75 | 7 | 10.45 | 10 |
| | | 36.65 | 12 | 34.00 | 17 | 34.01 | 17 | 26.64 | 12 | 11.86 | 17 |
| | | 37.68 | 20 | 35.31 | 27 | 34.77 | 27 | 27.54 | 20 | 13.27 | 27 |
| | | 38.71 | 31 | 36.62 | 41 | 35.53 | 41 | 28.43 | 31 | 14.68 | 41 |
| | | 39.01 | 75 | 36.96 | 87 | 35.83 | 87 | 28.79 | 75 | 15.45 | 87 |
| | | 39.31 | 91 | 37.30 | 97 | 36.13 | 97 | 29.16 | 91 | 16.22 | 97 |
| | | 39.61 | 97 | 37.64 | 99 | 36.43 | 99 | 29.52 | 97 | 16.99 | 99 |
| | | 39.91 | 99 | 37.98 | 100 | 36.73 | 100 | 29.88 | 99 | 17.76 | 100 |
| | | 40.21 | 100 | 38.32 | 100 | 37.03 | 100 | 30.25 | 100 | 18.53 | 100 |
| | | 40.51 | 100 | 38.66 | 100 | 37.33 | 100 | 30.61 | 100 | 19.30 | 100 |
| | | 40.81 | 100 | 39.00 | 100 | 37.63 | 100 | 30.97 | 100 | 20.07 | 100 |
| | | 41.11 | 100 | 39.34 | 100 | 37.93 | 100 | 31.34 | 100 | 20.84 | 100 |
| | | 41.41 | 100 | 39.68 | 100 | 38.23 | 100 | 31.70 | 100 | 21.61 | 100 |
| | | 41.71 | 100 | 40.02 | 100 | 38.53 | 100 | 32.06 | 100 | 22.38 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ31 | | SJ32 | | SJ33 | | SJ34 | | SJ35 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Stewart Tract | | East Lathrop | | Lathrop/ Sharpe | | French Camp | | Moss Tract | |
| Toe Elevation[3] | | 13.7 | | 16.6 | | 12.7 | | 10.7 | | 4.4 | |
| AWSE | | 23.4 | | 22.8 | | 18.2 | | 17.0 | | 11.7 | |
| Crest Elevation[3] | | 28.8 | | 30.9 | | 29.0 | | 26.0 | | 19.4 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 13.75 | 0 | 16.65 | 0 | 12.67 | 0 | 10.69 | 0 | 4.41 | 0 |
| | | 14.72 | 0 | 17.27 | 0 | 13.22 | 0 | 11.32 | 0 | 5.14 | 0 |
| | | 15.69 | 0 | 17.89 | 0 | 13.77 | 0 | 11.95 | 0 | 5.87 | 0 |
| | | 16.66 | 1 | 18.51 | 0 | 14.32 | 0 | 12.58 | 0 | 6.60 | 0 |
| | | 17.63 | 2 | 19.13 | 0 | 14.87 | 0 | 13.21 | 0 | 7.33 | 1 |
| | | 18.60 | 3 | 19.75 | 0 | 15.42 | 0 | 13.84 | 0 | 8.06 | 1 |
| | | 19.57 | 5 | 20.37 | 1 | 15.97 | 1 | 14.47 | 1 | 8.79 | 3 |
| | | 20.54 | 7 | 20.99 | 1 | 16.52 | 1 | 15.10 | 1 | 9.52 | 4 |
| | | 21.51 | 12 | 21.61 | 2 | 17.07 | 2 | 15.73 | 2 | 10.25 | 7 |
| | | 22.48 | 20 | 22.23 | 3 | 17.62 | 3 | 16.36 | 3 | 10.98 | 11 |
| | | 23.45 | 31 | 22.85 | 5 | 18.17 | 5 | 16.99 | 5 | 11.71 | 19 |
| | | 23.99 | 75 | 23.66 | 7 | 19.25 | 9 | 17.89 | 8 | 12.48 | 51 |
| | | 24.53 | 91 | 24.47 | 10 | 20.33 | 12 | 18.79 | 10 | 13.25 | 71 |
| | | 25.07 | 97 | 25.28 | 12 | 21.41 | 16 | 19.69 | 13 | 14.02 | 83 |
| | | 25.61 | 99 | 26.09 | 15 | 22.49 | 19 | 20.59 | 15 | 14.79 | 90 |
| | | 26.15 | 100 | 26.90 | 17 | 23.57 | 22 | 21.49 | 18 | 15.56 | 94 |
| | | 26.69 | 100 | 27.71 | 19 | 24.65 | 26 | 22.39 | 20 | 16.33 | 97 |
| | | 27.23 | 100 | 28.52 | 21 | 25.73 | 29 | 23.29 | 23 | 17.10 | 98 |
| | | 27.77 | 100 | 29.33 | 24 | 26.81 | 32 | 24.19 | 25 | 17.87 | 99 |
| | | 28.31 | 100 | 30.14 | 26 | 27.89 | 35 | 25.09 | 27 | 18.64 | 100 |
| | | 28.85 | 100 | 30.95 | 100 | 28.97 | 100 | 25.99 | 100 | 19.41 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ36 | | SJ37 | | SJ38 | | SJ39 | | SJ40 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | | Roberts Island | | Rough and Ready Island | | Drexler Tract | | Union Island | | SE Union Island | |
| Toe Elevation[3] | | 4.6 | | 2.7 | | -2.8 | | 8.6 | | 5.3 | |
| AWSE | | 17.0 | | 8.6 | | 7.7 | | 13.5 | | 13.4 | |
| Crest Elevation[3] | | 26.1 | | 13.9 | | 8.4 | | 23.4 | | 19.3 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 4.58 | 0 | 2.75 | 0 | -2.85 | 0 | 8.61 | 0 | 5.28 | 0 |
| | | 5.82 | 0 | 3.34 | 0 | -1.80 | 0 | 9.10 | 0 | 6.09 | 0 |
| | | 7.06 | 0 | 3.93 | 0 | -0.74 | 0 | 9.59 | 0 | 6.90 | 1 |
| | | 8.30 | 1 | 4.52 | 0 | 0.31 | 0 | 10.08 | 1 | 7.71 | 1 |
| | | 9.54 | 1 | 5.11 | 0 | 1.37 | 1 | 10.57 | 2 | 8.52 | 2 |
| | | 10.78 | 2 | 5.70 | 0 | 2.43 | 1 | 11.06 | 3 | 9.33 | 4 |
| | | 12.02 | 3 | 6.29 | 0 | 3.48 | 2 | 11.55 | 5 | 10.14 | 6 |
| | | 13.26 | 4 | 6.88 | 0 | 4.54 | 3 | 12.04 | 7 | 10.95 | 10 |
| | | 14.50 | 7 | 7.47 | 1 | 5.59 | 5 | 12.53 | 12 | 11.76 | 17 |
| | | 15.74 | 12 | 8.06 | 1 | 6.65 | 8 | 13.02 | 20 | 12.57 | 27 |
| | | 16.98 | 20 | 8.65 | 2 | 7.71 | 13 | 13.51 | 31 | 13.38 | 41 |
| | | 17.89 | 52 | 9.18 | 3 | 7.78 | 29 | 14.50 | 75 | 13.97 | 87 |
| | | 18.80 | 71 | 9.71 | 3 | 7.85 | 39 | 15.49 | 91 | 14.56 | 97 |
| | | 19.71 | 83 | 10.24 | 4 | 7.92 | 45 | 16.48 | 97 | 15.15 | 99 |
| | | 20.62 | 90 | 10.77 | 5 | 7.99 | 48 | 17.47 | 99 | 15.74 | 100 |
| | | 21.53 | 94 | 11.30 | 5 | 8.06 | 50 | 18.46 | 100 | 16.33 | 100 |
| | | 22.44 | 97 | 11.83 | 6 | 8.13 | 52 | 19.45 | 100 | 16.92 | 100 |
| | | 23.35 | 98 | 12.36 | 7 | 8.20 | 53 | 20.44 | 100 | 17.51 | 100 |
| | | 24.26 | 99 | 12.89 | 7 | 8.27 | 53 | 21.43 | 100 | 18.10 | 100 |
| | | 25.17 | 100 | 13.42 | 8 | 8.34 | 54 | 22.42 | 100 | 18.69 | 100 |
| | | 26.08 | 100 | 13.95 | 100 | 8.41 | 100 | 23.41 | 100 | 19.28 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | SJ41 | | SJ42 | | SJ43 | |
|---|---|---|---|---|---|---|---|
| Name | | Fabian Tract | | RD 1007 | | Grayson | |
| Toe Elevation[3] | | 5.5 | | 6.3 | | 31.6 | |
| AWSE | | 10.4 | | 10.4 | | 42.4 | |
| Crest Elevation[3] | | 21.3 | | 19.3 | | 46.2 | |
| Type of Project (ULE or NULE) | | NULE | | NULE | | NULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 5.49 | 0 | 6.27 | 0 | 31.60 | 0 |
| | | 5.98 | 0 | 6.68 | 0 | 32.68 | 0 |
| | | 6.47 | 0 | 7.09 | 0 | 33.76 | 0 |
| | | 6.95 | 0 | 7.50 | 0 | 34.84 | 0 |
| | | 7.44 | 0 | 7.91 | 0 | 35.92 | 0 |
| | | 7.93 | 0 | 8.32 | 0 | 37.00 | 1 |
| | | 8.42 | 1 | 8.73 | 0 | 38.08 | 1 |
| | | 8.91 | 1 | 9.14 | 1 | 39.16 | 1 |
| | | 9.40 | 2 | 9.55 | 1 | 40.24 | 2 |
| | | 9.89 | 3 | 9.96 | 2 | 41.32 | 4 |
| | | 10.38 | 4 | 10.37 | 3 | 42.40 | 6 |
| | | 11.47 | 8 | 11.26 | 6 | 42.78 | 7 |
| | | 12.57 | 11 | 12.15 | 9 | 43.16 | 8 |
| | | 13.67 | 15 | 13.04 | 12 | 43.54 | 9 |
| | | 14.76 | 18 | 13.93 | 15 | 43.92 | 10 |
| | | 15.86 | 21 | 14.82 | 17 | 44.30 | 11 |
| | | 16.95 | 24 | 15.71 | 20 | 44.68 | 11 |
| | | 18.05 | 28 | 16.60 | 22 | 45.06 | 12 |
| | | 19.15 | 31 | 17.49 | 25 | 45.44 | 13 |
| | | 20.24 | 33 | 18.38 | 27 | 45.82 | 14 |
| | | 21.34 | 100 | 19.27 | 100 | 46.20 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | STK6 | | STK7 | | STK8 | |
|---|---|---|---|---|---|---|---|
| Name | | Stockton Diverting Canal | | Calaveras River North | | Bear Creek South | |
| Toe Elevation[3] | | 31.2 | | 8.6 | | 19.8 | |
| AWSE | | 33.8 | | 9.9 | | 25.7 | |
| Crest Elevation[3] | | 36.8 | | 17.6 | | 30.0 | |
| Type of Project (ULE or NULE) | | NULE | | ULE | | ULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 31.16 | 0 | 8.58 | 0 | 19.85 | 0 |
| | | 31.42 | 0 | 9.03 | 1 | 20.36 | 0 |
| | | 31.68 | 0 | 9.48 | 1 | 20.87 | 0 |
| | | 31.94 | 0 | 9.93 | 1 | 21.38 | 0 |
| | | 32.20 | 0 | 10.38 | 1 | 21.89 | 1 |
| | | 32.46 | 0 | 10.83 | 1 | 22.40 | 1 |
| | | 32.72 | 0 | 11.28 | 2 | 22.91 | 1 |
| | | 32.98 | 0 | 11.73 | 2 | 23.42 | 1 |
| | | 33.24 | 1 | 12.18 | 2 | 23.93 | 1 |
| | | 33.50 | 1 | 12.63 | 2 | 24.44 | 1 |
| | | 33.76 | 2 | 13.08 | 14 | 24.95 | 4 |
| | | 34.06 | 3 | 13.53 | 17 | 25.46 | 8 |
| | | 34.36 | 4 | 13.98 | 21 | 25.97 | 13 |
| | | 34.66 | 5 | 14.43 | 26 | 26.48 | 19 |
| | | 34.96 | 6 | 14.88 | 32 | 26.99 | 26 |
| | | 35.26 | 6 | 15.33 | 40 | 27.50 | 35 |
| | | 35.56 | 7 | 15.78 | 49 | 28.01 | 46 |
| | | 35.86 | 8 | 16.23 | 59 | 28.52 | 58 |
| | | 36.16 | 9 | 16.68 | 68 | 29.03 | 67 |
| | | 36.46 | 10 | 17.13 | 76 | 29.54 | 75 |
| | | 36.76 | 100 | 17.58 | 81 | 30.05 | 81 |
| | | | | 17.59 | 100 | 30.06 | 100 |

**Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)**

| ID | | STK9 | | STK10 | |
|---|---|---|---|---|---|
| Name | | Bear Creek North | | Central Stockton | |
| Toe Elevation[3] | | 16.4 | | 2.1 | |
| AWSE | | 19.8 | | 9.6 | |
| Crest Elevation[3] | | 24.0 | | 15.6 | |
| Type of Project (ULE or NULE) | | ULE | | ULE | |
| Water Surface Elevation (NGVD29) (feet) | Associated Probability of Failure (breach) (percent) | 16.39 | 0 | 2.08 | 0 |
| | | 16.77 | 0 | 2.75 | 1 |
| | | 17.15 | 0 | 3.43 | 1 |
| | | 17.53 | 0 | 4.10 | 2 |
| | | 17.91 | 0 | 4.78 | 2 |
| | | 18.29 | 1 | 5.45 | 2 |
| | | 18.67 | 1 | 6.13 | 3 |
| | | 19.05 | 1 | 6.80 | 4 |
| | | 19.43 | 1 | 7.48 | 5 |
| | | 19.81 | 1 | 8.15 | 6 |
| | | 20.19 | 1 | 8.83 | 8 |
| | | 20.57 | 2 | 9.50 | 11 |
| | | 20.95 | 2 | 10.18 | 15 |
| | | 21.33 | 2 | 10.85 | 22 |
| | | 21.71 | 2 | 11.53 | 30 |
| | | 22.09 | 4 | 12.20 | 41 |
| | | 22.47 | 6 | 12.88 | 55 |
| | | 22.85 | 8 | 13.55 | 69 |
| | | 23.23 | 11 | 14.23 | 78 |
| | | 23.61 | 14 | 14.90 | 85 |
| | | 23.99 | 18 | 15.58 | 90 |
| | | 24.00 | 100 | 15.59 | 100 |

## 4.2 Limitations

This assessment has been performed in accordance with the standard of care commonly used as the state-of-practice in the civil engineering profession. Standard of care is defined as the ordinary diligence exercised by fellow practitioners in this geographic area performing the same services under similar circumstances during the same time period. The levee performance curves are intended to be used in current hydraulic and economic damage modeling being performed by DWR for the CVFPP; these curves should not be taken out of this context in forecasting local levee performance issues.

The current version of the NULE levee performance curve Excel tool has produced curves for more than 200 NULE levee segments using cross-section-specific geometry, GAR categories, and a few curve-fitting parameters. Because geometries of levees vary widely, some curves may look distorted when compared to the expected curve shapes presented in Figure 3-1. This distortion is present to greater or lesser degrees for levees with only one or two high (C) or lacking sufficient data (LD) ratings and is further exacerbated for levees that are either very short (particularly if they have more than 3 feet of freeboard) or very tall (particularly if they have less than 3 feet of freeboard). The tool provides a set of curves with consistent properties relative to each other that are appropriate for the intended use in systemwide models and that are sufficient for initial hydraulic and damage modeling. The impact of these distortions (if any) can be addressed once results of initial damage model runs become available.

As mentioned above, levee performance curves presented in this attachment are intended for use with systemwide hydraulic and economic damage modeling performed for the CVFPP. Actual hydraulic and economic damage modeling results depend on a number of factors beyond the geotechnical levee performance curves (such as hydrologic and hydraulic uncertainty), and although the levee performance curves may seem reasonable, they may, when combined with other factors and used in the modeling, produce unexpected results; therefore, care must be taken in their use.

In the methodology described in Section 3, individual failure mode levee performance curves were combined to yield a cumulative or combined levee performance curve. This approach assumed that the failure modes are independent, and that the different failure processes operate independently. This assumption is likely not true in all cases and has been offset to some extent by reducing the probability of failure for individual failure modes.

In developing NULE levee performance curves, for simplicity, the geometry and location of the under-seepage cross section that was assessed in the GARs (URS, 2010a; Kleinfelder, 2010) was used for each curve. For some NULE segments, the GARs used different cross sections for different failure modes. In developing levee performance curves, geometry and location from the GAR under-seepage cross section was used as input for hydraulic and flood damage models.

As noted previously, levee crest elevations used in the Comprehensive Study (USACE, 2002) are sometimes different from those identified in the ULE and NULE projects. The ULE and NULE projects relied on recent LiDAR and CLD topographic data to estimate topographic parameters. The Comprehensive Study relied on older, since superseded, topographic information and, in most instances, the ULE and NULE levee crest elevations were used.

In developing NULE levee performance curves, results from the draft North and South GARs (URS, 2010b; Kleinfelder, 2010) were used without modification. There are ongoing efforts to finalize these GARs, and some of the data used in development of the levee performance curves may change. Similarly, ULE data that were current through the FCSSR, and some data used to develop the levee performance curves, may change as the ULE Project proceeds.

DWR makes no warranty that actual encountered site and subsurface conditions will exactly conform to the conditions described herein, nor that the interpretations and recommendations in this attachment will be sufficient for construction-planning aspects of any future work to reconstruct or remediate levees. The design engineer or contractor should perform a sufficient number of independent explorations and tests that the engineer or contractor believes are necessary to verify subsurface conditions rather than relying solely on the information presented in this attachment or other referenced documentation.

DWR does not attest to the accuracy, completeness, or reliability of maps, data sources, and geotechnical borings and other subsurface data produced by others that were presented in the GARs and used to develop levee performance curves described in this attachment. DWR has not performed independent validation or verification of data reported by others.

Data presented in this attachment are time-sensitive in that they apply only to locations and conditions that were identified at the time this attachment was prepared. Data should not be applied to any other projects in or near the area of this study nor should they be applied at a future time without

appropriate verification, at which point the entity verifying the data takes on the responsibility for the data and any liability for its use.

The levee performance curve information and results contained in this attachment is for the use and benefit of DWR. Use by any other party is at their own discretion and risk.

Information in this attachment should not to be used as a basis for design, construction, remedial action, or major project-specific capital spending decisions.

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# 5.0 References

California Department of Water Resources (DWR). 2007. Delta Risk Management Strategy Phase 1 – Risk Analysis Report. Draft 2.

———. 2010. State Plan of Flood Control Descriptive Document. November.

———. 2011. Flood Control System Status Report. December.

DWR. *See* California Department of Water Resources.

Kleinfelder. 2010. Geotechnical Assessment Report, South NULE Study Area. Unpublished consulting report submitted to the California Department of Water Resources, Division of Flood Management. June.

URS. *See* URS Corporation

URS Corporation (URS). 2010a. Flood Control System Status Report Tables and Maps, Sacramento and San Joaquin River Basin Study Areas. Unpublished consulting report submitted to the California Department of Water Resources, Division of Flood Management. August.

———. 2010b. Geotechnical Assessment Report, North NULE Study Area. Unpublished consulting report submitted to the California Department of Water Resources, Division of Flood Management. June.

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

U.S. Army Corps of Engineers (USACE). 1996. Engineers Manual (EM) 1110-2-1619. Risk-Based Analysis for Flood Damage Reduction Studies. August 1.

———. 1999. Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies. Army Corps of Engineers Manual Engineering Technical Letter (ETL) 1102-2-556. Includes appendices. May.

———. 2002. Sacramento and San Joaquin River Basins, California, Comprehensive Study, Interim Report. Prepared by the USACE Sacramento District and The Reclamation Board of the State of California. December 20.

———. 2006. Engineering Regulations (ER) 1105-2-101. Planning-Risk Analysis for Flood Damage Reduction Studies. January 3.

# 6.0 Acronyms and Abbreviations

AWSE ..... Assessment Water Surface Elevation

Board ..... Central Valley Flood Protection Board

CLD ..... California Levee Database

Comprehensive Study Sacramento and San Joaquin River Basins Comprehensive Study

CVFPP ..... Central Valley Flood Protection Plan

Delta ..... Sacramento-San Joaquin Delta

DWR ..... California Department of Water Resources

ETL ..... Engineer Technical Letter

FCSSR ..... Flood Control System Status Report

FS ..... factor of safety

GAR ..... Geotechnical Assessment Reports

HEC-FDA ..... Hydrologic Engineering Center Flood Damage Assessment model

i ..... vertical exit gradient

LD ..... lacking sufficient data

LiDAR ..... light detection and ranging

NULE ..... Non-Urban Levee Evaluation

Pf ..... probability of failure

PFP ..... probable failure point

PNP ..... probable non-failure point

SPFC ..... State Plan of Flood Control

ULE ..... Urban Levee Evaluation

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

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES