McMullin On-Farm Flood Capture and Recharge Project:
Hydrologic and Hydraulic Analyses (H&H),

Final Report

TO# 01

Prepared for:

Kings River Conservation District
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TETRA TECH

January 2014
Tetra Tech 100-LCC-T31035

ABBREVIATIONS

B/C	Benefit:Cost Ratio
CBBS	Chowchilla Bypass Bifurcation Structure
CDEC	California Data Exchange Center
cfs	cubic feet per second
COMP Study	Sacramento San Joaquin River Comprehensive Study
CVFPP	Central Valley Flood Protection Plan
DWR	California Department of Water Resources
EAD	Expected Annual Damages
FCM	Flood Control Manual (The Reclamation Board, 1969)
FCP	DWR Flood Corridor Program
FEMA	Federal Emergency Management Agency's
HEC-FDA, FDA	HEC Flood Damage Analysis
LFP	Likely failure point; elevation corresponding to a 50 percent probability of failure
Ph1	Phase 1 of the project, diversion of 150 cfs onto Terranova Ranch in partnership with KRCD
Ph2/3	Phase 2 and 3 completion, diversion of 500 cfs on Terranova Ranch and other landowners in partnership with KRCD
PVFB	Present Value of Future Benefits
PVDC	Total Present Value of Discounted Costs
UNET	One-Dimensional Unsteady Network Flow Model
USACE	U.S. Army Corps of Engineering (Corps)

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EXECUTIVE SUMMARY

Approval of a Hydrologic and Hydraulic Analyses (H&H) by California Department of Water Resources (DWR) is a pre-requisite for projects being funded through DWR's Flood Corridor Program. The H&H needs to show early in the project schedule in analysis acceptable to DWR that the project will produce the anticipated flood risk reduction benefits. A Benefit:Cost (B/C) ratio provides a metric for comparing benefits from a project in relation to DWR costs for the project. In our analysis, we calculated a B/C of 1.86 for Phase 1, the diversion of 150 cubic feet per second (cfs) from the Kings River onto the project during flood flow conditions between December and May, and of 1.98 for Phase 2/3, the diversion of 500 cfs from the Kings River onto the project during the same conditions. Below we provide background on the project and the area that will be affected by the project (the study area), summarize our methods, and present our findings.

Two large hydrologic issues face the Kings Basin: severe and chronic overdraft of about 0.16M ac-ft annually (WRIME 2007), and flood risks along the Kings River and the downstream San Joaquin River. Since 1983, downstream communities along the Kings and San Joaquin Rivers have suffered over $1B in flood damages (2013$; USBR, 2005). To help mitigate these two issues, this project proposes diverting and capturing Kings River floodwater at the James Bypass onto agricultural lands adjacent to the Kings River for conjunctive use purposes (e.g. recharge, in lieu recharge, irrigation). This project is planned in three phases: Phase 1 (Ph1) will divert 150 cubic feet per second (cfs) onto agricultural fields from December through May and 100 cfs from June through September. Fifty-five hundred acres are planned for enrollment in Ph1 with 375 acres under flood easements; 1,125 acres managed under dual purpose of accepting flood flows and being managed for farming; and the remaining acreage receiving flood flows when available for in lieu recharge. Phases 2 and 3 (Ph 2/3) together will expand enrollment to 16,000 acres with expected equivalent ratios for flood easements, dual purpose and farming. Ph2/3 is planned to have a 500 cfs flood diversion and capture capacity. We assessed hydrologic and hydraulics conditions and economics for these planned phases following the scope of work defined in Task Order 1 between Kings River Conservation District (KRCD) and Tetra Tech.

For the hydrologic assessment, we reviewed the operating criteria for structures in the Kings River and San Joaquin River to assess potential project effects on the operations of the various flood control structures in the two systems. Phase 1 (Ph 1) and Phase 2 and 3 (Ph 2/3) are not expected to affect flood operations of Kings River structures. In the Kings River North, the limiting flow capacity of 4,750 cfs applies to the entire reach between the Crescent Weir to the beginning of the James Bypass and 4750 cfs is also the assumed capacity through the James Bypass Channel. Any diversions that would occur from the James Bypass as part of the proposed project would, therefore, not result in changes to the operating criteria in the Kings River System. In the San Joaquin River, flood flow control to the Chowchilla Bypass and Reach 2B of the San Joaquin River are controlled by the Chowchilla Bypass Bifurcation Structure (CBBS). The operating criteria at this structure, as historically practiced, depend on the discharge from the James Bypass via Fresno Slough. Our review of California Data Exchange Center (CDEC) data indicate the CBBS operation is consistent with its operating criteria and that some variance occurs because of local irrigation demands and the goal to minimize flood damage through the flood-control project and protected area. The effect of this project on the CBBS operation is not readily known. For the purpose of this analysis we assumed the project would not affect operation of the CBBS.

The project will affect flows into the Fresno Slough. During Ph 1, up to 150 cfs can be withdrawn during flood flow conditions just upstream of the James Bypass and during Ph 2/3, up to 500 cfs can be withdrawn during flood flow conditions.

The Sacramento/San Joaquin River's Comprehensive Study (Comp Study) (USACE, 2002) identified the design capacity of the James Bypass Channel as 4,750 cfs, and used that discharge rate in Comp Study modeling. Thus, 4,750 cfs capacity was assumed for the analyses in this study as well.

To provide input to the flood damage analysis, we performed 1-dimensional (1D) unsteady hydraulic modeling using the USACE UNET modeling software (USACE, 1997). The original unsteady hydraulic (UNET) model of the Sacramento River and San Joaquin River systems was completed for the Comp Study. This model was recently updated as part of the CVFPP (DWR, 2012) to account for setback/strengthened levee configurations and modified channel geometry. The majority of the model updates involved adjustment to the likely failure point (LFP) criteria for the levees to reflect recent levee strengthening activities.

The model input files include input hydrographs for the 10-, 25-, 50-, 100-, 200- and 500-year storm events with six storm centerings developed as part of the Comp Study (USACE 2002): 1) San Joaquin River at Friant, 2) San Joaquin River at the latitude of El Nido, 3) San Joaquin River at the latitude of Newman and 4) San Joaquin River at the latitude of Vernalis; 5) Merced River Tributary; and 6) Kings River (Fresno Slough) Tributary. As part of the Comp Study, these model input were substantially reviewed and are well vetted. Historic flow data compare relatively well with the inflow hydrographs. The only modification to the hydrologic model input required for this study was the adjustment to the upstream flow hydrographs in the Fresno Slough under with-project conditions. The CVFPP "no-project" UNET model represented the baseline (no-project) condition model for this study. For Ph1 and Ph2/3 conditions, 150 and 500 cfs was removed from the inflow hydrographs respectively.

For the economic analysis performed using the HEC-FDA model, we subdivided the San Joaquin River system into 43 damage areas. These 43 damages areas are defined as our study area. The HEC-FDA model developed as part of the CVFPP study (DWR 2012) was obtained and used here. UNET results were used to develop representative stage-frequency curves for each damage area as required inputs to the FDA model (DWR, 2012). CVFPP tools were used to assess the flood depth grid on the landward side of the levees, to develop the interior/exterior stage relationships, and to develop the depth-frequency information for individual parcels. This information was used to develop the HEC-FDA input files. The FDA model used within this study utilized the existing structure inventory and depth-damage functions from the CVFPP. No updates to structure, farm, or business values were performed. Modeling results indicate most project effects occur in reaches near Fresno Slough and effects are much less significant in the downstream reaches of the San Joaquin River system.

Expected annual damages (EAD) through the study area are estimated at $20M. 73% of those damages are associated with crop losses, with most the remainder (24%) associated with structures, mostly residential (19%), and their contents. Implementation of the project will reduce EAD by about $300,000 annually for Phase 1 and about $800,000 for Phase 2/3.

Historic storm events in 1983, 1986, 1995 and 1997 have resulted in an estimated $1.4B in damages along the San Joaquin River (USBR 2005). These storm events are in the range of 5 – 40 year events (USBR 2005). The FDA model predicted total damage for these four storm events to be between $0.5 – 2.3B.

In predicting damages to the areas, the FDA model and DWR tools identify the 50- and 100-year storm events as the most damaging. Two reasons underlay this finding. First, total predicted structural damages from a 50-year storm event are over an order of magnitude greater than for a 10-year storm event, but about 80% of a 100-year storm event and 60% of a 500-year storm event. Second, the 50- and 100-year storm events are relatively frequent compared to the larger storm events. Based upon DWR tools, we estimate the 50- and 100-year storm events contribute to nearly 70% of EAD totals. For those reasons, most EAD are associated with 50- and 100-year storm events.

Structural damages are the reason for the the large increase in damages associated with a 50-year storm event as opposed to a 10-year storm event. Over 75% of total damages for a 10-year storm event are associated with crop damages. We predicted crop losses of $166,000 for a 10-year storm event. With a 50-year storm event, crop losses increase by 75% from $166,000 to $281,000. Increasingly large storm events continue to increase crop losses but those losses are generally linear with the increase in storm events. Losses to structures are relatively minor for the 10-year storm event, comprising about 20% of total damages. However, the 50-year storm event results in losses that are 15X greater, comprising 65% of total damages. This jump in structure losses between the 10- and 50-year storm events causes total damages to jump 5X between a 10- and 50-year storm event.

The implementation of Phase 1 and Phase 2/3 will reduce costs associated with flood damages. Greatest structural savings are associated with the 10-, 50- and 100-year storm events. Greatest total EAD savings are expected to occur for the 50- and 100-year storm events as it is for those storm events EAD is greatest under no project and with project conditions. The project will result in an

EAD savings of about $300,000 annually for Phase 1 and about $800,000 for Phase 2/3 as discussed earlier. Benefit costs (B/C) analyses for this project are 1.86 for Phase 1 and 1.98 for Phase 2/3.

1 INTRODUCTION

Two large hydrologic issues face the Kings Basin: severe and chronic overdraft of about 0.16M ac-ft annually (WRIME 2007), and flood risks along the Kings River and the downstream San Joaquin River. Since 1983, downstream communities along the Kings and San Joaquin Rivers have suffered over $1B (2013$; USBR 2005) in damages. To help mitigate these two issues, this project proposes diverting and capturing Kings River floodwater at the James Bypass onto agricultural lands adjacent to the Kings River for conjunctive use purposes (e.g. recharge, *in lieu* recharge, irrigation). This project is planned in three phases: Phase 1 (Ph1) will divert 150 cubic feet per second (cfs) onto agricultural fields from December through May and 100 cfs from June through September. Fifty-five hundred acres are planned for enrollment in Ph1 with 375 acres under flood easements; 1,125 acres managed under dual purpose of accepting flood flows and being managed for farming; and the remaining acreage receiving flood flows when available for *in lieu* recharge and over irrigation. After the completion of Phases 2 and 3 (Ph 2/3), the project will have expanded to 16,000 acres and is expected to have equivalent increases in acres under flood easements, being managed for dual flood flow and farming purposes, and receiving flood flows for *in lieu* recharge and over irrigation. Ph2/3 is planned to have a 500 cfs flood diversion and capture capacity.

This project is funded by the Department of Water Resources (DWR) Flood Protection Corridor Program (FPCP) to reduce flood risk to lands downstream that are within the 100-year floodplain. The FPCP requires a Hydrologic and Hydraulic (H&H) Analysis prior to project funding in order to demonstrate that the project provides sufficient flood mitigation benefits from the invested public funds. The H&H is submitted to DWR to verify the flood damage reduction benefits stated in the grant proposal. If DWR or KRCD determine that the stated benefits cannot be reasonably achieved in the manner contemplated by the project, the project may be redesigned or terminated.

This document is the H&H study for this project. This analysis includes the following:

- An assessment of the Kings River and San Joaquin River systems and how Ph1 and Ph 2/3 will affect the hydrology. We define this area as our study area.

- A hydraulic assessment of the project using 1-Dimensional unsteady hydraulic modeling (UNET) model initially developed for the Sacramento San Joaquin River Comprehensive Study (Comp Study) and the Central Valley Flood Protection Plan (CVFPP).
- A HEC Flood Damage Analysis (FDA), using the above analyses as inputs, to assess damages through the San Joaquin / Kings Rivers system and to develop a Benefits to Cost Ratio (B/C) for Ph1 and Ph2/3 of this project.

2 HYDROLOGY

This section discusses the current flood operations of the Kings River and San Joaquin River systems; describes the HEC-DSS boundary condition files used in the CVFPP for generating hydrographs for floods of varying frequency (i.e., 10-, 25, 50-, 100-, 200- and 500-year flood events); relates and validates those model hydrographs against historic flow records; and presents how implementation of Ph1 and Ph2/3 will affect the hydrology of these systems.

2.1 CURRENT FLOOD OPERATIONS

The control structures along the Kings River and San Joaquin River systems are currently operated based on criteria designed to avoid or reduce damaging flood flows in downstream reaches. In the Kings River system, the distribution of flow between Kings River North (which delivers flows to the James Bypass and ultimately to the San Joaquin River) and the Kings River South (which delivers flows to the Tulare Lake bed) is controlled first by the Army Weir and then by the Crescent and Crescent Bypass Weirs (Figure 2-1). Based on the Upper San Joaquin River Basin Storage Investigation Initial Alternatives Information Report prepared by BOR and DWR (MWH, 2005), the Crescent Weir is operated such that the first 4,750 cfs of flood release is diverted to the Kings River North (Figure 2-2). *The design capacity for the Kings River North is 4,750 cfs.* The next 3,200 cfs of flood release is diverted into the Kings River South through the Army Weir into the Clarks Fork and through Crescent Bypass Weir into the Crescent Bypass (Figure 2-3). The Clarks Fork and Crescent Bypass merge into the Kings River South and the design capacity of the Kings River South is 3,200 cfs. At flows above 7,950 cfs upstream of the Army Weir, flows are divided equally between the north and south by the Army and Crescent weirs or as conditions dictate (Figure 2-2, Figure 2-3 and Figure 2-4). All Kings River flood operations and diversions are directed by the U.S. Army Corps of Engineers. This description is consistent with that presented in the Comp Study documentation. A flow capacity of 4,750 cfs is applied to the James Bypass Channel in the Comp Study documentation and modeling; thus, a flow capacity of 4,750 cfs was assumed for this study.

In the San Joaquin River system, flows in the vicinity of the project near Mendota Dam are controlled by the Chowchilla Bypass Bifurcation Structure (CBBS; Figure 2-5). The Flood Control Manual (FCM; The Reclamation Board, 1969) provides two options for splitting the flow at the CBBS.

According to the Flood Control Manual (FCM), the first increment of flow down the San Joaquin River may be routed down either the San Joaquin River (Reach 2B) or the Chowchilla Bypass Channel. Up to 2,500 cfs shall normally be routed down Reach 2B of the San Joaquin River insofar as it does not exceed the capacity of the Reach 3 of the San Joaquin River (4500 cfs) when added to the contributions from Fresno Slough. Kings River flood flows have priority in Reach 3. Up to 5,500 cfs shall be passed down the Chowchilla Bypass Channel. When the flow upstream from the CBBS is between 2,500 and 8,000 cfs, 2,500 cfs is delivered to Reach 2B of the San Joaquin River and the remainder is delivered to the Chowchilla Bypass Channel. A total flow of 8,000 cfs at the CBBS will normally be divided with 2,500 cfs routed into the San Joaquin River and 5,500 cfs routed into the Chowchilla Bypass Channel. (The FCM assumes the capacity of the Bypass Channel is 5,500 cfs.)

When the flow upstream from the Bifurcation Structure exceeds 8,000 cfs, or when the combined flows in the Chowchilla Bypass Channel and the San Joaquin River downstream of Mendota Dam exceed 10,000 cfs, "the District (Lower San Joaquin Levee District) will operate the control structures at their discretion with the objective of minimizing damage to the flood-control project and protected area."

In historical practice, the operating criteria have been modified so the first flows to the river are limited to about 1,300 cfs to avoid seepage problems in the overbanks between the CBBS and Mendota Dam (Paul Romero, DWR, pers. comm., August 20, 2009). This practice, in effect, results in the following operating criteria at the CBBS (Figure 2-6):

1. When the flow upstream from the Bifurcation Structure is less than or equal to 1,300 cfs, all flow is delivered to Reach 2B of the San Joaquin River. If contributions from Fresno Slough result in flows that are in excess of the design capacity in Reach 3 (4,500 cfs), diversions to the Chowchilla Bypass Channel are made until the capacity of Reach 3 is not exceeded (if possible).

2. When the flow upstream from the Bifurcation Structure is between 1,300 and 8,000 cfs, 1,300 cfs is delivered to Reach 2B of the San Joaquin River and the remainder is delivered to the Chowchilla Bypass Channel. (Under these operating criteria, the capacity of the Bypass Channel is assumed to be 6,700 cfs.) Because flows in Fresno Slough that are above 3,200 cfs could result in flows that exceed the design capacity in Reach 3 (4,500 cfs), additional diversions to the Chowchilla Bypass Channel are made until the capacity of Reach 3 is not exceeded, if possible, or until the excess flows are equalized between Reach 3 and the Bypass Channel.

3. When the flow upstream from the Bifurcation Structure exceeds 8,000 cfs, the structure is operated such that the excess flows are equalized between the Bypass Channel and either Reach 2B or Reach 3, depending on the discharge in Fresno Slough.

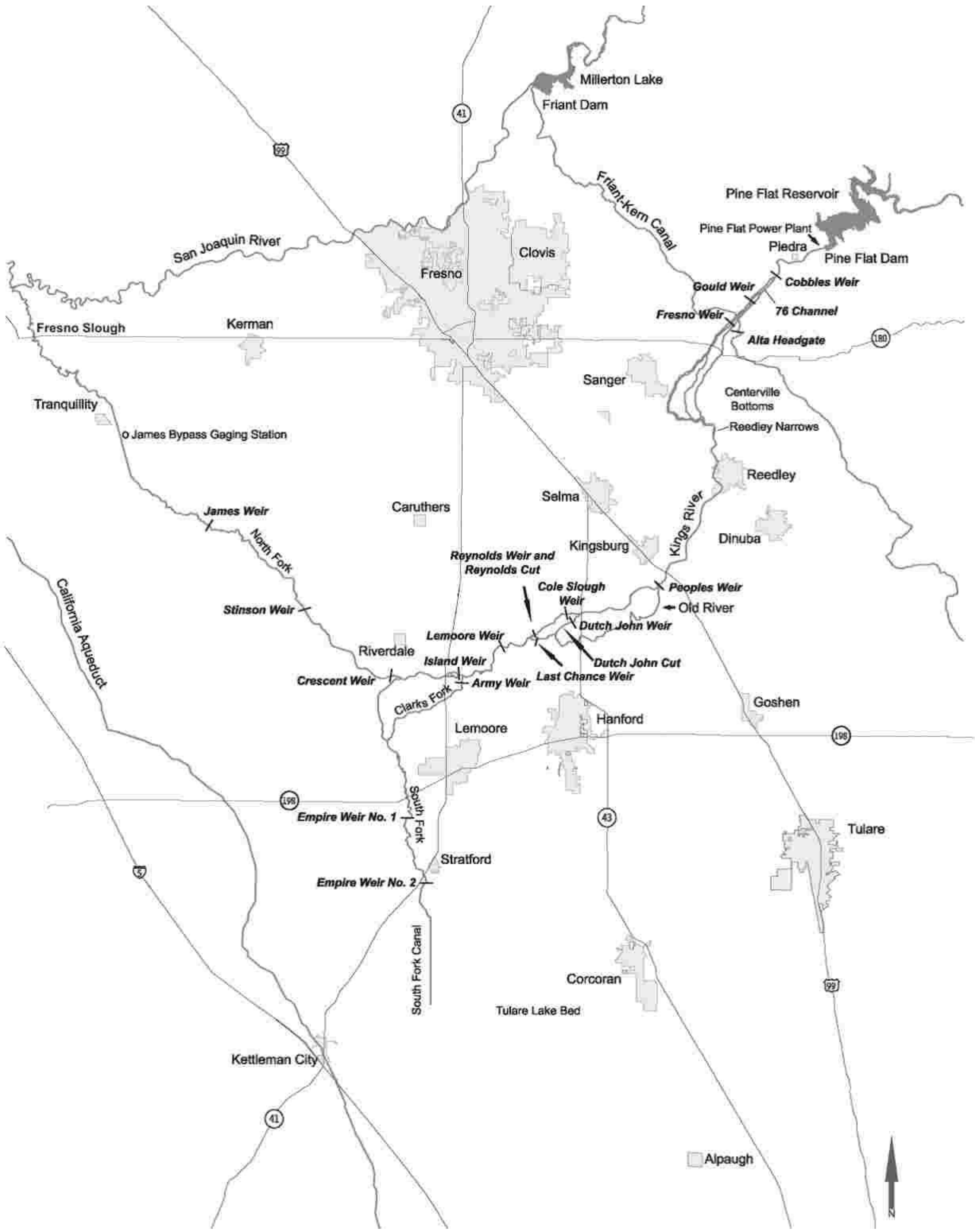

Figure 2-1. Kings River flood-control system (revised from KRCD and KRWA, 2009).

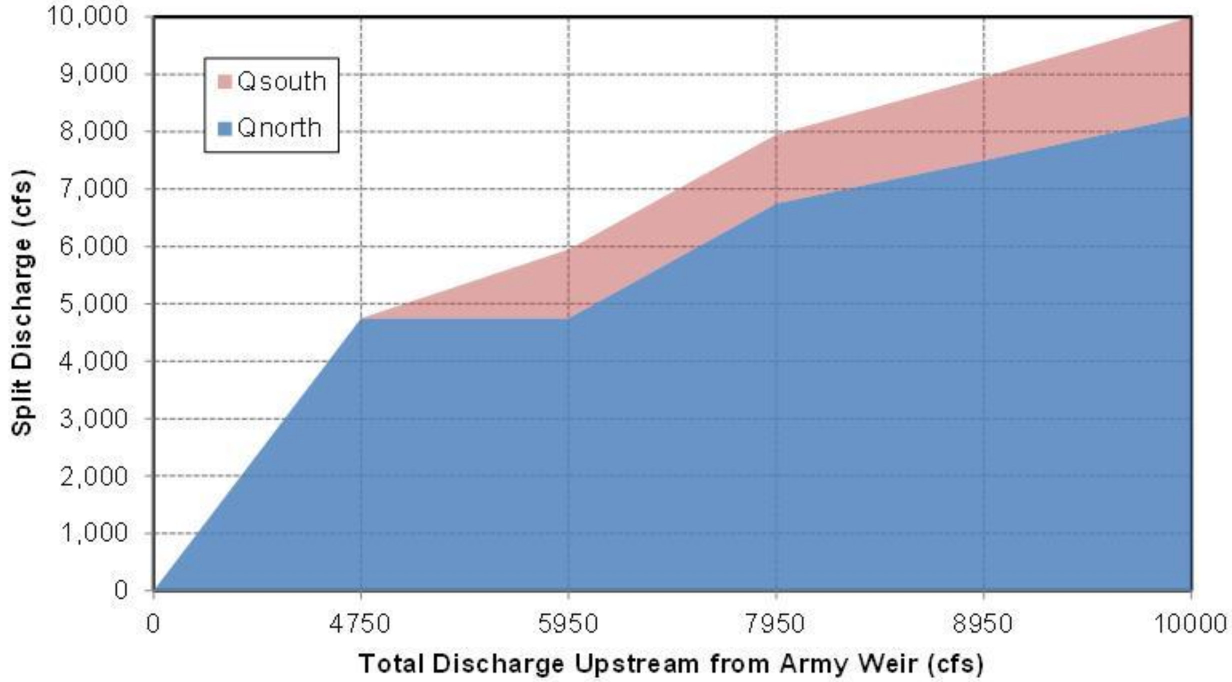

Figure 2-2. Flood-operating criteria at the Army Weir.

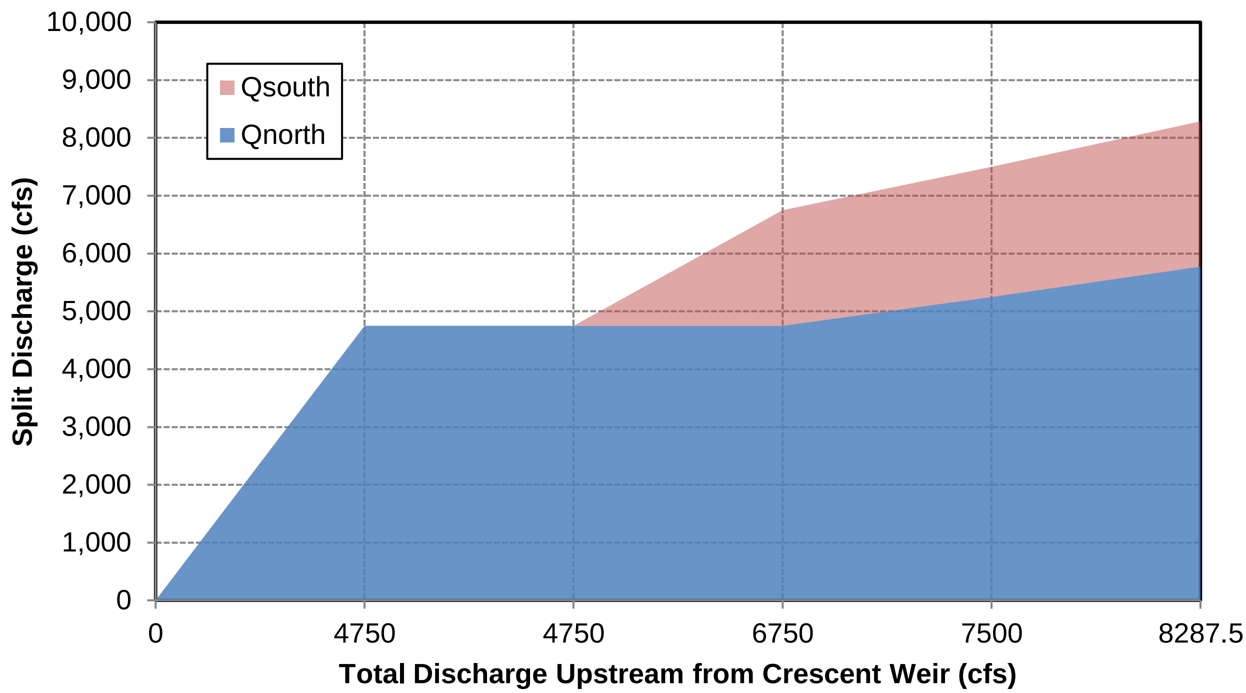

Figure 2-3. Flood-operating criteria at the Crescent Weir.

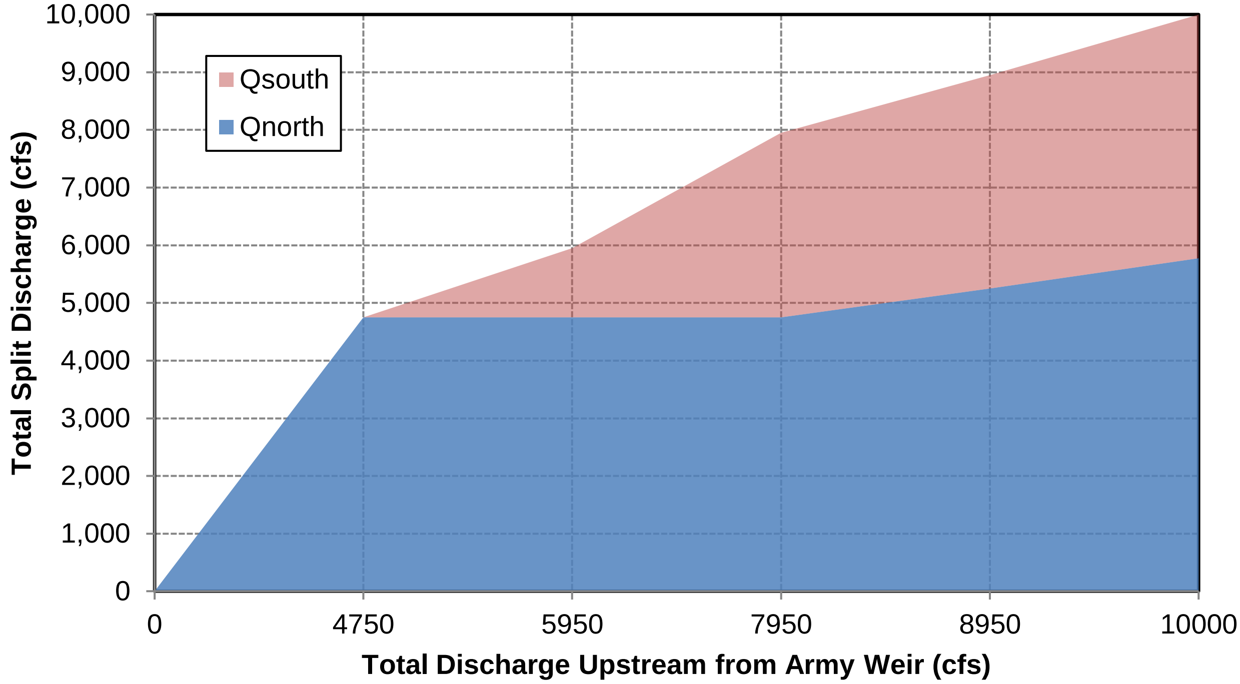

Figure 2-4. Combined flood-operating criteria at the Army and Crescent Weirs.

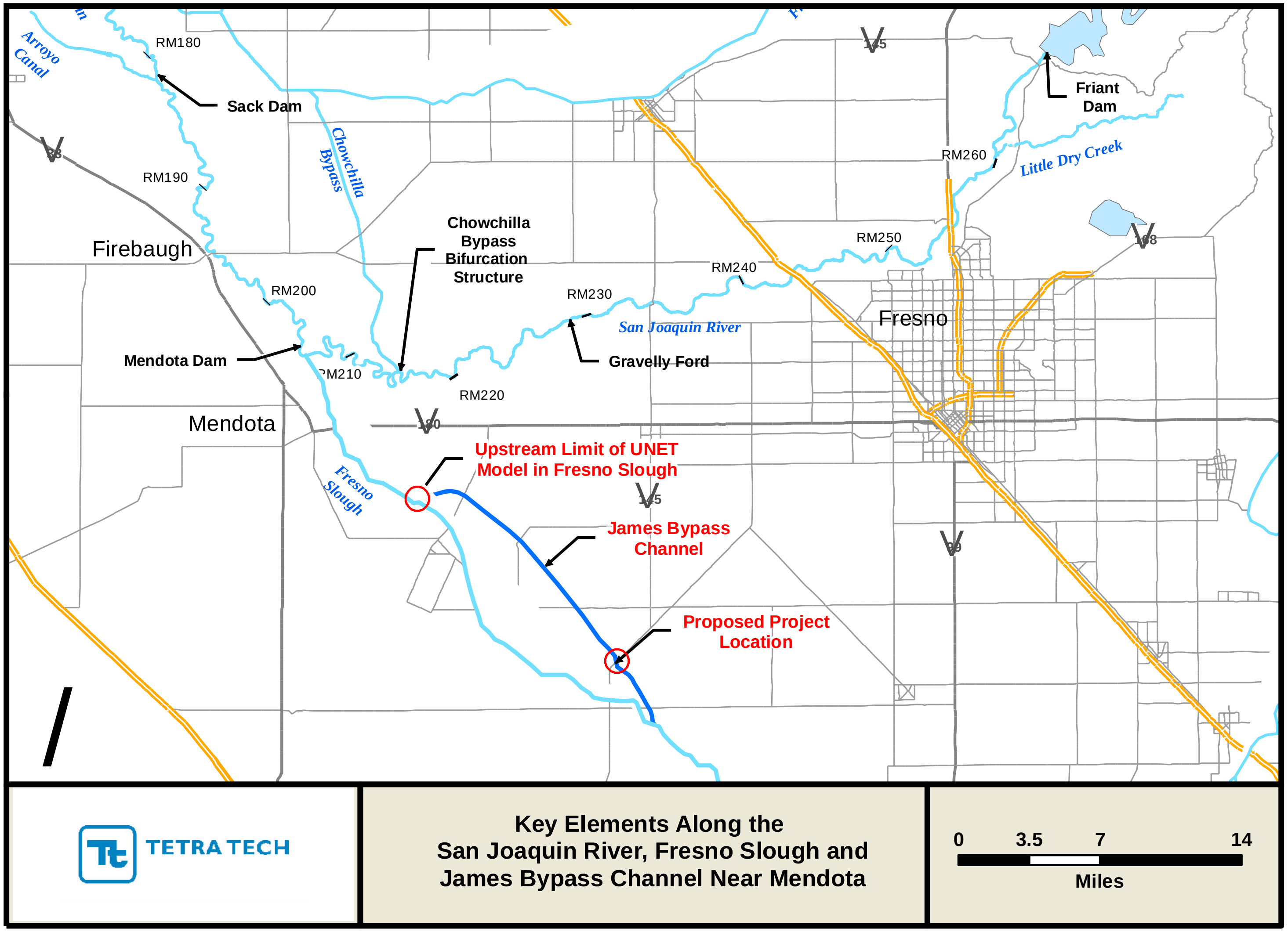

Figure 2-5. Map of the San Joaquin River system.
Map shows major features included in the UNET model, including the Chowchilla Bypass Bifurcation Structure at the downstream end of Reach 2A.

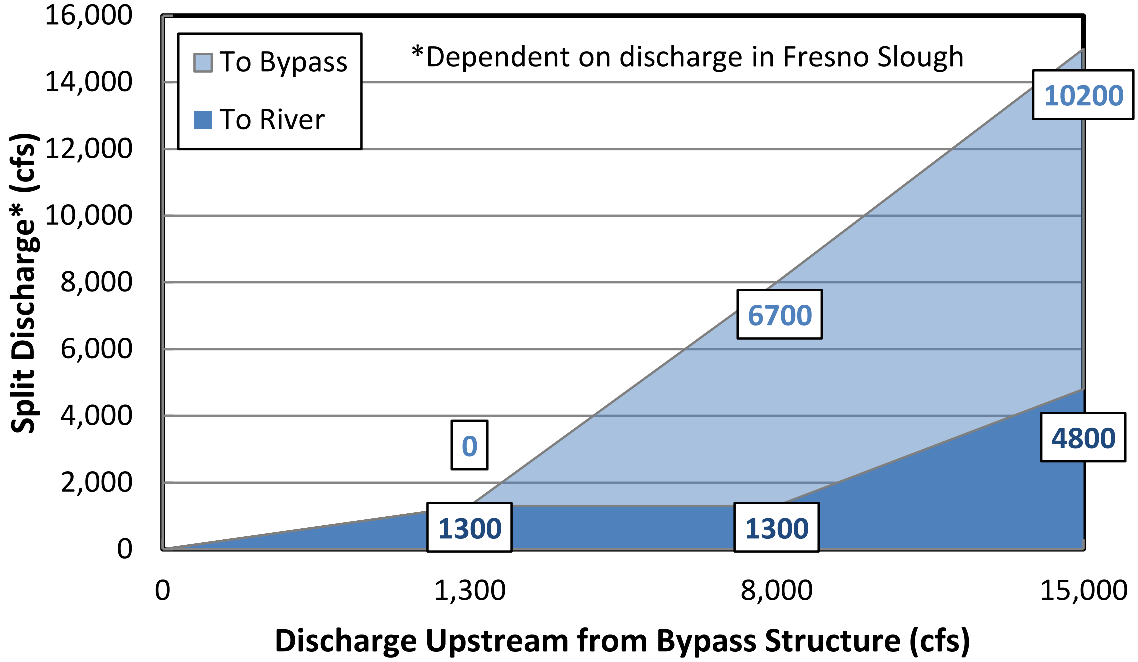

Figure 2-6. Flood operating criteria for CBBS flow distribution to the San Joaquin River and the Bypass under historical practices.

2.2 Historical Data

We reviewed available USGS gage data at the James Bypass gage (James Bypass Fresno Slough near San Joaquin, CA; USGS Gage No. 11253500) to assess the range of flows that have occurred along the bypass near our project over the available period of record, and to compare to UNET model hydrographs. Mean daily flows at the gage are available for the period between Water Year (WY) 1947 to WY1954, WY1974, WY1977 to WY2006, and WY2008 to WY2009 (Figure 2-7). The flow capacity of the James Bypass Channel of 4,750 cfs identified and used in the Comp Study modeling was assumed for this study. The measured discharges are within 5 percent of the assumed capacity of 4,750 cfs in each of the years except WY1983, when the maximum measured discharge of 5,360 cfs exceeded the assumed capacity by 610 cfs, and the discharge exceeded 4,750 cfs for about 150 days. In total, the measured discharge exceeded the assumed capacity of 4,750 cfs in six of the forty years (1980, 1982, 1983, 1986, 1997, 1998; Figure 2-8) and for about 200 days.

Peak flow data at the gage are limited to the period from WY2003 to WY2009, and no data are available in WY2007, so the period of record is insufficient to perform a peak flood frequency analysis. However, it is unlikely that the measured mean daily flow data differ significantly from instantaneous peak flow data because of operating rules at Pine Flat Dam and the Army and Crescent Weirs. Available data for WY2003 to WY2009 support this contention as published peak flows are identical to the maximum mean daily flows. Because of the effects of regulation, the data do not fit a standard frequency distribution typically used for flood frequency analysis. The Weibull plotting positions, however, provide an indication of the relative frequency distribution of the estimated peak flow data. The resulting plotting positions of the peak flow data indicate the 1983 event has a recurrence interval of approximately 41 years (Figure 2-9).

California Data Exchange Center (CDEC) data indicate the CBBS was operated during the 2011 high flows in a manner generally consistent with the operating criteria as historically practiced (Figure 2-10 and Figure 2-11). The San Joaquin River discharge through the CBBS was limited to about 1,300 cfs regardless of the upstream discharge from the upstream San Joaquin River (Figure 2-10 and Figure 2-11). In April, 2011, when discharges upstream from the CBBS were between 5,000 cfs and 7,200 cfs, the flow to the river (Reach 2B) was limited to about 1,200 cfs until the James Bypass flows exceeded 3,500 cfs on April 9 (Figure 2-10). When the flows from the James Bypass were near 4,500 cfs on April 18 and 19, the CBBS was still delivering about 550 cfs to the river. Similar operation occurred on July 10 and 11 (Figure 2-11) when the discharge in Fresno Slough was between 3,500 cfs and 3,600 cfs and about 1,300 cfs was being delivered to the river through the CBBS. Based on these data, operations of the CBBS and inflows from Fresno Slough appear to vary from the operating criterion as historically practiced by 400 cfs to 600 cfs. Thus, operations are generally consistent with operational criteria. Variance in operation occurs and this variance is probably affected by local irrigation demands and the goal to minimize flood damage through the flood-control project and protected area. Variance would be expected to change on a seasonal, if not a monthly basis.

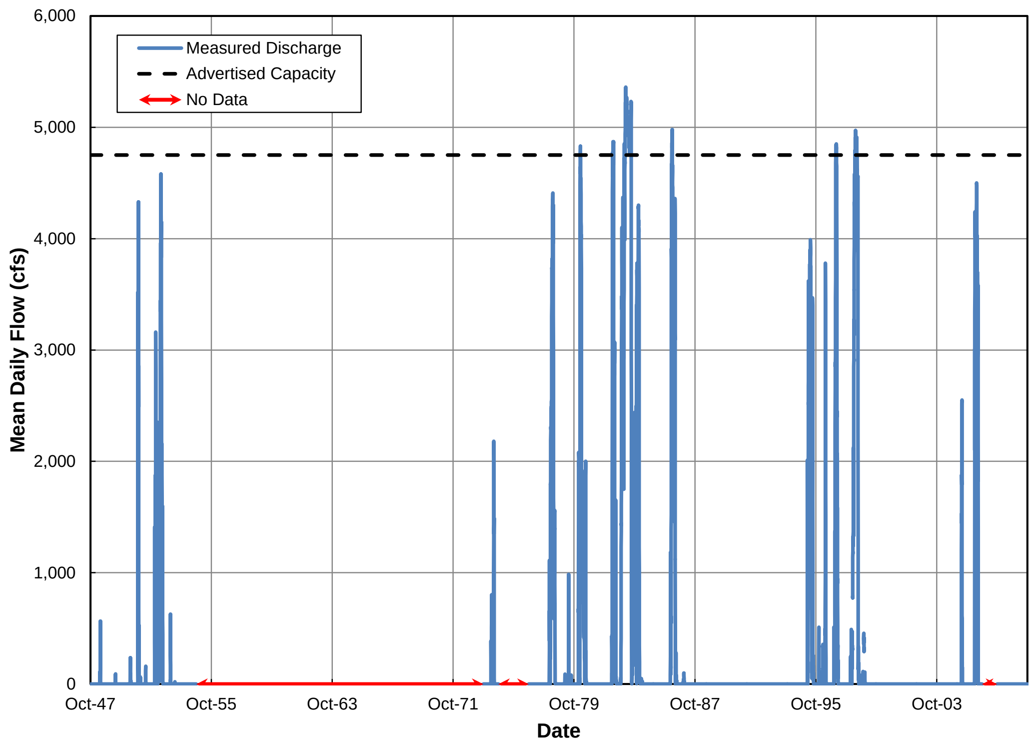

Figure 2-7. Measured mean daily flows at the James Bypass gage (USGS Gage No. 11253500).

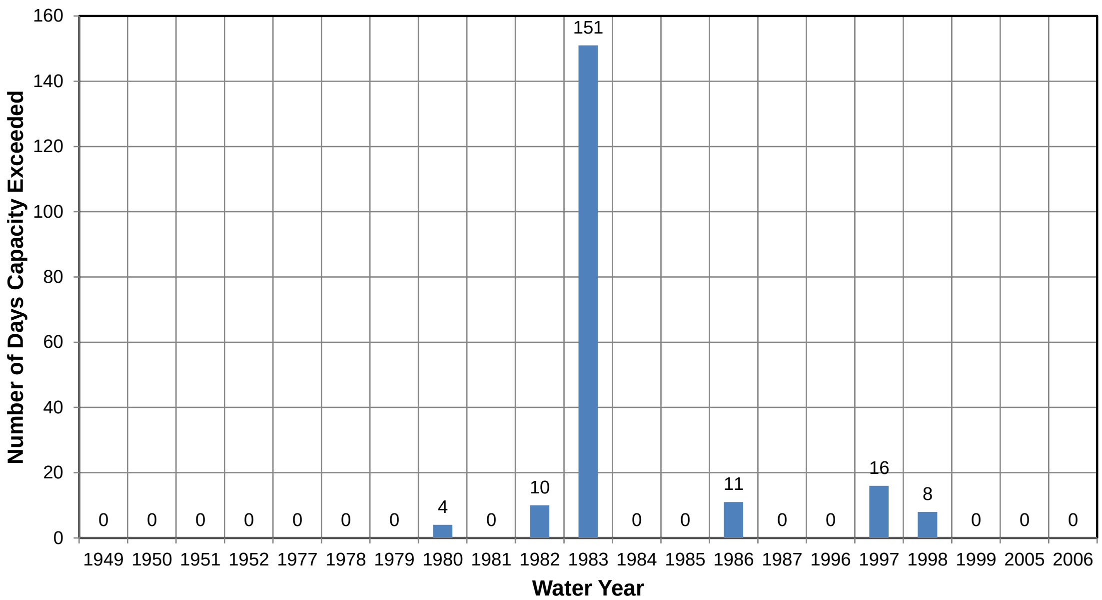

Figure 2-8. Number of days design flow capacity exceeded at the James Bypass.

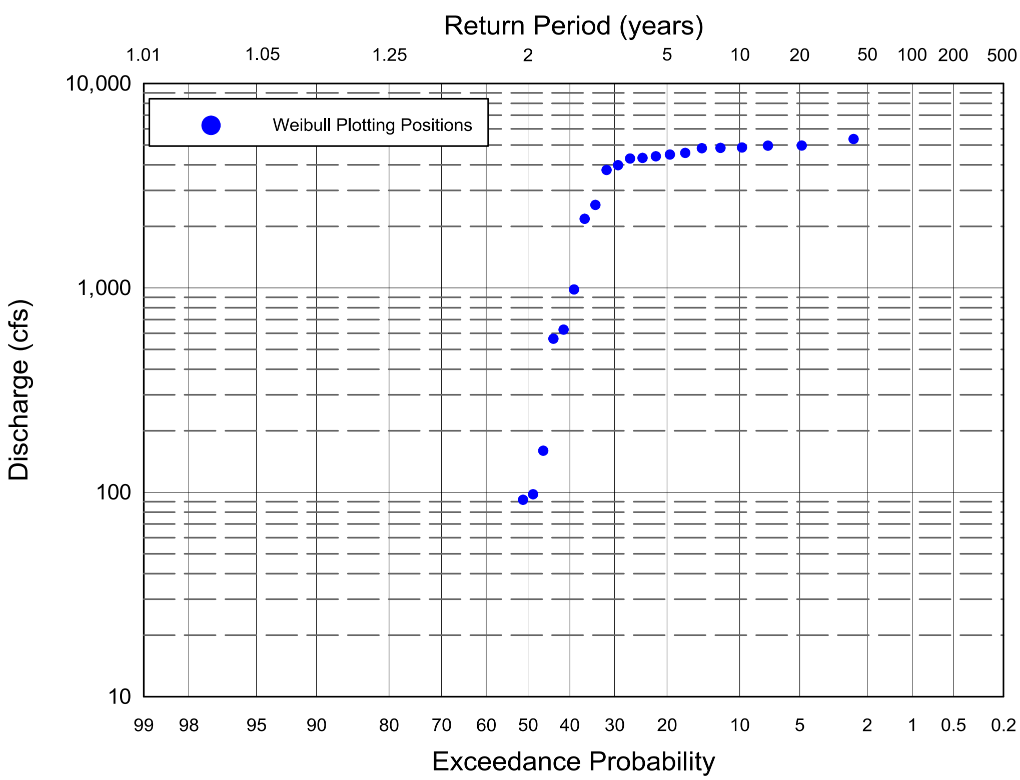

Figure 2-9. Weibull plotting positions from the flood-frequency analysis of the maximum annual mean daily flow at the James Bypass gage.

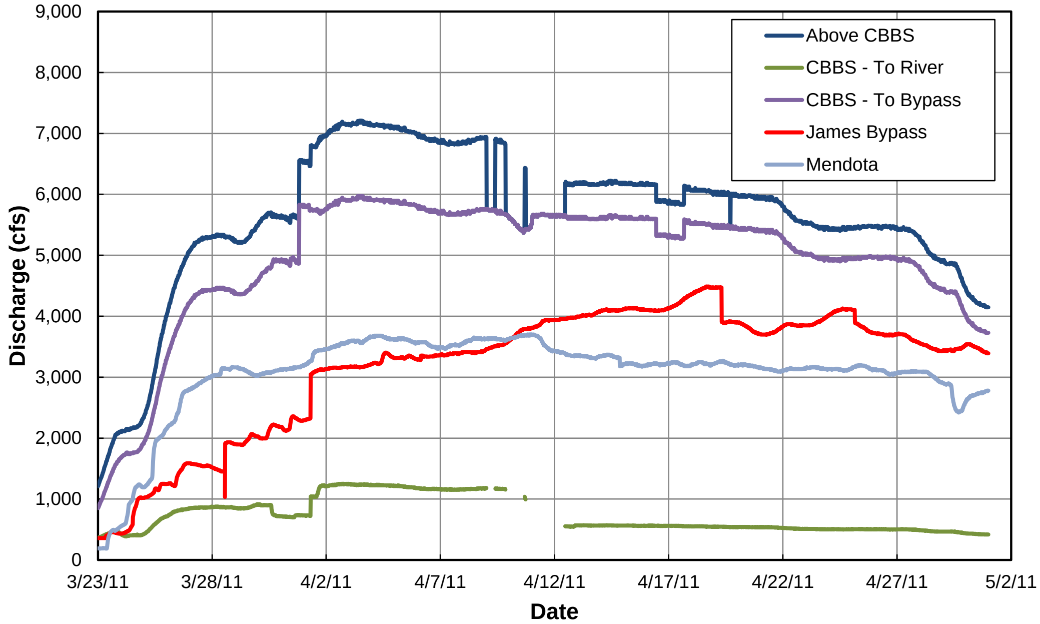

Figure 2-10. Measured hydrographs in the vicinity of the CBBS, in the James Bypass, and at Mendota during the March and April, 2011 period.

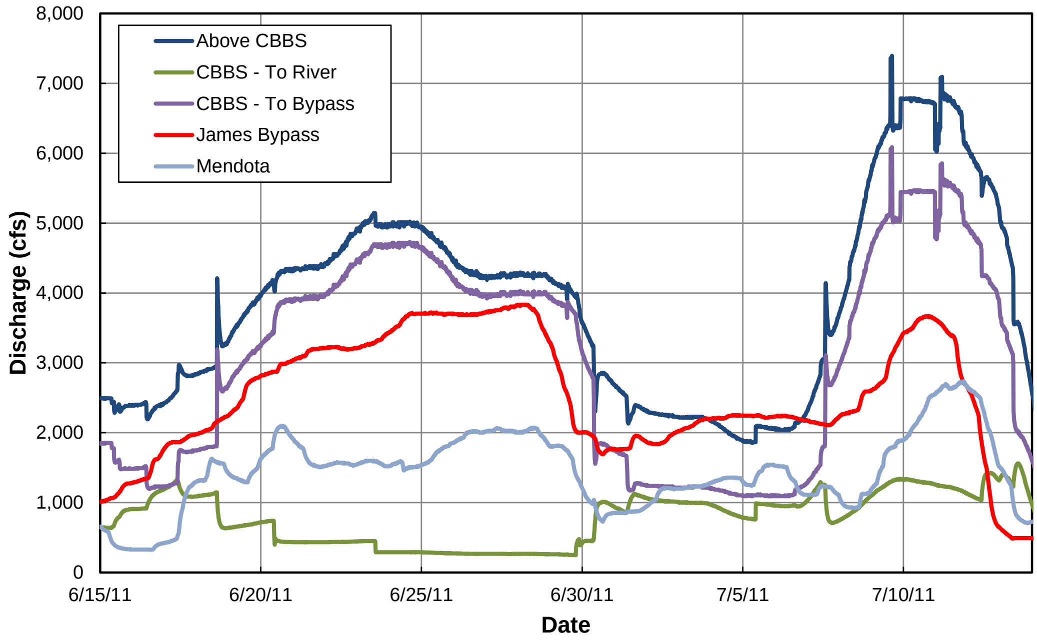

Figure 2-11. Measured hydrographs in the vicinity of the CBBS, in the James Bypass, and at Mendota during the June and July, 2011 period.

2.3 UNET MODEL INPUT

The original unsteady hydraulic model (One-Dimensional Unsteady Network Flow model; UNET) of the Sacramento and San Joaquin River systems was completed for the Sacramento/San Joaquin River Comprehensive Study (Comp Study) (USACE, 2002). This model was recently updated as part of the Central Valley Flood Protection Plan [CVFPP (DWR, 2012)] to account for setback/strengthened levee configurations and modified channel geometry. The majority of the model updates involved adjustment of the likely failure point (LFP) criteria, the elevation corresponding to a 50 percent probability of failure for the levees to reflect recent levee strengthening.

Hydrologic input to the UNET model is included in the HEC-DSS boundary condition files. These boundary condition files include stage and discharge data at the downstream limit of the model subreaches, initial flow conditions, and upstream flow hydrographs for the mainstem San Joaquin River at Friant Dam and for each of the modeled tributaries. For this analysis, we adopted downstream stage-flow boundary conditions, initial flow conditions and inflow hydrographs used in the Comp Study and CVFPP modeling.

The boundary condition files include input hydrographs for the 10-, 25-, 50-, 100-, 200- and 500-year storm events over a range of storm centerings. A storm centering is a set of synthetic floods for a range of annual exceedance probabilities (AEP) that would result in peak flows at a given location. The Comp Study included an evaluation of 23 storm centerings, while the CVFPP Study used 10 of these storm centerings (5 in the Sacramento River Basin and 5 in the San Joaquin River Basin) to reduce the complexity of the analysis. The 5 storm centerings that were evaluated in the CVFPP Study included:

- San Joaquin River at Friant
- San Joaquin River at the latitude of El Nido
- San Joaquin River at the latitude of Newman
- San Joaquin River at the latitude of Vernalis
- Merced River Tributary

In addition to these five storm centerings, the San Joaquin River Alternatives Assessment Study (AAS; Tetra Tech, 2009) also included the Kings River (Fresno Slough) Tributary storm centering due to the relative importance of this storm centering on flood conditions in the San Joaquin River system, especially in the vicinity of Mendota Dam. As such, those six storm centerings were evaluated as part of this study. The input hydrographs for all of these storm centerings were developed as part of the Comp Study modeling. The downstream stage-flow boundary condition and initial flow conditions input data were also obtained from the Comp Study modeling and is the same input that was used for the CVFPP study.

A wide range of hydrologic analyses were performed as part of the CVFPP study, including analysis of historical regulated and unregulated flood events, development of synthetic exceedance frequency flood events, reservoir operations modeling, and hydrologic routing of the various hydrographs. Of particular interest to this study are the flows delivered from the James Bypass to Fresno Slough, which is the upstream limit of the model in this tributary. The UNET model input for the Fresno

Slough indicates that, under most of the storm centerings, the 4,750 cfs channel capacity is not exceeded at flows up to and including the 100-year event (Figure 2-12**,** Figure 2-13**,** Figure 2-14**,** Figure 2-15**,** Figure 2-16**,** Figure 2-17). The capacity of the James Bypass is not exceeded at flows up to and including the 200-year event for the Merced storm centering (Figure 2-17).

2.4 EFFECTS OF PROPOSED PROJECT

The only modification to the hydrologic model input required for this study involved adjustment to the upstream flow hydrographs in Fresno Slough to represent with-project conditions. The proposed project is designed to be implemented in two phases: Phase 1 – to divert up to 150 cfs from the James Bypass at the proposed structure, Phases 2/3 – to divert up to 500 cfs. This project proposes to divert the flows from the James Bypass onto agricultural lands composed of a mosaic of flood easement lands, dual use purpose farm and flood lands, and farm lands. A project summary describing the implementation strategies are included in Appendix C. Appendix D and Appendix E contain background technical materials used in developing the specifications and strategies for the project.

In the Kings River North, the limiting flow capacity of 4,750 cfs applies to the entire reach between the Crescent Weir to the beginning of the James Bypass and 4750 cfs is also the assumed capacity through the James Bypass Channel (Comp Study, USACE, 2002). Any diversions that would occur from the James Bypass as part of the proposed project would, therefore, not result in changes to the operating criteria in the Kings River System. Operation of CBBS is affected by irrigation demands and goals to reduce risks and the variance exceeds the project's flow reduction. Thus, the effect of this project on the CBBS operation is not readily known. For the purpose of this analysis we assumed the project would not affect operation of the CBBS.

It was, therefore, assumed that the only change to the baseline (no-project) UNET model that is required to represent project conditions is a reduction to the Fresno Slough inflow hydrographs by either 150 cfs (Phase 1) or 500 cfs (Phase 2/3). The details of these adjustments are discussed in Section 3.1.2, below.

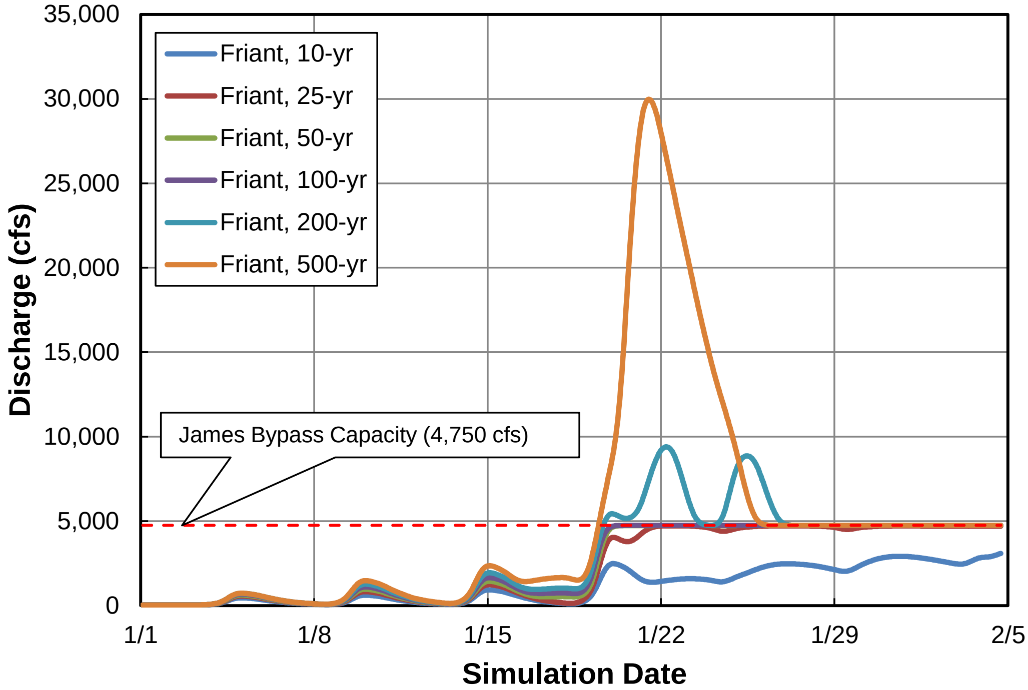

Figure 2-12. UNET model inflows at Fresno Slough near the downstream limit of the James Bypass (Friant Storm Centering).

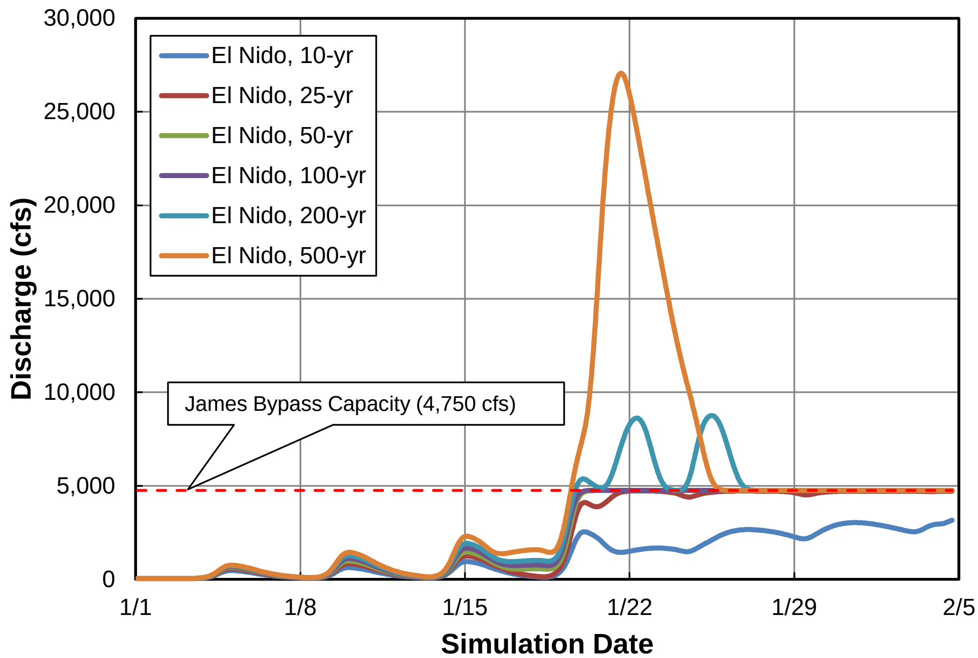

Figure 2-13. UNET model inflows at Fresno Slough near the downstream limit of the James Bypass (El Nido Storm Centering).

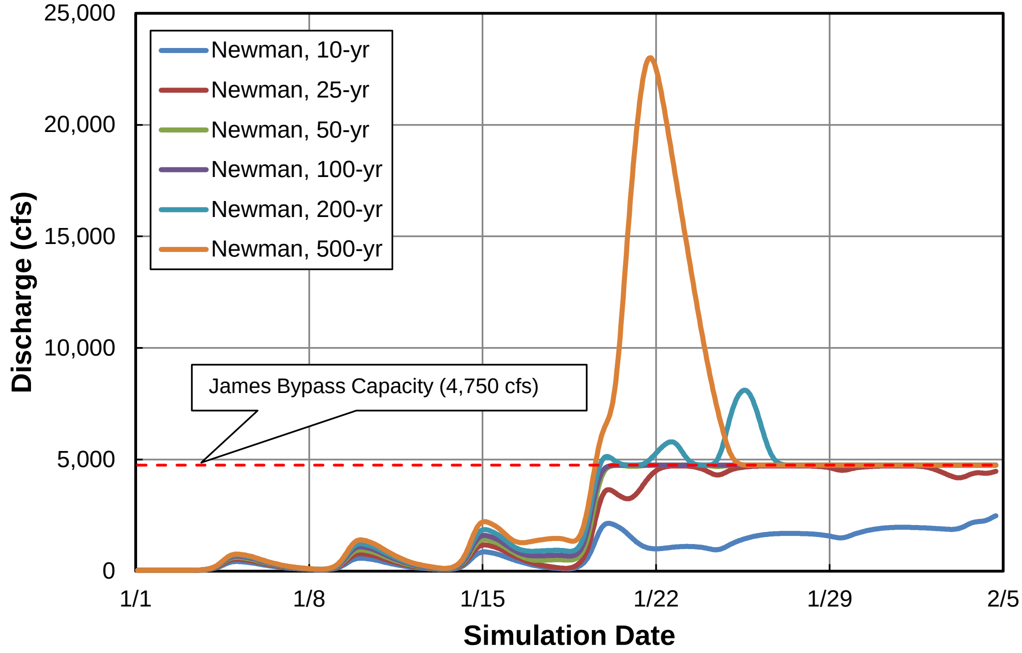

Figure 2-14. UNET model inflows at Fresno Slough near the downstream limit of the James Bypass (Newman Storm Centering).

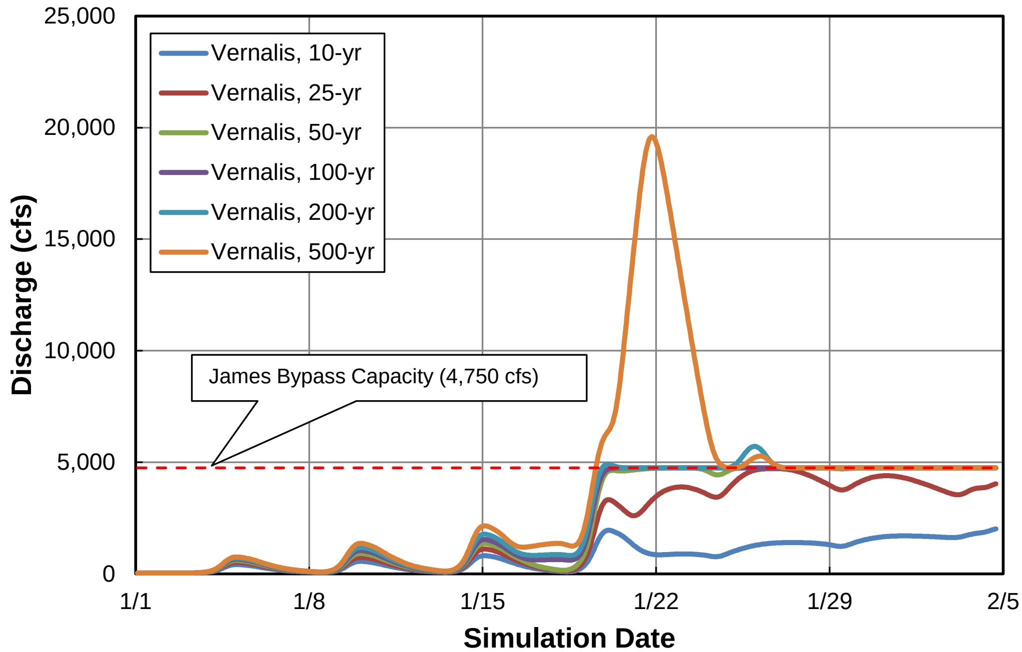

Figure 2-15. UNET model inflows at Fresno Slough near the downstream limit of the James Bypass (Vernalis Storm Centering).

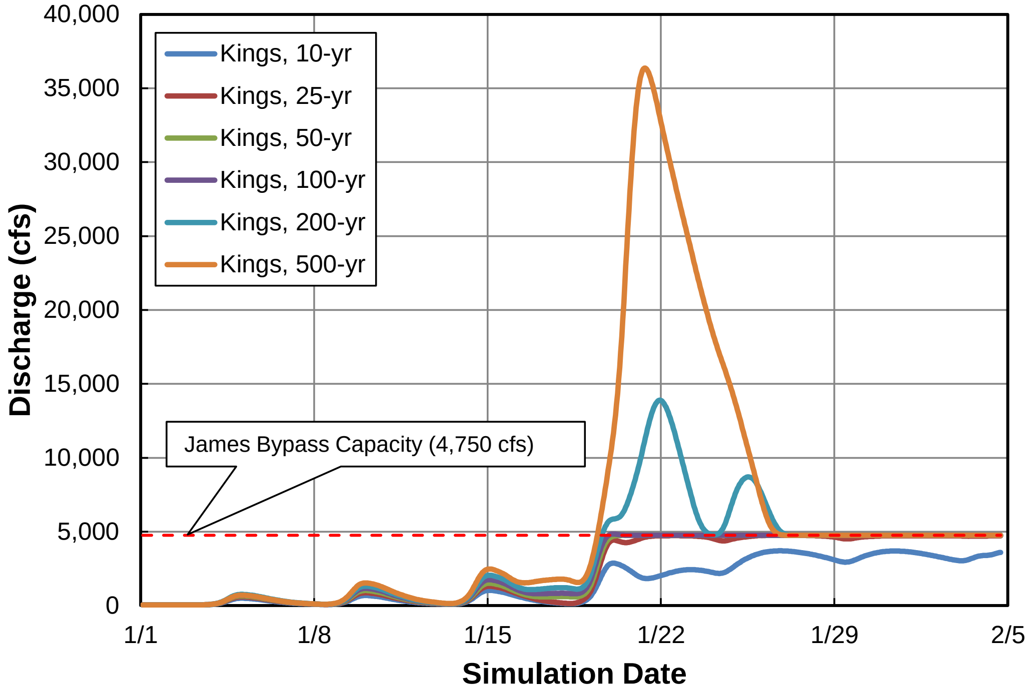

Figure 2-16. UNET model inflows at Fresno Slough near the downstream limit of the James Bypass (Kings River Storm Centering).

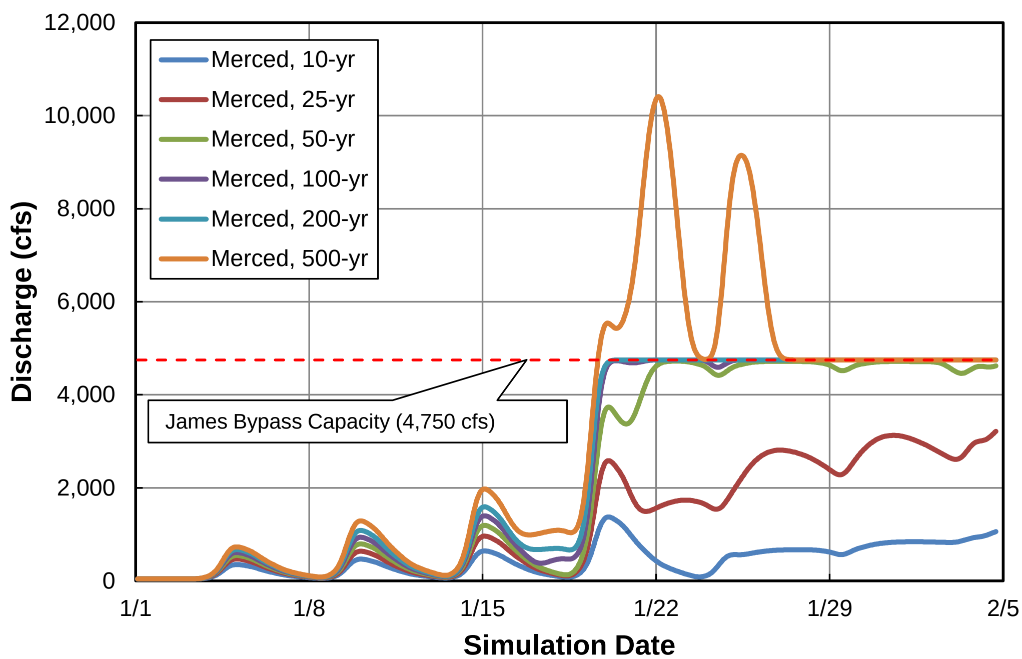

Figure 2-17. UNET model inflows at Fresno Slough near the downstream limit of the James Bypass (Merced River Storm Centering).

3 HYDRAULIC ANALYSIS

This section describes our use of the UNET model to develop discharge- and stage-frequency curves throughout the San Joaquin and Kings Rivers system under 10-, 25-, 50-, 100-, 200- and 500-year flood events. These results are the nexus between river hydrology and predicted economic damages. In the previous section, hydrographs were presented for the downstream limit of the James Bypass for a variety of storm centering locations likely to affect the river system. These hydrographs are then used as inputs into the UNET system which can then be used to characterize discharge and stage throughout the study area. The use of UNET to predict discharge and stage throughout the study area is described in this section. In the next section, these changes in river hydraulics serve as inputs to the HEC-FDA model for the generation of property flooding conditions and the subsequent identification of flood damage throughout the region.

3.1 METHODS

To provide input to the flood damage analysis, 1-Dimensional (1D) unsteady hydraulic modeling was performed using the above described UNET model. As discussed above, these models were originally developed for the Comp Study and updated for the 2012 CVFPP study by MWH Global. The model input files are made up of the geometric data file that defines the channel geometry and model structure (subreach and storage area linkage, hydraulic structure data, cross-section spacing, and hydraulic roughness information) and the boundary condition files. The boundary condition files include stage and discharge data at the downstream limit of the model subreaches, initial flow conditions and upstream flow hydrographs for the mainstem San Joaquin River at Friant Dam and each of the modeled tributaries.

3.1.1 BASELINE MODELS

The CVFPP "no-project" model was directly used for the baseline (no-project) condition model for this study. The baseline models were executed over all six storm events (the 10-, 25-, 50-, 100-, 200- and 500-year storm events) for each of the six storm centerings. The models were executed by first running the geometric data pre-processor program followed by the UNET model program. To facilitate execution of the models, batch files were set up to execute the range of storm events under each storm centering. Results from the models were written to HEC-DSS files for post-processing purposes.

3.1.2 PROJECT CONDITIONS MODELS

Two separate model sets were prepared to represent project conditions:

- Phase 1: 150 cfs diverted from the James Bypass, and
- Phase 2/3: 500 cfs diverted from the James Bypass.

For the project conditions models, no change was made to the UNET geometric data files since the portion of the James Bypass that would be affected by the project is not included in the UNET model. Modification to the boundary conditions files was necessary to represent the effects of the proposed project on flows that would be delivered to Fresno Slough by the James Bypass. The model input for the Fresno Slough was developed for project conditions Phase 1 by removing 150 cfs from the inflow hydrograph at this location. For discharges in the James Bypass that are less than 150 cfs, it was assumed that all flow would be diverted to the flood capture project, resulting in a zero discharge at the upstream model limit in Fresno Slough. Example hydrographs comparing no-project and Phase 1 conditions are shown in Figure 3-1 and Figure 3-2. Similarly, the model input for project conditions Phase 2/3 was prepared by removing 500 cfs from the Fresno Slough hydrograph at discharges greater than 500 cfs, and removing all flow from the hydrograph at discharges less than 500 cfs. Example hydrographs comparing no-project and Phase 2/3 conditions are presented in Figure 3-3 and Figure 3-4.

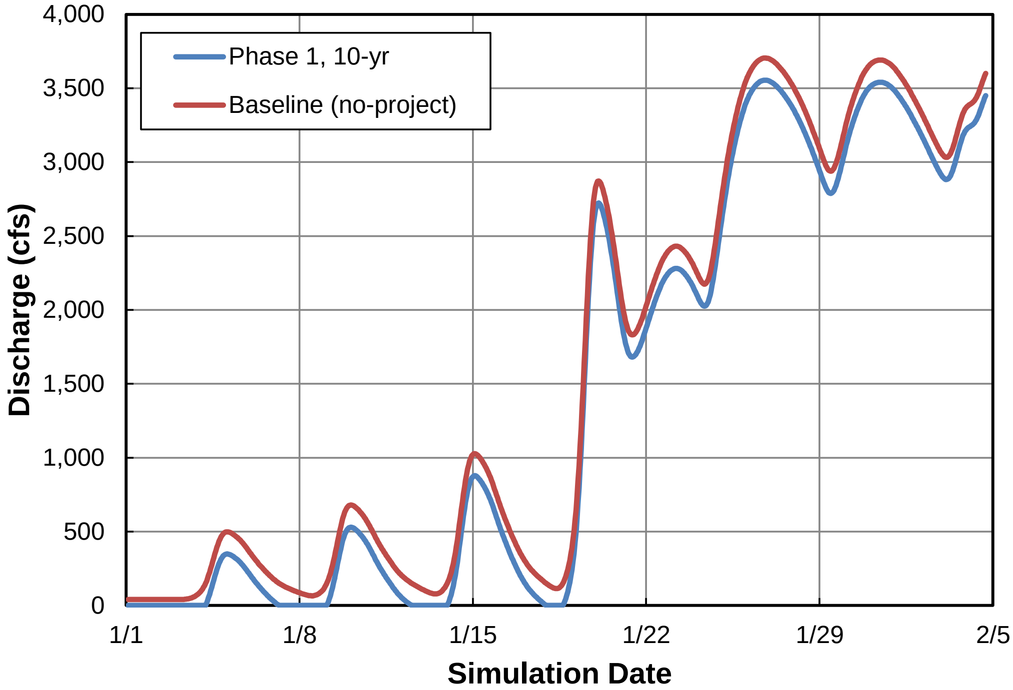

Figure 3-1. Example showing the 10-year storm event hydrographs (Kings River storm centering) at the upstream model limit of Fresno Slough under no-project and project Phase 1 conditions.

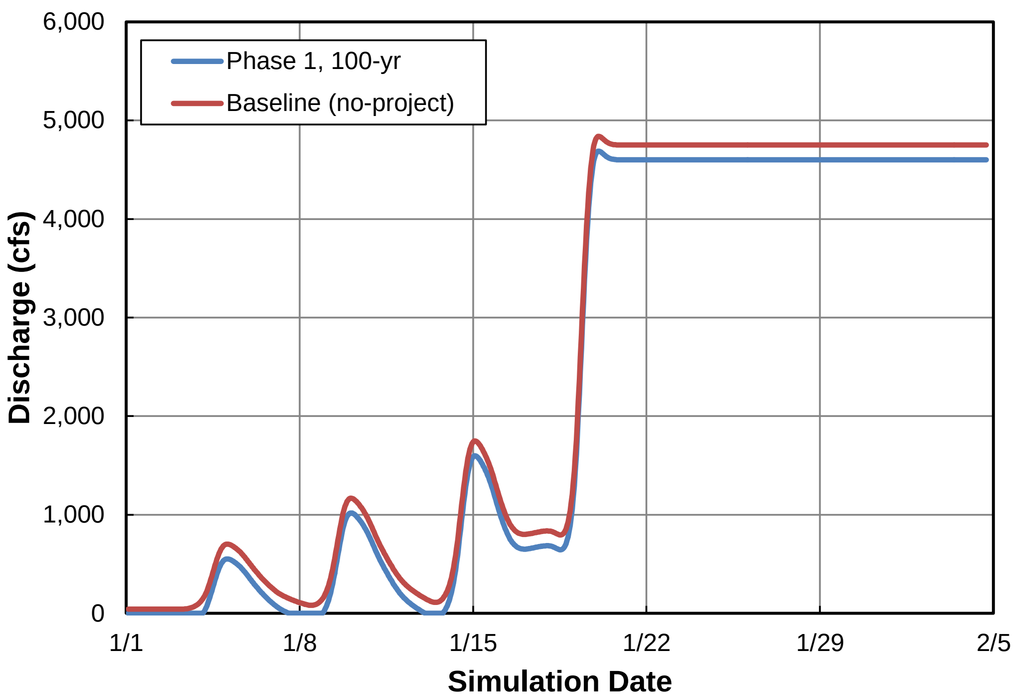

Figure 3-2. Example showing the 100-year storm event hydrographs (Kings River storm centering) at the upstream model limit of Fresno Slough under no-project and project Phase 1 conditions.

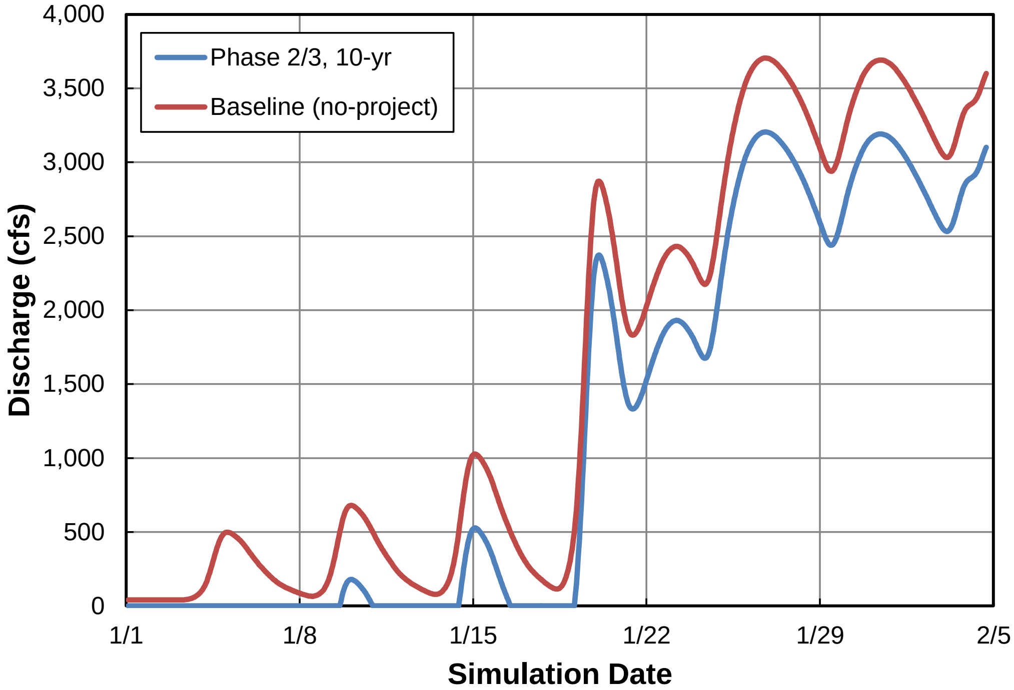

Figure 3-3. Example showing the 10-year storm event hydrographs (Kings River storm centering) at the upstream model limit of Fresno Slough under no-project and project Phase 2/3 conditions.

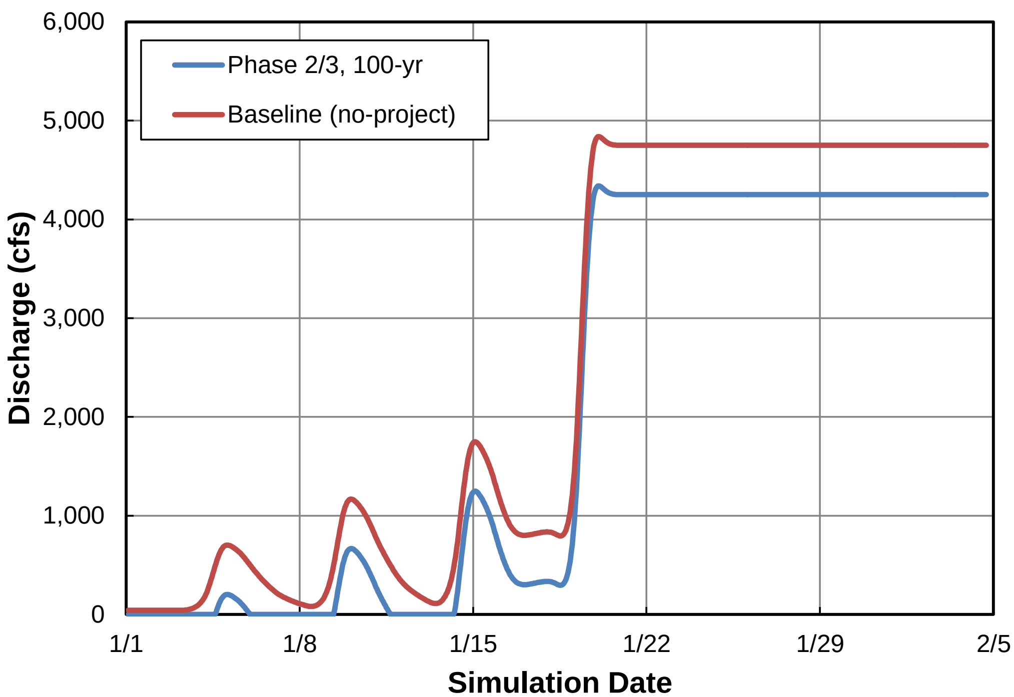

Figure 3-4. Example showing the 100-year storm event hydrographs (Kings River storm centering) at the upstream model limit of Fresno Slough under no-project and project Phase 2/3 conditions.

3.1.3 Infinite Channel Models

The Flood Damage Analysis (HEC-FDA) models require input from the UNET models in the form of stage-frequency curves. HEC-FDA Monte Carlo sampling requires a stage-frequency curve that covers a full range of potential flood frequencies that have increasing stage with decreasing frequency (increasing flow magnitude) (Figure 3-5). However, at some locations, especially in downstream reaches, the simulated stages are below the levee failure elevation due to progressive floodwater loss through upstream levee breaches (Figure 3-6). Under simulated levee breach conditions, the water-surface elevation remains relatively constant for all higher flood frequencies as flows escape through levee breaches into the floodplain. The resulting stage-frequency curves either flatten or tail over at the breach elevation. As a result, a second set of model runs is required to define the stage-frequency curve above the LFP. This second set of models, termed infinite channel models, assume levees are infinitely tall and no levee failure can occur during the simulation. Methods used to combine the results from the finite channel and infinite channel model runs into representative “hybrid” stage-frequency curves are discussed below.

We directly used the infinite channel model runs developed for no-project conditions in the Comp Study and modified for the 2012 CVFPP study for the infinite channel, no-project condition in this study. For project conditions, we adjusted the boundary condition files for the infinite channel models similarly as used for the with-project, finite channel boundary condition files. For project conditions Phase 1, we adjusted the Fresno Slough hydrograph by removing 150 cfs at flows greater than 150 cfs, and by removing all flow from the hydrograph at discharges less than 150 cfs. Under project conditions Phase 2/3, we made similar adjustments but for 500 cfs instead of 150 cfs. Consistent with the finite channel model runs, no other changes to the no-project condition infinite channel models were necessary for Phase 1 and Phase 2/3 models.

A numerical instability was encountered in executing the infinite channel model run for the 500-year storm event with Merced River storm centering under Phase 2/3. To resolve the instability, it was necessary to include a nominal discharge (20 cfs) during periods when the James Bypass discharge upstream from the project actions was less than 500 cfs. Because this discharge is relatively small and does not affect peak flows or stages used in the HEC-FDA modeling, this adjustment did not affect the economic analysis.

3.1.4 UNET Model Results

From the UNET modeling results, we developed stage-frequency curves as input to the HEC-FDA modeling. Two hundred sixteen UNET simulations were run for 6 storm centerings, 6 storm events, finite and infinite channel models for no-project, and Phase 1 and Phase 2/3 conditions.

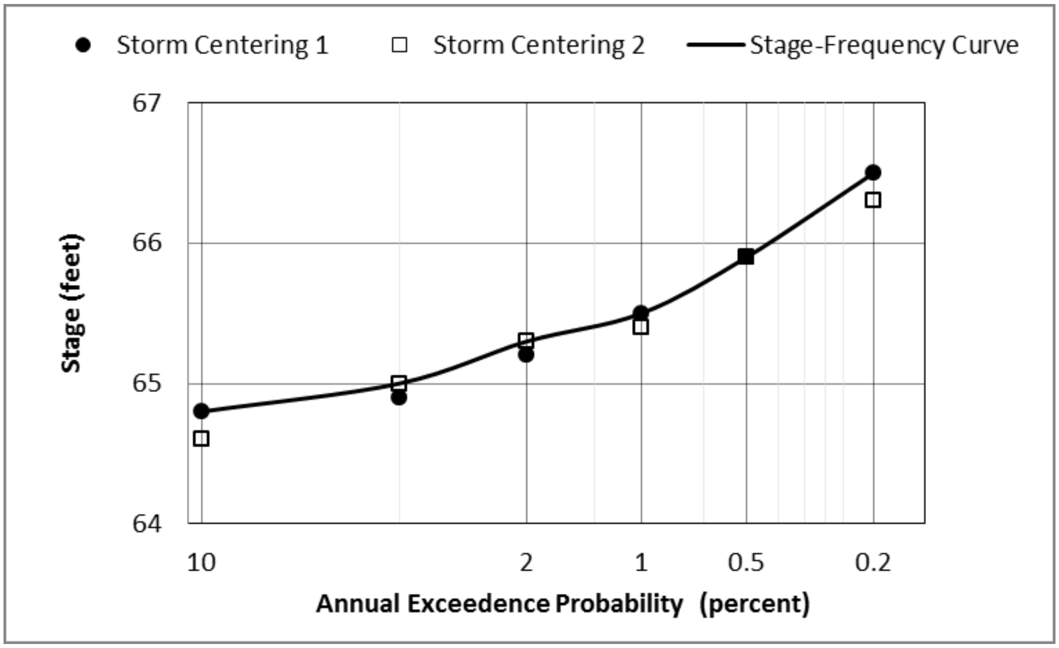

Figure 3-5. Example of maximum stage-frequency curve development [from 2012 Central Valley Flood Protection Plan (DWR, 2012, Attachment 8C)].

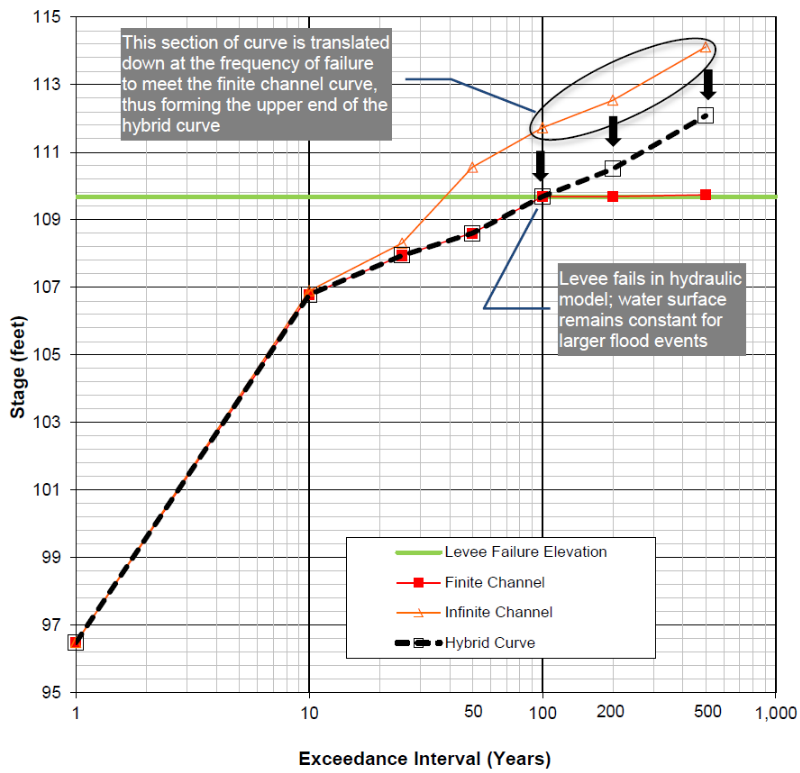

Figure 3-6. Example of hybrid stage-frequency curve development [from 2012 Central Valley Flood Protection Plan (DWR 2012, Attachment 8F)].

3.2 Results

UNET modeling results include stage and flow hydrographs at key locations along the San Joaquin River system channels, and stage and water flux information in the modeled storage areas. We initially reviewed the results for reasonableness, comparing modeled no-project stage and flow hydrographs with Phase 1 and Phase 2/3 model runs. Generally, the largest flow and stage reductions are shown in areas nearest to Fresno Slough. For example, at Index Point SJ105 near Mendota, the 10-year event peak discharge (Kings River storm centering) reduces 130 cfs from about 4,920 cfs under no-project conditions to about 4,790 cfs under Phase 1 conditions, and reduces an additional 330 cfs to about 4,450 under Phase 2/3 (Figure 3-7). Similarly, the maximum stage for this storm event at this location reduces from 148.76 feet under no-project conditions to 148.64 feet and 148.28 feet under Phase 1 and Phase 2/3, with peak stages reducing by about 0.1 and nearly 0.5 feet respectively (Figure 3-8). Farther downstream at Index Point SJ115, located in the vicinity of the Sand Slough/San Joaquin River Control Structures, the peak discharge at the 10-year event (Kings River storm centering) reduces from about 11,040 cfs under no-project conditions to about 10,990 cfs under Phase 1 conditions, and reduces to about 10,910 cfs under Phase 2/3 conditions, with respective peak flow reductions of between 50 cfs and 120 cfs (Figure 3-9). The maximum stage for this storm event at this location reduces from 104.33 feet under no-project conditions to 104.30 feet and 104.27 feet under Phase 1 and Phase 2/3, respectively, indicating the project would result in relatively minor reductions to the peak stage (Figure 3-10).

Appendix A provides the UNET modeling results in digital format on a disc.

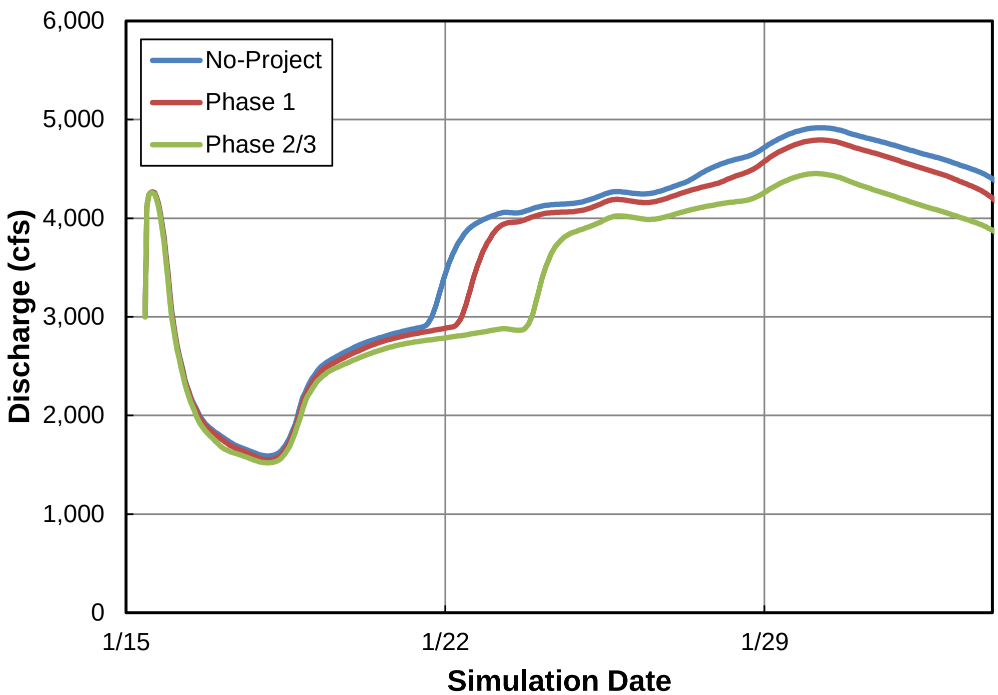

Figure 3-7. Example showing the simulated 10-year storm event flow discharge hydrographs (Kings River storm centering) at Index Point SJ105 near Mendota under no-project conditions and project Phase 1 and Phase 2/3 conditions.

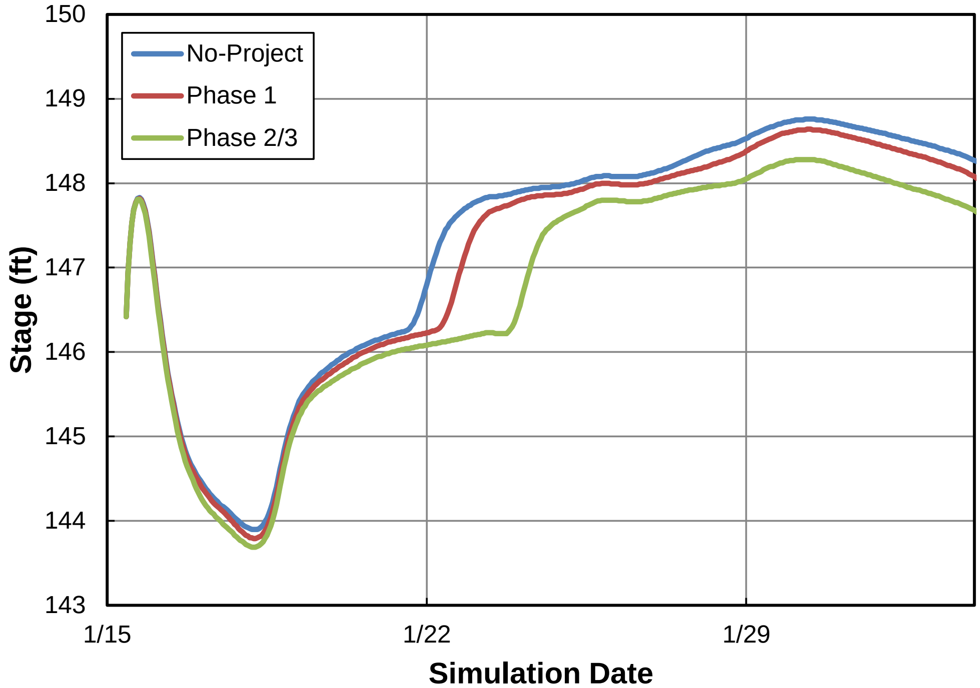

Figure 3-8. Example showing the simulated 10-year storm event stage hydrographs (Kings River storm centering) at Index Point SJ105 near Mendota under no-project conditions and project Phase 1 and Phase 2/3 conditions.

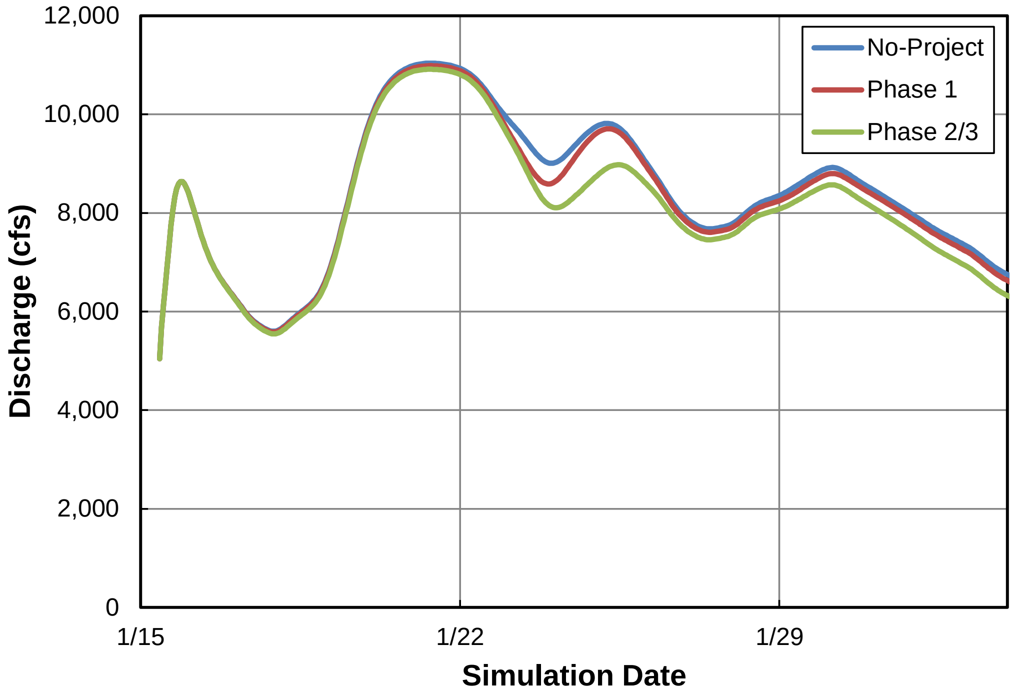

Figure 3-9. Example showing the simulated 10-year storm event flow discharge hydrographs (Kings River storm centering) at Index Point SJ115 near Mendota under no-project conditions and project Phase 1 and Phase 2/3 conditions.

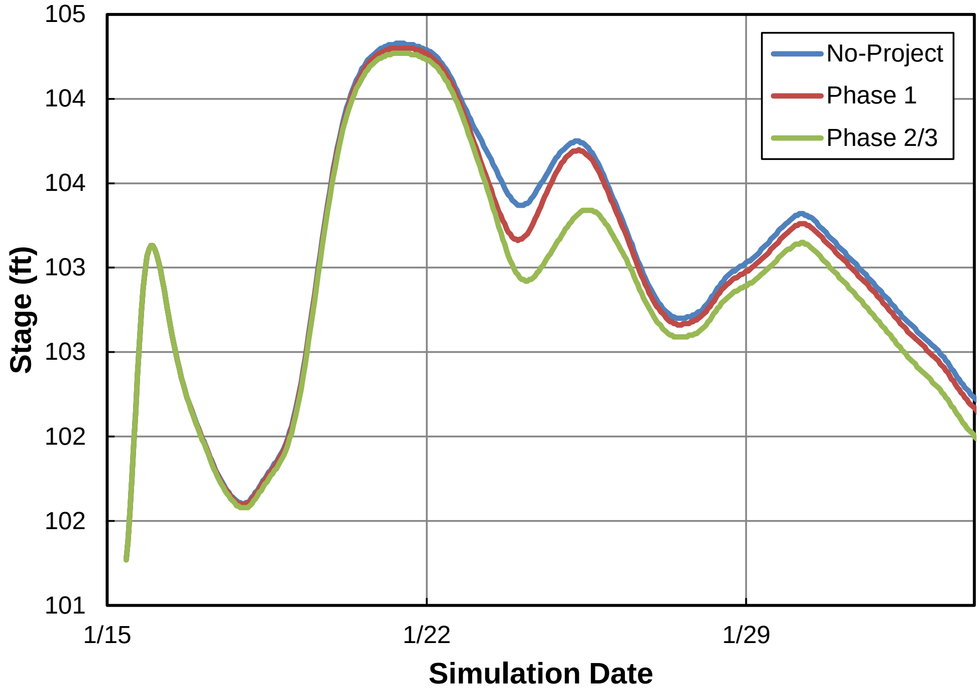

Figure 3-10. Example showing the simulated 10-year storm event stage hydrographs (Kings River storm centering) at Index Point SJ115 near Mendota under no-project conditions and project Phase 1 and Phase 2/3 conditions.

4 ECONOMIC ANALYSIS

4.1 METHODS

The economic analysis was performed using the HEC-FDA computer software with input from the UNET model results. The HEC-FDA model that was developed as part of the 2012 CVFPP study was obtained and used for this study with updated hydrologic inputs. A summary of the HEC-FDA model, including the methods used to prepare the model input and a discussion of the model results, is presented in the following sections.

4.1.1 HEC-FDA MODEL DESCRIPTION

4.1.1.1 PROJECT SCOPE

The U.S. Army Corps of Engineers (USACE) National Economic Development Procedures Manual – Urban Flood Damage identifies that in flood damage reduction studies, most benefits come from the reduction of inundation damages. These damages include both physical and non-physical costs. Physical costs include inundation damage to infrastructure, structures and their contents, and agriculture. Non-physical costs include flood cleanup costs, costs of flood fighting, evacuation, traffic/transportation rerouting, and loss of business transactions.

This study, based on the foundations of the Comp and CVFPP studies referenced previously, analyzes the inundation damages to structures and their contents, agriculture, and business losses. No updating of the previous studies (Comp and CVFPP) structure counts, values, agriculture lands, or business loss data was completed. The existing information in regards to these damage categories has been used as provided.

4.1.1.2 FLOOD DAMAGE MODEL

For this study, expected annual damages (EAD) were estimated using the USACE' risk-based Monte Carlo simulation program called HEC-FDA (FDA). The FDA program integrates available hydrology, hydraulics, geotechnical and economic relationships to determine damages, flooding risk and project performance. Uncertainty is incorporated for each relationship, and the model samples from a distribution for each observation to estimate damage and flood risk.

4.1.2 ECONOMIC STUDY AREA

The study area addressed for the economic analysis in this report consists of the potential San Joaquin River floodplain. The study area stretches from Fresno, on the upstream (south) end, to Stockton on the downstream (north) end. The study area consists of approximately 700,000 acres of land in total and has been separated into 43 damage areas for ease of analysis (CVFPP). The full extent of the area analyzed and the location of each damage area can be seen in Figure 4-1.

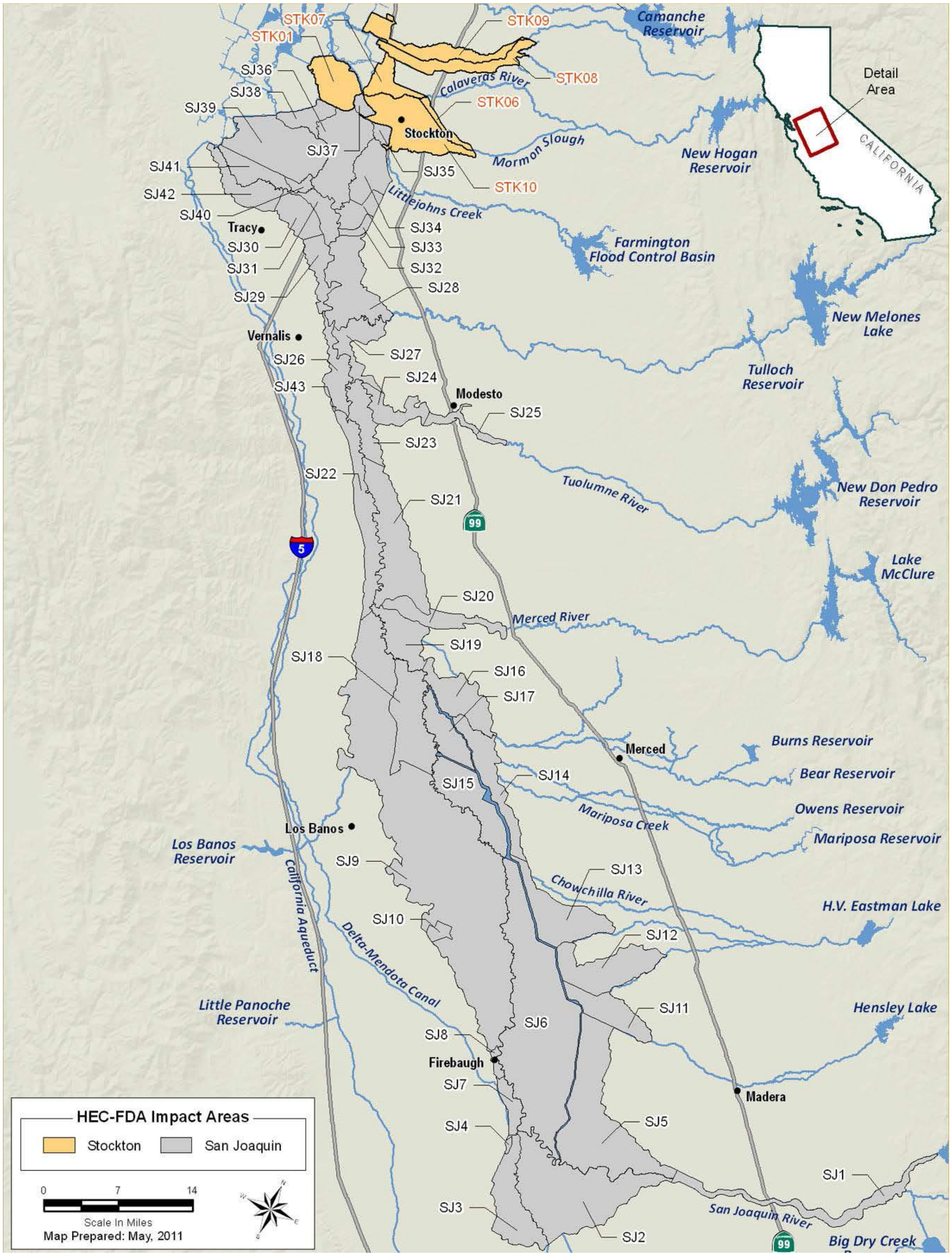

Figure 4-1. Damage areas for the San Joaquin River used in the CVFPP flood damage analysis [from 2012 Central Valley Flood Protection Plan (DWR 2012, Attachment 8F)].

4.1.3 HEC-FDA Model Input

The FDA program incorporates the various hydrology, hydraulic, geotechnical and economic relationships into its calculations to develop estimated damages. Hydrologic input to the model was based on representative stage-frequency relationships at representative index point locations within the damage areas. These stage-frequency relationships were then translated to the individual structures as depth-frequency relationships. All other model inputs used for this study were developed outside this study and included the structure inventory and valuations, agricultural land valuations, estimated losses to businesses in the floodplain, and geotechnical data in regards to the levees found throughout the study area.

4.1.3.1 Development of Hybrid Stage-Frequency Curves from 43 Index Points

We developed hydrologic inputs to the HEC-FDA model from the UNET modeling results. This process involved the development of “hybrid” stage-frequency curves for of the 43 index points representative of levee failure conditions in each of the 43 damage areas. The hybrid stage-frequency curves were developed using Comp Study and 2012 CVFPP study methods. We first selected the maximum simulated stage at each index point for the range of storm centerings (see example in Figure 3-5). A summary of the storm centering that resulted in the maximum stage at each damage area index point over the range of modeled discharges under no-project conditions, Phase 1 and Phase 2/3 is presented in Table 4-1, Table 4-2 and Table 4-3, respectively. We then developed hybrid curves through an evaluation of the levee performance curves and identifying the elevation corresponding to a 50 percent probability of failure, termed the likely failure point (LFP). (A detailed discussion of the levee performance curves and identification of the LFPs is included in the 2012 CVFPP documentation.) The lower portion of the hybrid stage-frequency curve below the frequency of levee failure is defined using the simulated stages from the finite channel model simulations (i.e., the with-LFP-failure models); the upper portion of the curve above the frequency of levee failure is based on the simulated stages from the infinite channel simulations. Because the infinite channel simulations result in higher stages than the LFP at the LFP frequency, it is necessary to translate the infinite-channel-based stage-frequency curve down to match the actual LFP stage-frequency point. An example of the development of a hybrid stage-frequency curve is presented in Figure 3-6.

The hybrid stage-frequency curves were developed for each of the 43 damage areas under no-project, Phase 1 and Phase 2/3 conditions. One of the most significant differences between the 2002 Comp Study and the 2012 CVFPP study is the set of refinements made to the levee performance curves and the associated application of these curves to the various damage areas in the more recent study. In some cases, it appears that representative index point locations were adjusted. To ensure the updates included in the 2012 CVFPP study were reflected in this analysis, the hybrid stage-frequency curves developed for the CVFPP no-project condition were adopted for the no-project condition here. We used the hybrid stage-frequency curves developed for this study (at Comp Study index points) to determine the difference between Phase 1 and Phase 2/3 stage-frequency curves as compared to no project stage-frequency curves (Figure 4-2 and Figure 4-3). We then applied these differences to the 2012 CVFPP stage-frequency curves under no-project conditions to prepare the stage-frequency curves under Phase 1 and Phase 2/3 for this project.

Table 4-1. Summary of the storm centering that results in the maximum stage at the modeled events that was used to develop the hybrid stage-frequency curves for each damage area under no-project conditions.

Damage Area	Name	Controlling Storm Centering*					
		10 YR	25 YR	50 YR	100 YR	200 YR	500 YR
SJ 01	Fresno	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 02	Fresno Slough East	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 03	Fresno Slough West	Kings	Friant	Friant	Friant	Friant	Kings
SJ 04	Mendota	Vernalis	Friant	Friant	Friant	Friant	Kings
SJ 05	Chowchilla Bypass	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 06	Lone Willow Slough	El Nido	Friant	Merced	Friant	Merced	Merced
SJ 07	Mendota North	Kings	Friant	Friant	Friant	Friant	Kings
SJ 08	Firebaugh	Kings	Friant	Friant	Friant	Friant	Kings
SJ 09	Salt Slough	Kings	Friant	Friant	Friant	Friant	Kings
SJ 10	Dos Palos	Kings	Friant	Friant	Friant	Friant	Kings
SJ 11	Fresno River	El Nido	Merced	El Nido	Friant	El Nido	Merced
SJ 12	Berenda Slough	El Nido	El Nido	El Nido	El Nido	Merced	Merced
SJ 13	Ash Slough	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 14	Sandy Mush	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 15	Turner Island	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 16	Bear Creek	Newman	Vernalis	Merced	Merced	Merced	Merced
SJ 17	Deep Slough	Newman	El Nido	Merced	Newman	Merced	Merced
SJ 18	West Bear Creek	El Nido	Vernalis	El Nido	El Nido	El Nido	El Nido
SJ 19	Fremont Ford	El Nido	Vernalis	El Nido	El Nido	El Nido	Friant
SJ 20	Merced River	Newman	Merced	Merced	Merced	Merced	Merced
SJ 21	Merced River North	El Nido	Vernalis	Newman	Newman	Newman	Vernalis
SJ 22	Orestimba	El Nido	Vernalis	Newman	Newman	Newman	Vernalis
SJ 23	Tuolumne South	El Nido	Vernalis	Newman	Newman	Vernalis	Vernalis
SJ 24	Tuolumne River	Newman	Vernalis	Newman	Vernalis	Vernalis	Vernalis
SJ 25	Modesto	Vernalis	Vernalis	Vernalis	Vernalis	Vernalis	Vernalis
SJ 26	3 Amigos	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 27	Stanislaus South	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 28	Stanislaus North	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 29	Banta Carbona	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 30	Paradise Cut	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 31	Stewart Tract	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 32	East Lathrop	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 33	Lathrop/ Sharpe	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 34	French Camp	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 35	Moss Tract	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 36	Roberts Island	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 37	Rough and Ready Island	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 38	Drexler Tract	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 39	Union Island	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 40	SE Union Island	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 41	Fabian Tract	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 42	RD 1007	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 43	Grayson	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis

*Storm centering that controls development of hybrid stage-frequency curves.

Table 4-2. Summary of the storm centering that results in the maximum stage at the modeled events that was used to develop the hybrid stage-frequency curves for each damage area under Phase 1 conditions.

Damage Area	Name	Controlling Storm Centering*					
		10 YR	25 YR	50 YR	100 YR	200 YR	500 YR
SJ 01	Fresno	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 02	Fresno Slough East	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 03	Fresno Slough West	Kings	Friant	Friant	Friant	Friant	Kings
SJ 04	Mendota	Newman	Friant	Friant	Friant	Friant	Kings
SJ 05	Chowchilla Bypass	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 06	Lone Willow Slough	El Nido	Friant	Merced	Friant	Merced	Merced
SJ 07	Mendota North	Kings	Friant	Friant	Friant	Friant	Kings
SJ 08	Firebaugh	Kings	Friant	Friant	Friant	Friant	Kings
SJ 09	Salt Slough	Kings	Friant	Friant	Friant	Friant	Kings
SJ 10	Dos Palos	Kings	Friant	Friant	Friant	Friant	Kings
SJ 11	Fresno River	El Nido	Merced	El Nido	Friant	El Nido	Merced
SJ 12	Berenda Slough	El Nido	El Nido	El Nido	El Nido	Merced	Merced
SJ 13	Ash Slough	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 14	Sandy Mush	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 15	Turner Island	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 16	Bear Creek	Newman	Vernalis	Merced	Merced	Merced	Merced
SJ 17	Deep Slough	Newman	El Nido	Merced	Newman	Merced	Merced
SJ 18	West Bear Creek	El Nido	Vernalis	El Nido	El Nido	El Nido	El Nido
SJ 19	Fremont Ford	El Nido	Vernalis	El Nido	El Nido	El Nido	Friant
SJ 20	Merced River	Newman	Merced	Merced	Merced	Merced	Merced
SJ 21	Merced River North	El Nido	Vernalis	Newman	Newman	Newman	Vernalis
SJ 22	Orestimba	El Nido	Vernalis	Newman	Newman	Newman	Vernalis
SJ 23	Tuolumne South	El Nido	Vernalis	Newman	Newman	Vernalis	Vernalis
SJ 24	Tuolumne River	Newman	Vernalis	Newman	Vernalis	Vernalis	Vernalis
SJ 25	Modesto	Vernalis	Vernalis	Vernalis	Vernalis	Vernalis	Vernalis
SJ 26	3 Amigos	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 27	Stanislaus South	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 28	Stanislaus North	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 29	Banta Carbona	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 30	Paradise Cut	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 31	Stewart Tract	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 32	East Lathrop	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 33	Lathrop/ Sharpe	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 34	French Camp	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 35	Moss Tract	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 36	Roberts Island	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 37	Rough and Ready Island	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 38	Drexler Tract	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 39	Union Island	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 40	SE Union Island	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 41	Fabian Tract	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 42	RD 1007	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 43	Grayson	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis

*Storm centering that controls development of hybrid stage-frequency curves; controlling storm centerings that differ from the no-project condition are highlighted in grey.

Table 4-3. Summary of the storm centering that results in the maximum stage at the modeled events that was used to develop the hybrid stage-frequency curves for each damage area under Phase 2/3 conditions.

Damage Area	Name	Controlling Storm Centering*					
		10 YR	25 YR	50 YR	100 YR	200 YR	500 YR
SJ 01	Fresno	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 02	Fresno Slough East	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 03	Fresno Slough West	Kings	Friant	Friant	Friant	Friant	Kings
SJ 04	Mendota	El Nido	Friant	Friant	Friant	Friant	Kings
SJ 05	Chowchilla Bypass	El Nido	El Nido	Friant	Friant	Friant	Friant
SJ 06	Lone Willow Slough	El Nido	Friant	Merced	Friant	Merced	El Nido
SJ 07	Mendota North	Kings	Friant	Friant	Friant	Friant	Kings
SJ 08	Firebaugh	Kings	Friant	Friant	Friant	Friant	Kings
SJ 09	Salt Slough	Kings	Friant	Friant	Friant	Friant	Kings
SJ 10	Dos Palos	Kings	Friant	Friant	Friant	Friant	Kings
SJ 11	Fresno River	El Nido	Merced	El Nido	Friant	El Nido	Merced
SJ 12	Berenda Slough	El Nido	El Nido	El Nido	El Nido	Merced	El Nido
SJ 13	Ash Slough	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 14	Sandy Mush	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 15	Turner Island	El Nido	Vernalis	Merced	El Nido	El Nido	Merced
SJ 16	Bear Creek	Newman	Vernalis	Merced	Merced	Merced	Merced
SJ 17	Deep Slough	Newman	El Nido	Merced	Newman	Merced	Merced
SJ 18	West Bear Creek	El Nido	Vernalis	El Nido	El Nido	El Nido	El Nido
SJ 19	Fremont Ford	El Nido	Vernalis	Newman	El Nido	El Nido	Friant
SJ 20	Merced River	Newman	Merced	Merced	Merced	Merced	Merced
SJ 21	Merced River North	El Nido	Vernalis	Newman	Newman	Newman	Vernalis
SJ 22	Orestimba	El Nido	Vernalis	Newman	Newman	Newman	Vernalis
SJ 23	Tuolumne South	El Nido	Vernalis	Newman	Newman	Vernalis	Vernalis
SJ 24	Tuolumne River	Newman	Vernalis	Newman	Vernalis	Vernalis	Vernalis
SJ 25	Modesto	Vernalis	Vernalis	Vernalis	Vernalis	Vernalis	Vernalis
SJ 26	3 Amigos	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 27	Stanislaus South	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 28	Stanislaus North	El Nido	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 29	Banta Carbona	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 30	Paradise Cut	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 31	Stewart Tract	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 32	East Lathrop	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 33	Lathrop/ Sharpe	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 34	French Camp	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 35	Moss Tract	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 36	Roberts Island	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 37	Rough and Ready Island	Vernalis	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 38	Drexler Tract	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 39	Union Island	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 40	SE Union Island	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 41	Fabian Tract	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 42	RD 1007	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis
SJ 43	Grayson	Newman	Vernalis	Vernalis	Newman	Vernalis	Vernalis

*Storm centering that controls development of hybrid stage-frequency curves; controlling storm centerings that differ from the no-project condition are highlighted in grey.

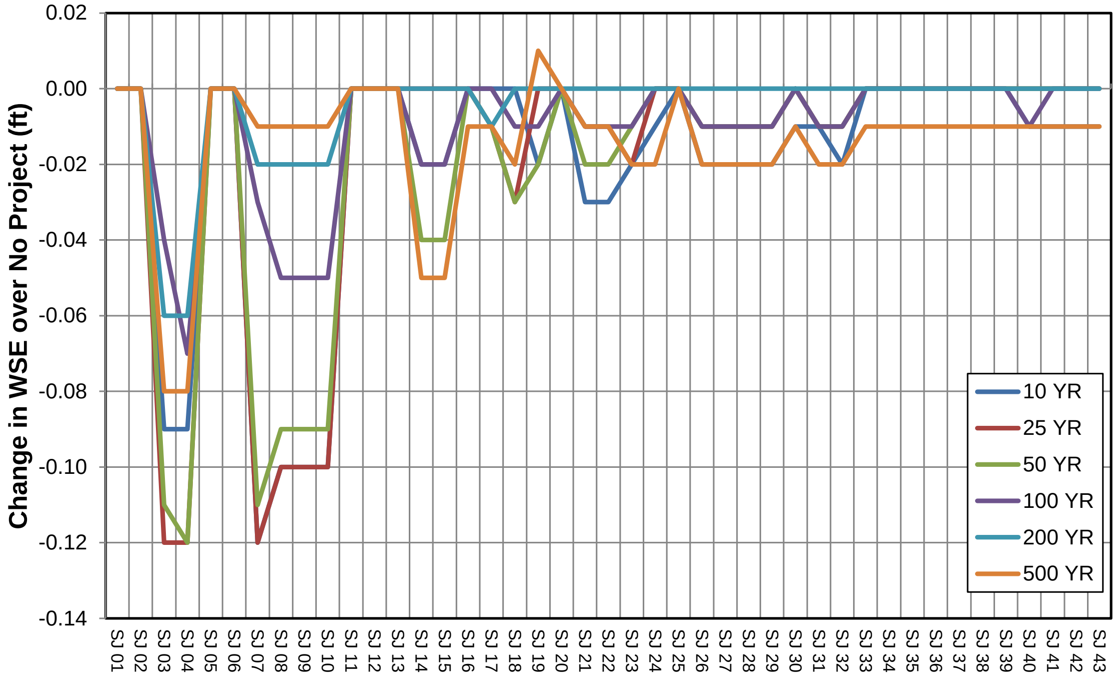

Figure 4-2. Difference in water-surface elevation between no-project conditions and Phase 1 based on the hybrid stage-frequency curves at the Comp Study damage areas (index points).

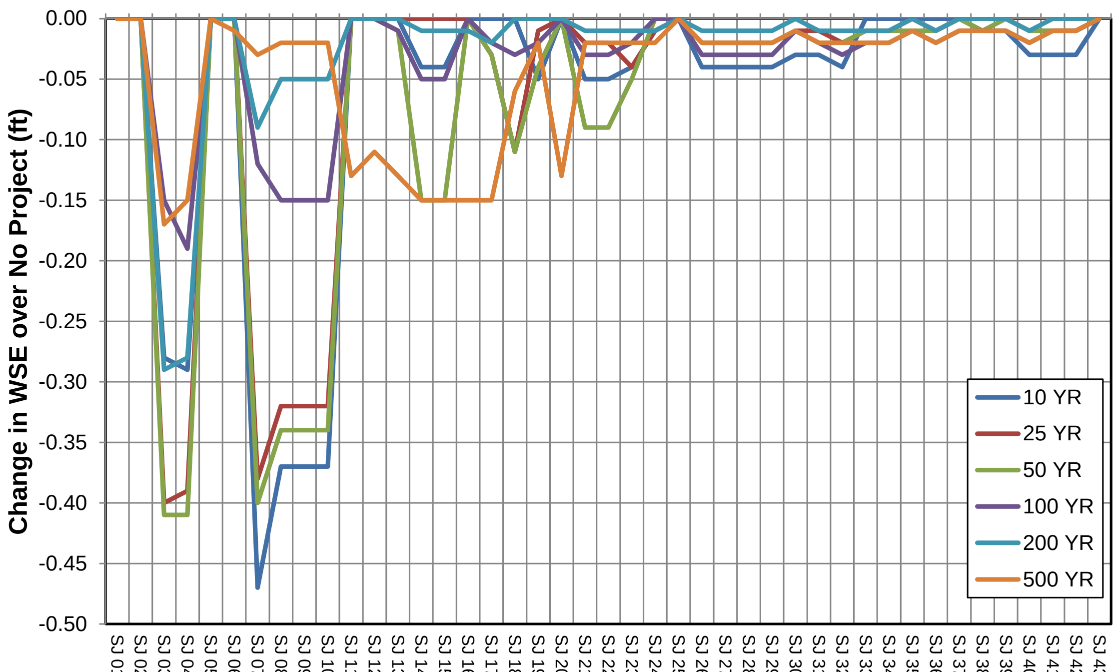

Figure 4-3. Difference in water-surface elevation between no-project conditions and Phase 2/3 based on the hybrid stage-frequency curves at the Comp Study damage areas (index points).

4.1.3.2 Flood Depth Grid

A key input to HEC-FDA is a flood depth grid for each damage area floodplain over the range of flood events. The flood depth grid is overlaid on the geospatial structure and crop inventory to estimate the total damages that would result from different flood events, which is in turn used to develop the stage-damage relationships. Development of the flood depth grid generally involves use of the levee performance curves and UNET modeling results, along with FLO-2D modeling of the floodplain on the landward side of the levee that relates exterior (river) stage to the interior stage. A detailed discussion of the methods used to conduct this analysis for the CVFPP study is included in Attachment 8F of CVFPP study report (DWR, 2012). Incorporation of this analysis in this study would not significantly, if at all, affect the results from the economic analysis and this level of analysis was outside the scope of this project, so the tools that were used to perform the analysis in the CVFPP study were used for this study. These tools included a series of spreadsheets and Visual Basic code that incorporates the results of the flood depth grid analysis to convert the exterior (river) stages to interior (landward) water depths for land parcels within each damage area. These tools were provided to Tetra Tech by MWH Global at the request of DWR.

4.1.3.3 Structure Inventory Database and Valuations

The creation of a structure inventory database is a key part of the economic analysis. This database was developed during the CVFPP study, and we made no modifications of the database for this analysis. A more detailed discussion of the structure inventory development is provided in reference section 3.7 in Attachment 8F from the 2012 CVFPP study.

The structure inventory utilized contains vital information on each individual structure found in the study area. Each structure is assigned to a structure category: Commercial, Industrial, Public, and Residential. We further assigned a more detailed breakdown of the structure type, known as the occupancy type. Other data included in the database for each structure were the number of stories, structure square footage, construction class (building materials), construction quality (qualitative estimation of the structures building materials; ex. “cheap”, “average”, “good”, etc.), depreciation percentage (loss in value compared to brand-new cost), and the foundation height.

Using this information and Marshall & Swift Valuation costs per square foot by occupancy type, we calculated depreciated replacement values. We took all structure square foot values from 3rd quarter, October 2010, edition of Marshall & Swift and then updated based on Marshall & Swift cost and local multipliers (CVFPP). Values for the contents inside each structure are calculated based on multiplying the depreciated replacement value of the structure by the contents-to-structure ratio. As noted in the CVFPP study, the ratios used in this study were taken from the USACE’ *American River Watershed Project, Folsom Dam Modifications and Folsom Dam Raise Project Final Economic Reevaluation Report*. Due to the various types of structures and structure uses found, the contents-to-structure ratio varies by occupancy type.

Appendix B contains summary tables for the structure counts, depreciated replacement values, and occupancy types developed during the CVFPP study, and utilized in the analysis for this report.

4.1.3.4 Crop Land

As with the structure inventory database, we used the 2012 CVFPP study for crop land valuations and FDA inputs. To generate the FDA inputs for the agricultural land in each damage area, the CVFPP followed the steps listed in the CVFPP report as noted:

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

We did not modify the outputs referenced in this study for this current FDA model effort. Section 3.8 of Attachment 8F from the 2012 CVFPP study has a more detailed discussion of the calculations completed to generate the crop damage FDA inputs.

4.1.3.5 Business Losses

Flood events impact businesses due to loss of business activity during the inundation. The 2012 CVFPP study estimated the damages associated with decreased business activity for each damage area. We used these estimates here and did not gather new information nor make any new business loss update estimates from the 2012 study.

The CVFPP study looked at each non-residential structure to generate business losses. Several pieces of information were gathered to estimate these losses. The economic output per day by the various occupancy types was obtained from the Energy Information Administration. Temporary business interruption days were applied to each structure utilizing the flood depth grid, and Federal Emergency Management Agency's (FEMA) depth-damage functions. The daily output and estimated interruption days was then used to calculate an estimated output per flood event, from which the potential lost business value for each non-residential structure is calculated. The total business losses in each damage area were then aggregated for each flood event. A stage-damage curve was then created based on the aggregate values, and input into FDA.

The CVFPP study does mention some caveats to the business loss analysis. For instance, business losses in this study are measures as reduction in gross business output or sales, but the more appropriate measure of business loss is net income. Gross business output is thus used as a proxy estimate of net income. Additionally, if a business floods it can make up some lost business once it reopens, temporarily relocate to continue business, or go out of business. None of these factors are considered in this analysis. Due to these and other simplifications, it is possible that actual business losses are lower than in this study.

4.1.3.6 Geotechnical Data

Levee performance curves were input into FDA because these curves establish geotechnical relationships between river water stage and the probability that a levee segment will fail or breach at that stage. Again, this levee information was generated during the CVFPP study, and all information from that study was used within this report. The CVFPP study discusses that past flood information, field data, and laboratory geotechnical data used to calculate and/or validate the levee performance curves.

4.1.4 HEC-FDA Model Outputs

Outputs from the model included Expected Annual Damages (EAD) for the different alternatives (i.e. No Project, Phase 1, Phase 2/3) and Flood Event Damages. EAD integrate damages by flood event into an annual damage and these damages are shown by category (i.e. structural and structural content, crop, business). Results were compared against historical data as validation of the methodology.

4.1.5 DWR Tools to Evaluate Relative Impacts from Different Storm Events

Our economic analysis assessed the relative impact of different storm events on EAD. FDA provides a total EAD in the output files and cannot identify which storm events most affect EAD calculations. DWR grant applications provide tables which use simple calculations to estimate EAD (eEAD) (Table 4-4). As the FDA program uses complex models and statistical techniques for calculating EAD, the results from these two approaches are not expected to match exactly. But the DWR eEAD can illustrate what events are having a more significant impact, and these results should hold in the FDA program as well.

For this analysis the seven most heavily damaged sites, in terms of EAD, have been utilized for further investigation:

- SJ 05 Chowchilla Bypass
- SJ 09 Salt Slough
- SJ 12 Brenda Slough
- SJ 13 Ash Slough
- SJ 15 Turner Island
- SJ 20 Merced River
- SJ 33 Lathrop/Sharpe

These seven sites account for approximately 66.5% of the total EAD of the project. The inputs into the eEAD tables include the total damage results for each event, as well as levee failure probabilities that have been utilized in the FDA analysis. From this information eEAD values are calculated by event for each reach and phase.

Table 4-4. Sample DWR Table for Calculating eEAD for Damage Area SJ12 under No Project Scenario

SJ 12 - BRENDA SLOUGH							
Hydrologic Event	Event Exceedance Probability	Event Damage if Flood Structures Fail	Probability Structural Without Project	Expected Event Damage Without Project	Interval Probability	Average Damage in Without Project	Average Damage in Without Project
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
				(c) x (d)	from (b)	from (e)	(f) x (g)
2-Year	0.5	$0	0	$0	-	-	-
5-Year	0.2	$0	0.05	$0	0.3	$0	$0
6.67-Year	0.15	$0	0.1	$0	0.05	$0	$0
10-Year	0.1	$23,545	1	$23,545	0.05	$11,772	$589
50-Year	0.02	$23,581	1	$23,581	0.08	$23,563	$1,885
100-Year	0.01	$23,581	1	$23,581	0.01	$23,581	$236
200-Year	0.005	$25,620	1	$25,620	0.005	$24,600	$123
500-Year	0.002	$26,717	1	$26,717	0.003	$26,168	$79
						Expected Annual Damages:	**$2,910.96**

Note: All dollar values are in $1,000's.

4.1.6 Benefit Costs Analyses

A benefit costs analyses was conducted for this project to compare project costs with expected benefits. The benefits in this calculation are the Present Value of Future Benefits (PVFB), which is derived from the EAD of the without-project minus the EAD of the with-project. This expected annual benefit value is then taken to PVFB by using the current discount rate of 3.75%, and the project life span of assumed 50-years. The calculation of the PVFB can be seen in Appendix B. This calculation was conducted for both the original EAD analyses and the frequency shifted EAD analyses (Section 4.1.4).

The costs for the benefit-cost ratio are the construction and miscellaneous project expenses required to complete the project, all taken to the total present value. The budget developed for this project was the source of cost estimates for this project and includes public costs (incurred by DWR) and private costs (incurred by Terranova Ranch). This project includes construction of infrastructure for full implementation of Ph2/3, which includes the turnout upgrades and the McMullin Grade crossing. Other costs are strictly based upon Ph1 needs such as the easements and the upgrades on Terranova Ranch. We estimated that upgrades to the turnout would be only half if their capacities were designed only for Ph1 as compared to full implementation of Ph2/3. For full implementation of Ph2/3, we assumed further farm infrastructure upgrades and the purchase of additional easements. Thus, for only Ph1 implementation, we assumed an initial project cost of about $4M and for Ph2/3 $10.5M. This cost used in the ratio is known as the Total Present Value of Discounted Costs (PVDC), which is also calculated using the current discount rate of 3.75%, and the assumed project life-span of 50-years. The calculation of this value can be seen in Appendix B.

4.2 RESULTS

4.2.1 SITE OMISSIONS

In the EAD analyses, we omitted three sites: SJ03 (Fresno Slough West), SJ22 (Orestimba), and SJ34 (French Camp). These sites were omitted because economic predictions were not consistent with hydrologic results. For each of these sites, the UNET modeling (and resulting hydrologic inputs to the FDA model) show water levels decrease as the project moves to Phase 1 and then to Phase 2/3. Decreasing water levels should result in decreasing damages. However, at these three sites, the resulting FDA model produced increasing damages for Phase 1, Phase 2/3, or both as compared to the no project conditions. Thus these sites have been removed from this analysis.

We consider the removal of these three damage areas negligible with regard to our analyses' conclusions. The No Project EAD total for these sites is calculated at $147,700, which is less than 1% of the No Project EAD total for this study area.

4.2.2 FDA EXPECTED ANNUAL DAMAGES (EAD)

4.2.2.1 SUMMARY

Table 4-5 summarizes the Expected Annual Damages (EAD) with values in the thousands of dollars. Phase 1 reduces EAD by nearly $300,000 over no project conditions. Phase 2/3 reduces EAD by nearly $800,000 over no project conditions. Subsequent sections provide additional details.

4.2.2.2 DISTRIBUTION BY CATEGORY

Crop damages make up the largest percentage of damages for each of the phases (Table 4-6). Crop damages are 73% of total damages under each alternative.

Table Table 4-7 through Table 4-9 provide greater details showing the EAD for the various structure categories, crop losses and business losses in each damage area by each alternative. Seven damage areas account for 2/3 the EAD all three alternatives:

- SJ 05 Chowchilla Bypass
- SJ 09 Salt Slough
- SJ 12 Brenda Slough
- SJ 13 Ash Slough
- SJ 15 Turner Island
- SJ 20 Merced River
- SJ 33 Lathrop/Sharpe

Table 4-5. Expected Annual Damage Totals by Project ($1000s)

Alternative	Struc/Cont	Crop	Bus. Loss	Total
No Project	$ 4,806	$ 14,639	$ 735	$ 20,180
Phase 1	$ 4,703	$ 14,453	$ 728	$ 19,884
Phase 2+3	$ 4,556	$ 14,122	$ 715	$ 19,393
Savings Compared to No Project				
Phase 1	$ 103	$ 186	$ 7	$ 296
Phase 2+3	$ 250	$ 516	$ 20	$ 786

* Note: All values in $1,000's

Table 4-6. Percent of EAD under No Project, Ph 1 and Ph 2/3 Scenarios.

Scenario	Total Damages ($1000s)	% of Total						
		Commercial	Industrial	Public	Residential	Crop	Business	Total
No Project	20,180	0.9%	1.4%	2.9%	18.6%	72.5%	3.6%	100.0%
Ph 1	19,884	0.9%	1.4%	2.8%	18.6%	72.7%	3.7%	100.0%
Ph 2/3	19,393	0.9%	1.4%	2.7%	18.6%	72.8%	3.7%	100.0%

Table 4-7. Expected Annual Damages by Damage Area – No Project

Impact Area		No Project EAD ($1000s)						
Area	Name	Commercial	Industrial	Public	Residential	Crop	Business Loss	Total
SJ_01	Fresno	3.35	47.79	3.99	20.45	3.48	7.36	86.42
SJ_02	Fresno Slough East	0.00	0.01	28.00	67.37	429.33	5.36	530.07
SJ_03	Fresno Slough West	-	-	-	-	-	-	-
SJ_04	Mendota	0.00	0.15	0.45	26.37	0.28	0.34	27.59
SJ_05	Chowchilla Bypass	0.00	0.00	0.00	40.78	728.43	0.00	769.21
SJ_06	Lone Willow Slough	0.00	0.00	0.00	16.46	464.90	0.00	481.36
SJ_07	Mendota North	0.00	0.00	0.00	0.73	9.69	0.00	10.42
SJ_08	Firebaugh	2.60	1.11	0.77	21.69	0.11	0.00	26.28
SJ_09	Salt Slough	30.66	33.98	356.51	486.55	2,089.98	83.78	3,081.46
SJ_10	Dos Palos	27.32	1.58	33.50	172.20	17.60	3.70	255.90
SJ_11	Fresno River	0.00	0.00	0.00	4.26	489.18	0.00	493.44
SJ_12	Berenda Slough	2.38	18.12	0.00	249.77	3,431.42	9.59	3,711.28
SJ_13	Ash Slough	0.24	7.11	0.00	17.11	723.38	6.11	753.95
SJ_14	Sandy Mush	0.00	0.00	7.35	2.75	428.66	1.38	440.14
SJ_15	Turner Island	0.00	0.00	0.00	45.96	2,500.31	0.00	2,546.27
SJ_16	Bear Creek	0.24	0.52	3.42	7.51	28.82	1.10	41.61
SJ_17	Deep Slough	0.00	0.00	2.90	3.01	26.56	0.28	32.75
SJ_18	West Bear Creek	0.00	0.00	32.59	0.00	91.41	7.40	131.40
SJ_19	Fremont Ford	0.04	0.57	0.24	2.41	4.38	0.42	8.06
SJ_20	Merced River	0.00	7.31	22.29	112.51	841.39	27.05	1,010.55
SJ_21	Merced River North	0.26	12.79	6.60	66.54	218.13	71.00	375.32
SJ_22	Orestimba	-	-	-	-	-	-	-
SJ_23	Tuolumne South	0.00	0.00	10.73	46.32	238.42	7.84	303.31
SJ_24	Tuolumne River	19.92	0.00	3.38	223.11	18.34	69.75	334.50
SJ_25	Modesto	10.48	109.41	5.23	112.09	1.35	191.93	430.49
SJ_26	3 Amigos	0.17	0.00	3.98	13.92	220.07	5.78	243.92
SJ_27	Stanislaus South	0.00	0.00	9.40	34.70	131.05	7.67	182.82
SJ_28	Stanislaus North	3.15	1.00	24.69	247.96	345.90	33.13	655.83
SJ_29	Banta Carbona	0.10	1.55	1.64	119.35	126.58	1.96	251.18
SJ_30	Paradise Cut	0.85	2.07	1.80	28.68	183.05	1.95	218.40
SJ_31	Stewart Tract	0.00	0.00	0.00	0.15	2.15	0.00	2.30
SJ_32	East Lathrop	12.95	14.53	0.79	6.24	6.82	29.22	70.55
SJ_33	Lathrop/ Sharpe	51.39	14.95	14.95	1,350.86	6.01	117.04	1,555.20
SJ_34	French Camp	-	-	-	-	-	-	-
SJ_35	Moss Tract	8.78	8.55	0.91	118.98	0.36	16.71	154.29
SJ_36	Roberts Island	0.00	0.00	3.13	47.48	643.32	6.06	699.99
SJ_37	Rough and Ready Island	0.00	0.10	0.07	0.00	0.59	0.88	1.64
SJ_38	Drexler Tract	2.18	0.11	0.00	3.59	69.17	14.01	89.06
SJ_39	Union Island	0.00	0.49	0.48	5.97	80.71	4.70	92.35
SJ_40	SE Union Island	0.00	0.00	0.00	4.14	14.66	0.00	18.80
SJ_41	Fabian Tract	0.38	0.00	0.08	2.24	13.82	0.27	16.79
SJ_42	RD 1007	1.61	0.30	0.51	4.43	8.86	0.16	15.87
SJ_43	Grayson	0.42	0.00	0.84	26.64	0.02	1.10	29.02
TOTALS		**179**	**284**	**581**	**3,761**	**14,639**	**735**	**20,180**

Table 4-8. Expected Annual Damages by Damage Area – Phase 1

Impact Area		PH1 EAD ($1000s)						
Area	Name	Commercial	Industrial	Public	Residential	Crop	Business Loss	Total
SJ_01	Fresno	3.35	47.79	3.99	20.45	3.48	7.36	86.42
SJ_02	Fresno Slough East	0.00	0.01	28.00	67.37	429.33	5.36	530.07
SJ_03	Fresno Slough West	-	-	-	-	-	-	-
SJ_04	Mendota	0.00	0.15	0.44	26.00	0.27	0.32	27.18
SJ_05	Chowchilla Bypass	0.00	0.00	0.00	40.78	728.43	0.00	769.21
SJ_06	Lone Willow Slough	0.00	0.00	0.00	16.46	464.90	0.00	481.36
SJ_07	Mendota North	0.00	0.00	0.00	0.71	9.51	0.00	10.22
SJ_08	Firebaugh	2.57	1.10	0.76	20.89	0.11	0.00	25.43
SJ_09	Salt Slough	29.06	32.39	337.89	460.87	1,972.29	79.23	2,911.73
SJ_10	Dos Palos	22.83	1.36	27.51	139.58	16.36	3.45	211.09
SJ_11	Fresno River	0.00	0.00	0.00	4.26	489.18	0.00	493.44
SJ_12	Berenda Slough	2.38	18.12	0.00	249.77	3,431.42	9.59	3,711.28
SJ_13	Ash Slough	0.24	7.06	0.00	16.98	722.16	6.09	752.53
SJ_14	Sandy Mush	0.00	0.00	7.15	2.69	424.98	1.36	436.18
SJ_15	Turner Island	0.00	0.00	0.00	44.90	2,470.58	0.00	2,515.48
SJ_16	Bear Creek	0.24	0.52	3.39	7.48	28.32	1.09	41.04
SJ_17	Deep Slough	0.00	0.00	2.90	3.00	26.52	0.28	32.70
SJ_18	West Bear Creek	0.00	0.00	32.11	0.00	90.30	7.30	129.71
SJ_19	Fremont Ford	0.04	0.56	0.24	2.38	4.29	0.41	7.92
SJ_20	Merced River	0.00	7.31	22.29	112.51	841.39	27.05	1,010.55
SJ_21	Merced River North	0.26	12.55	6.46	65.56	215.52	70.18	370.53
SJ_22	Orestimba	-	-	-	-	-	-	-
SJ_23	Tuolumne South	0.00	0.00	10.58	45.77	236.02	7.76	300.13
SJ_24	Tuolumne River	19.90	0.00	3.38	222.95	18.33	69.71	334.27
SJ_25	Modesto	10.48	109.41	5.23	112.09	1.35	191.93	430.49
SJ_26	3 Amigos	0.17	0.00	3.96	13.86	218.56	5.75	242.30
SJ_27	Stanislaus South	0.00	0.00	9.37	34.62	130.70	7.66	182.35
SJ_28	Stanislaus North	3.15	0.99	24.55	247.34	343.61	32.95	652.59
SJ_29	Banta Carbona	0.10	1.55	1.64	119.29	125.83	1.96	250.37
SJ_30	Paradise Cut	0.87	1.95	1.81	28.40	175.77	1.86	210.66
SJ_31	Stewart Tract	0.00	0.00	0.00	0.15	2.14	0.00	2.29
SJ_32	East Lathrop	12.94	14.52	0.78	6.24	6.80	29.18	70.46
SJ_33	Lathrop/ Sharpe	51.24	14.90	14.91	1,346.66	5.99	116.80	1,550.50
SJ_34	French Camp	-	-	-	-	-	-	-
SJ_35	Moss Tract	8.76	8.53	0.91	118.87	0.36	16.70	154.13
SJ_36	Roberts Island	0.00	0.00	3.12	47.46	643.30	6.06	699.94
SJ_37	Rough and Ready Island	0.00	0.10	0.07	0.00	0.59	0.88	1.64
SJ_38	Drexler Tract	2.14	0.11	0.00	3.53	69.03	13.98	88.79
SJ_39	Union Island	0.00	0.44	0.46	5.52	76.40	4.69	87.51
SJ_40	SE Union Island	0.00	0.00	0.00	3.99	5.89	0.00	9.88
SJ_41	Fabian Tract	0.38	0.00	0.08	2.23	13.80	0.27	16.76
SJ_42	RD 1007	1.60	0.30	0.51	4.42	8.84	0.16	15.83
SJ_43	Grayson	0.42	0.00	0.84	26.62	0.02	1.10	29.00
TOTALS		**173**	**282**	**555**	**3,693**	**14,453**	**728**	**19,884**

Table 4-9. Expected Annual Damages by Damage Area – Phase 2/3

Impact Area		PH2+3 ($1000s)						
Area	Name	Commercial	Industrial	Public	Residential	Crop	Business Loss	Total
SJ_01	Fresno	3.35	47.79	3.99	20.45	3.48	7.36	86.42
SJ_02	Fresno Slough East	0.00	0.01	28.00	67.37	429.33	5.36	530.07
SJ_03	Fresno Slough West	-	-	-	-	-	-	-
SJ_04	Mendota	0.00	0.15	0.42	24.59	0.24	0.29	25.69
SJ_05	Chowchilla Bypass	0.00	0.00	0.00	40.78	728.43	0.00	769.21
SJ_06	Lone Willow Slough	0.00	0.00	0.00	16.37	464.03	0.00	480.40
SJ_07	Mendota North	0.00	0.00	0.00	0.71	9.29	0.00	10.00
SJ_08	Firebaugh	2.53	1.07	0.73	19.09	0.09	0.00	23.51
SJ_09	Salt Slough	25.50	28.76	300.63	406.00	1,703.65	68.76	2,533.30
SJ_10	Dos Palos	21.94	1.34	25.87	131.04	14.13	3.00	197.32
SJ_11	Fresno River	0.00	0.00	0.00	4.24	489.16	0.00	493.40
SJ_12	Berenda Slough	2.19	16.63	0.00	227.88	3,428.90	9.58	3,685.18
SJ_13	Ash Slough	0.23	6.97	0.00	16.77	720.63	6.05	750.65
SJ_14	Sandy Mush	0.00	0.00	6.71	2.56	421.32	1.35	431.94
SJ_15	Turner Island	0.00	0.00	0.00	43.73	2,441.01	0.00	2,484.74
SJ_16	Bear Creek	0.24	0.52	3.37	7.46	28.30	1.08	40.97
SJ_17	Deep Slough	0.00	0.00	2.89	2.99	26.37	0.28	32.53
SJ_18	West Bear Creek	0.00	0.00	31.30	0.00	87.59	7.10	125.99
SJ_19	Fremont Ford	0.04	0.55	0.23	2.33	4.21	0.40	7.76
SJ_20	Merced River	0.00	7.31	22.27	112.46	841.30	27.04	1,010.38
SJ_21	Merced River North	0.25	12.25	6.29	64.34	212.41	69.08	364.62
SJ_22	Orestimba	-	-	-	-	-	-	-
SJ_23	Tuolumne South	0.00	0.00	10.26	44.46	230.82	7.59	293.13
SJ_24	Tuolumne River	19.88	0.00	3.37	222.55	18.33	69.68	333.81
SJ_25	Modesto	10.48	109.41	5.23	112.09	1.35	191.93	430.49
SJ_26	3 Amigos	0.17	0.00	3.92	13.78	216.32	5.70	239.89
SJ_27	Stanislaus South	0.00	0.00	9.31	34.38	129.59	7.60	180.88
SJ_28	Stanislaus North	3.15	0.99	24.40	246.73	341.11	32.74	649.12
SJ_29	Banta Carbona	0.10	1.54	1.63	119.00	124.73	1.95	248.95
SJ_30	Paradise Cut	0.87	1.94	1.80	28.31	175.07	1.85	209.84
SJ_31	Stewart Tract	0.00	0.00	0.00	0.15	2.13	0.00	2.28
SJ_32	East Lathrop	12.89	14.47	0.78	6.23	6.77	29.07	70.21
SJ_33	Lathrop/ Sharpe	51.16	14.96	14.93	1,346.56	5.97	116.39	1,549.97
SJ_34	French Camp	-	-	-	-	-	-	-
SJ_35	Moss Tract	8.71	8.49	0.90	117.98	0.36	16.59	153.03
SJ_36	Roberts Island	0.00	0.00	3.12	47.92	642.09	6.03	699.16
SJ_37	Rough and Ready Island	0.00	0.10	0.07	0.00	0.59	0.88	1.64
SJ_38	Drexler Tract	2.14	0.10	0.00	3.52	68.70	13.92	88.38
SJ_39	Union Island	0.00	0.44	0.46	5.51	76.28	4.68	87.37
SJ_40	SE Union Island	0.00	0.00	0.00	3.98	5.84	0.00	9.82
SJ_41	Fabian Tract	0.38	0.00	0.08	2.23	13.75	0.27	16.71
SJ_42	RD 1007	1.60	0.30	0.51	4.38	8.70	0.15	15.64
SJ_43	Grayson	0.42	0.00	0.84	26.61	0.02	1.10	28.99
TOTALS		**168**	**276**	**514**	**3,598**	**14,122**	**715**	**19,393**

4.2.3 FDA FLOOD EVENT DAMAGES

FDA provides output files showing individual structure (structure and content) damages for the different flood events. The results below show the impact of different flood events on damages and are compared against historical records as validation of the methods used in this document.

4.2.3.1 FDA STRUCTURAL FLOOD EVENT DAMAGES

Structural damages (structure and structural content for commercial, industrial, public, residential) account for just under 25% of EAD (Table 4-6). Table 4-10 includes the individual structural and structural content damages by flood event estimated by FDA for each of the project phases; Table 4-11 shows the percent change as the phases are implemented.

When implementing Phase 2/3, there is almost a 19% savings in structural flood damages, equating to approximately $7.5 million in total damages, for the 0.1 (10-yr) flood event (Table 4-10, Table 4-11). For the larger flood events, total savings from flood damages decrease and the percent savings are all less than 1% for the fully implemented project (Table 4-11). This may be because for the larger flood events, the total amount of water moving through the flood plain greatly exceeds the amount the project will be able to remove, decreasing the projects impact with regard to decreasing structural damages.

Table 4-12 through Table 4-14 show the estimated structural damages for each reach and each phase under the different storm events (i.e. 2, 5, 7, 10, 50, 100, 200 and 500-year flood event). Since crop damages and business losses are not included in the total event damage tables, some of the significant sites have changed. The largest structure and content damages appear to come from damage areas SJ33 (Lathrop/Sharpe), SJ25 (Modesto), SJ35 (Moss Tract), SJ01 (Fresno), and SJ09 (Salt Slough).

Table 4-10. Total Structural and Structural Content Flood Event Damages. Values are in 1000s.

Alternative	0.5	0.2	0.15	0.1	0.02	0.01	0.005	0.002
No Project	$ -	$ -	$ -	$ 41,533	$ 659,544	$ 753,156	$ 906,464	$ 1,074,029
Phase 1	$ -	$ -	$ -	$ 36,087	$ 658,704	$ 752,532	$ 906,326	$ 1,073,367
Phase 2/3	$ -	$ -	$ -	$ 33,988	$ 656,718	$ 751,458	$ 905,786	$ 1,073,076
Total Savings over No Project								
Phase 1	-	-	-	$ 5,445	$ 840	$ 623	$ 138	$ 662
Phase 2/3	-	-	-	$ 7,545	$ 2,826	$ 1,698	$ 678	$ 953

Table 4-11. Percent Structural and Structural Content Flood Event Damages

Alternative	0.5	0.2	0.15	0.1	0.02	0.01	0.005	0.002
No Project	-	-	-	-	-	-	-	-
Phase 1	-	-	-	13.11%	0.13%	0.08%	0.02%	0.06%
Phase 2/3	-	-	-	5.82%	0.30%	0.14%	0.06%	0.03%
Total Savings	*-*	*-*	*-*	*18.93%*	*0.43%*	*0.23%*	*0.07%*	*0.09%*
Phase 1 (% of Total)	-	-	-	69.27%	29.70%	36.69%	20.33%	69.42%
Phase 2/3 (% of Total)	-	-	-	30.73%	70.30%	63.31%	79.67%	30.58%

Table 4-12. Total Structural Flood Event Damages by Damage Area – No Project ($1000s)

Impact Area		NPRJ - FLOOD EVENT DAMAGES							
Area	Name	0.5	0.2	0.15	0.1	0.02	0.01	0.005	0.002
SJ_01	Fresno	0	0	0	3,391	52,091	62,964	72,225	77,062
SJ_02	Fresno Slough East	0	0	0	310	4,030	6,234	6,437	6,550
SJ_03	Fresno Slough West	-	-	-	-	-	-	-	-
SJ_04	Mendota	0	0	0	403	444	527	1,220	1,400
SJ_05	Chowchilla Bypass	0	0	0	366	406	596	841	1,211
SJ_06	Lone Willow Slough	0	0	0	9	926	933	938	950
SJ_07	Mendota North	0	0	0	0	79	97	117	126
SJ_08	Firebaugh	0	0	0	1,720	13,503	14,399	14,411	14,415
SJ_09	Salt Slough	0	0	0	7,454	35,612	36,866	36,928	36,929
SJ_10	Dos Palos	0	0	0	4,454	7,453	7,811	7,824	7,824
SJ_11	Fresno River	0	0	0	0	64	64	64	191
SJ_12	Berenda Slough	0	0	0	2,060	2,096	2,096	2,116	2,272
SJ_13	Ash Slough	0	0	0	830	1,021	1,022	1,055	1,851
SJ_14	Sandy Mush	0	0	0	73	89	92	105	217
SJ_15	Turner Island	0	0	0	708	716	716	716	718
SJ_16	Bear Creek	0	0	0	0	0	378	539	858
SJ_17	Deep Slough	0	0	0	251	288	387	401	403
SJ_18	West Bear Creek	0	0	0	636	946	982	982	984
SJ_19	Fremont Ford	0	0	0	75	606	1,252	1,829	2,434
SJ_20	Merced River	0	0	0	742	2,384	3,580	4,631	6,330
SJ_21	Merced River North	0	0	0	4,567	6,778	8,380	9,134	10,575
SJ_22	Orestimba	-	-	-	-	-	-	-	-
SJ_23	Tuolumne South	0	0	0	932	1,249	1,397	1,780	2,426
SJ_24	Tuolumne River	0	0	0	2,323	4,307	5,374	11,220	19,610
SJ_25	Modesto	0	0	0	4,696	21,969	55,032	123,823	247,729
SJ_26	3 Amigos	0	0	0	275	375	523	972	1,676
SJ_27	Stanislaus South	0	0	0	655	1,307	1,646	1,957	2,864
SJ_28	Stanislaus North	0	0	0	3,403	5,601	6,122	8,133	10,705
SJ_29	Banta Carbona	0	0	0	71	92	99	20,220	20,355
SJ_30	Paradise Cut	0	0	0	254	1,031	1,338	1,620	1,803
SJ_31	Stewart Tract	0	0	0	0	0	0	146	162
SJ_32	East Lathrop	0	0	0	58	2,446	5,703	6,863	7,248
SJ_33	Lathrop/ Sharpe	0	0	0	271	450,645	454,751	460,078	467,629
SJ_34	French Camp	-	-	-	-	-	-	-	-
SJ_35	Moss Tract	0	0	0	200	38,859	68,306	90,942	90,968
SJ_36	Roberts Island	0	0	0	0	0	0	7,453	8,760
SJ_37	Rough and Ready Island	0	0	0	251	263	266	266	266
SJ_38	Drexler Tract	0	0	0	0	0	0	2,574	2,795
SJ_39	Union Island	0	0	0	0	0	0	0	1,608
SJ_40	SE Union Island	0	0	0	0	0	0	530	736
SJ_41	Fabian Tract	0	0	0	0	196	276	369	1,439
SJ_42	RD 1007	0	0	0	0	1,490	2,724	3,691	4,082
SJ_43	Grayson	0	0	0	94	182	223	1,312	7,870
	TOTALS	***0***	***0***	***0***	***41,533***	***659,544***	***753,156***	***906,464***	***1,074,029***

Table 4-13. Total Structural Flood Event Damages by Damage Area – Phase 1 ($1000s)

Impact Area		PH1 - FLOOD EVENT DAMAGES							
Area	Name	0.5	0.2	0.15	0.1	0.02	0.01	0.005	0.002
SJ_01	Fresno	0	0	0	3,391	52,091	62,964	72,225	77,062
SJ_02	Fresno Slough East	0	0	0	310	4,030	6,234	6,437	6,550
SJ_03	Fresno Slough West	-	-	-	-	-	-	-	-
SJ_04	Mendota	0	0	0	54	443	484	1,202	1,398
SJ_05	Chowchilla Bypass	0	0	0	366	406	596	841	1,211
SJ_06	Lone Willow Slough	0	0	0	9	926	933	938	950
SJ_07	Mendota North	0	0	0	0	77	97	117	125
SJ_08	Firebaugh	0	0	0	1,417	13,415	14,362	14,394	14,399
SJ_09	Salt Slough	0	0	0	7,271	35,163	36,677	36,859	36,887
SJ_10	Dos Palos	0	0	0	0	7,364	7,745	7,811	7,811
SJ_11	Fresno River	0	0	0	0	64	64	64	191
SJ_12	Berenda Slough	0	0	0	2,060	2,096	2,096	2,116	2,272
SJ_13	Ash Slough	0	0	0	830	1,021	1,021	1,055	1,851
SJ_14	Sandy Mush	0	0	0	71	84	89	105	214
SJ_15	Turner Island	0	0	0	708	715	716	716	717
SJ_16	Bear Creek	0	0	0	0	0	378	539	857
SJ_17	Deep Slough	0	0	0	251	288	387	401	403
SJ_18	West Bear Creek	0	0	0	636	944	980	982	982
SJ_19	Fremont Ford	0	0	0	73	588	1,249	1,829	2,437
SJ_20	Merced River	0	0	0	742	2,384	3,580	4,631	6,330
SJ_21	Merced River North	0	0	0	4,462	6,749	8,367	9,133	10,564
SJ_22	Orestimba	-	-	-	-	-	-	-	-
SJ_23	Tuolumne South	0	0	0	924	1,247	1,396	1,780	2,423
SJ_24	Tuolumne River	0	0	0	2,310	4,307	5,374	11,218	19,574
SJ_25	Modesto	0	0	0	4,696	21,969	55,032	123,823	247,729
SJ_26	3 Amigos	0	0	0	274	375	522	971	1,675
SJ_27	Stanislaus South	0	0	0	652	1,306	1,644	1,957	2,863
SJ_28	Stanislaus North	0	0	0	3,389	5,599	6,121	8,132	10,703
SJ_29	Banta Carbona	0	0	0	71	92	99	20,220	20,355
SJ_30	Paradise Cut	0	0	0	251	1,030	1,337	1,620	1,801
SJ_31	Stewart Tract	0	0	0	0	0	0	146	162
SJ_32	East Lathrop	0	0	0	58	2,416	5,685	6,863	7,248
SJ_33	Lathrop/ Sharpe	0	0	0	271	450,640	454,644	460,078	467,415
SJ_34	French Camp	-	-	-	-	-	-	-	-
SJ_35	Moss Tract	0	0	0	198	38,751	68,180	90,932	90,666
SJ_36	Roberts Island	0	0	0	0	0	0	7,453	8,760
SJ_37	Rough and Ready Island	0	0	0	251	263	266	266	266
SJ_38	Drexler Tract	0	0	0	0	0	0	2,574	2,795
SJ_39	Union Island	0	0	0	0	0	0	0	1,608
SJ_40	SE Union Island	0	0	0	0	0	0	530	736
SJ_41	Fabian Tract	0	0	0	0	196	276	368	1,437
SJ_42	RD 1007	0	0	0	0	1,486	2,714	3,686	4,079
SJ_43	Grayson	0	0	0	94	182	223	1,312	7,862
TOTALS		***0***	***0***	***0***	***36,087***	***658,704***	***752,532***	***906,326***	***1,073,367***

Table 4-14. Total Structural Flood Event Damages by Damage Area – Phase 2/3 ($1000s)

Impact Area		PH2+3 - FLOOD EVENT DAMAGES							
Area	**Name**	**0.5**	**0.2**	**0.15**	**0.1**	**0.02**	**0.01**	**0.005**	**0.002**
SJ_01	Fresno	0	0	0	3,391	52,091	62,964	72,225	77,062
SJ_02	Fresno Slough East	0	0	0	310	4,030	6,234	6,437	6,550
SJ_03	Fresno Slough West	-	-	-	-	-	-	-	-
SJ_04	Mendota	0	0	0	53	424	484	1,186	1,382
SJ_05	Chowchilla Bypass	0	0	0	366	406	596	841	1,211
SJ_06	Lone Willow Slough	0	0	0	9	926	933	938	938
SJ_07	Mendota North	0	0	0	0	71	95	115	125
SJ_08	Firebaugh	0	0	0	36	13,183	14,265	14,362	14,394
SJ_09	Salt Slough	0	0	0	6,745	34,054	36,203	36,689	36,842
SJ_10	Dos Palos	0	0	0	0	7,128	7,662	7,751	7,811
SJ_11	Fresno River	0	0	0	0	64	64	64	191
SJ_12	Berenda Slough	0	0	0	2,060	2,096	2,096	2,116	2,260
SJ_13	Ash Slough	0	0	0	830	1,020	1,019	1,055	1,769
SJ_14	Sandy Mush	0	0	0	68	71	86	104	208
SJ_15	Turner Island	0	0	0	707	712	715	716	714
SJ_16	Bear Creek	0	0	0	0	0	378	539	840
SJ_17	Deep Slough	0	0	0	251	287	386	401	401
SJ_18	West Bear Creek	0	0	0	636	936	980	982	978
SJ_19	Fremont Ford	0	0	0	73	580	1,242	1,828	2,425
SJ_20	Merced River	0	0	0	742	2,384	3,580	4,631	6,287
SJ_21	Merced River North	0	0	0	4,353	6,661	8,356	9,129	10,562
SJ_22	Orestimba	-	-	-	-	-	-	-	-
SJ_23	Tuolumne South	0	0	0	915	1,239	1,394	1,777	2,423
SJ_24	Tuolumne River	0	0	0	2,267	4,306	5,374	11,211	19,570
SJ_25	Modesto	0	0	0	4,696	21,969	55,032	123,823	247,729
SJ_26	3 Amigos	0	0	0	274	374	521	971	1,674
SJ_27	Stanislaus South	0	0	0	648	1,303	1,640	1,957	2,863
SJ_28	Stanislaus North	0	0	0	3,370	5,595	6,114	8,130	10,703
SJ_29	Banta Carbona	0	0	0	71	92	99	20,219	20,354
SJ_30	Paradise Cut	0	0	0	249	1,027	1,331	1,620	1,801
SJ_31	Stewart Tract	0	0	0	0	0	0	146	162
SJ_32	East Lathrop	0	0	0	58	2,380	5,658	6,863	7,248
SJ_33	Lathrop/ Sharpe	0	0	0	271	450,633	454,603	460,078	467,405
SJ_34	French Camp	-	-	-	-	-	-	-	-
SJ_35	Moss Tract	0	0	0	198	38,563	67,900	90,692	90,653
SJ_36	Roberts Island	0	0	0	0	0	0	7,453	8,760
SJ_37	Rough and Ready Island	0	0	0	251	263	266	266	266
SJ_38	Drexler Tract	0	0	0	0	0	0	2,574	2,795
SJ_39	Union Island	0	0	0	0	0	0	0	1,608
SJ_40	SE Union Island	0	0	0	0	0	0	530	736
SJ_41	Fabian Tract	0	0	0	0	196	275	368	1,437
SJ_42	RD 1007	0	0	0	0	1,472	2,690	3,686	4,077
SJ_43	Grayson	0	0	0	93	182	223	1,312	7,861
TOTALS		***0***	***0***	***0***	***33,988***	***656,718***	***751,458***	***905,786***	***1,073,076***

4.2.3.2 FLOOD EVENT DAMAGES TO STRUCTURES, BUSINESS AND CROPS

Table 4-15 and Figure 4-4 provide context regarding structural damages versus crop damages for the different flood events. As discussed earlier, FDA does not present crop and business losses by storm event. We provide a baseline no project analysis through using results from this study and crop and business losses are from the CVFPP (2012). Crop damages comprise about 73% of total EAD (Table 4-6). Using this analysis, we find that crop damages are greatest for the 10-year frequency storm account for over 75% of total damages. For the larger less frequent storm events, crop losses drop to the range of 20 – 30% of predicted total damages for the different flood events and structural losses are about 60% of total damages.

Table 4-15. Total crop and business damages for different size flood frequency events under no project conditions (from CVFPP, 2012)

Category	No Project Flood Event Damages 0.1	0.02	0.01	0.005	0.002	Source
Total						
Crop	$166,101	$280,913	$332,441	$400,690	$431,386	CCVFP
Business	$7,455	$75,323	$121,627	$190,611	$391,656	CCVFP
Structural	$41,533	$659,544	$753,156	$906,464	$1,074,029	FDA Model
Total	$215,089	$1,015,780	$1,207,224	$1,497,765	$1,897,071	
% of Total						
Crop	77%	28%	28%	27%	23%	CCVFP
Business	3%	7%	10%	13%	21%	CCVFP
Structural	19%	65%	62%	61%	57%	FDA Model

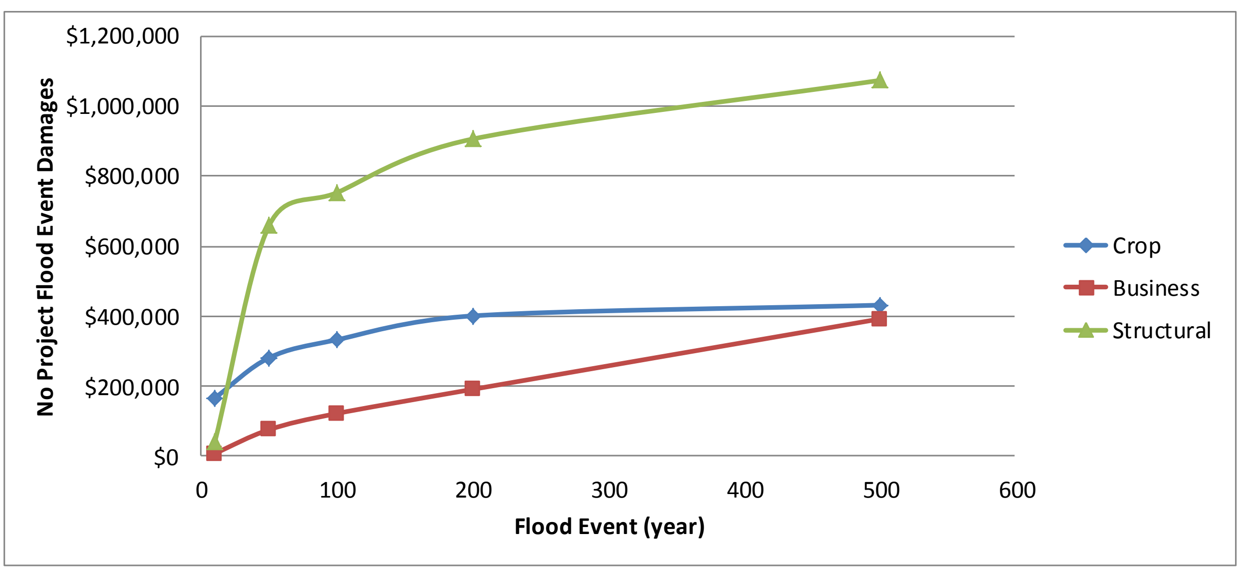

Figure 4-4. Calculated No Project Damages for Different Flood Events.

4.2.4 COMPARISON TO HISTORICAL RECORDS

Several previous flood events have occurred in the study area. Four historic events were analyzed: 1983, 1986, 1995, and 1995. These events when adjusted for inflation caused over $1B in damages along the San Joaquin River System (USACE, 1999) (Table 4-15). These four events occurred within 14 years of each other. This data suggest these storms are 5-year to 50-year events. Table 4-17 provides information from the USACE (1999) on estimated flood frequency for these storm events for areas along the San Joaquin River and Kings and Kaweah Rivers at their respective dams. These storm frequency estimates vary through the system depending upon the reach (USACE 1999). The USACE describes these events as in the range of 5-year to 40-year events. These predictions are in line with our frequency estimate for the 1983 flood event using Weibull plotting positions (Figure 2-9).

Based upon USACE (1999) estimated frequencies, we predicted damages for these storm events using FDA (Table 4-17). Overall, the damage predictions are in line with the historic data. From the FDA model, the 1983 would appear to be greater than a 30-year event and the 1995 and 1997 storms to be 10 – 20 year events. Only the 1986 historical damage estimates are below the range predicted by the FDA model. All other storm events show the historical damage estimates above the low prediction by FDA, which is based upon the higher frequency (smaller) storm exceedance by the USACE (1999) and generally within the range predicted. Thus, this methodology has provided a reasonable estimate of predicted storm damages, estimating the four storms causing significant flood damages over a fourteen year period to generally be in the range of 5- to 30- year storm events.

Table 4-16. Estimated exceedance interval of historical floods for the San Joaquin Rivers and Adjacent Rivers in the Study Area (USACE 1999)

Location		Historical Floods (Exceedence Interval, years			
		Feb / Mar 83	Feb-86	Mar-95	Dec 96 / Jan 97
San Joaquin River Basin					
	San Joaquin River below Friant Dam and at Gravelly Ford	18-19	10-20	25-50	10-25
	Fresno River below Hidden Dam	20	10-20	15-30	15-30
	Chowchilla River below Buchanan Dam Ash Slough below Chowchilla River Berenda Slough below Chowchilla River	21-23	10-20	15-30	10-20
	Eastside Bypass near El Nido	24	10-20	5-10	5-10
	Merced River at New Exchequer Dam and at Cressy	25-26	10-20	20-40	10-20
	San Joaquin River at Newman	27	25-50	10-20	5-10
	Tuolumne River at Don Pedro Dam and at Modesto	28-29	15-25	30-40	5-15
	San Joaquin River at Maze Road Bridge	30	15-25	10-20	5-10
	Stanislaus River at New Melones Dam and at Orange Blossom Bridge	31-32	5-10	30-50	10-15
	San Joaquin River at Vernalis	33	30-50	15-25	5-10
Kings River at Pine Flat Dam[1]		5-10	20-40	10-20	40-60
Kaweah River at Terminus Dam[1]		5-10	10-20	5-10	15-25

Table 4-17. Comparing Historical Flood Damage Records with FDA outputs

Flood	Estimated Flood Freq [1]	$M; Historical Flood Damage Record		$M; FDA Total Predicted Damages [2]	
		historic	2013 adjusted [3]	Min	Max
1983	5 - 30	$324	$761	$108	$616
1986	10 - 20	$15	$32	$215	$415
1995	5 - 40	$193	$295	$108	$816
1997	5 - 25	$223	$326	$108	$508

Notes

1. US Bureau Reclamation 2005
2. Damage for min and max flood frequencies linearly interpolated from FDA freq - damage relationships.
3. Adjusted for inflation.

4.2.5 eEAD using DWR Tools

Because FDA does not break down EAD by storm events, we utilized more simple DWR grant table tools as discussed in the Methods (Table 4-4). The seven most heavily damaged sites (see Section 5.1 Methods) in terms of EAD were analyzed with the DWR grant tools to estimate the impact of individual storm events on EAD. These sites account for two thirds the EAD of the project. Table 4-18 through Table 4-20 provide total eEAD values for no project and with project (i.e. Phase 1, Phase 2/3) conditions. The summation of the event totals at the bottom of these three tables provides the total eEAD for each phase for these seven damage areas. For example, the eEAD for the no project phase has been estimated to be $10,942 million (Table 4-18). These three tables also show the percent that each event makes up of the total eEAD.

The 50- and 100-year events (0.02 and 0.01 respectively) make up nearly 70% of the eEAD. These results are consistent with Table 4-12 through Table 4-14. Those tables show that with and without the project, the 50- and 100-year storm events have similar structural flood event damage totals, and those totals are 15X greater than for the 10-year storm event. Thus, two factors result in the 50- and 100-year storm events making up nearly 70% of the eEAD: 1) these events have much higher damage than smaller events; and 2) these events have relatively high frequencies when compared to the larger events.

Table 4-10 and Table 4-11 show the greatest structural savings (both as total and as percent of EAD) are associated with the 10-year storm event as discussed earlier. The fully implemented project saves $7.5M for the 10-year flood event, $2.8M for the 50-year flood event, and $1.7M for the 100-year flood event in structural damages. For the higher events, structural savings continue to drop. Structural damages make up about 25% of the total EAD (Table 4-6).

Combining the results above suggests that for the 50- and 100-year flood events as compared to the 10-year storm event, savings associated with crop losses are greater while savings associated with structures are lower. For flood events greater than the 100-year storm, all savings drop as the ability of the project to affect floods is minor in comparison to the events magnitude.

Table 4-18. Estimated EAD by Flood Event Without Project.
All values are in $1000s.

Reach	No.	WITHOUT PROJECT - Estimated EAD by Event					
		0.10	0.02	0.01	0.005	0.002	*Totals*
Berenda Slough	SJ 12	$ 589	$ 1,885	$ 236	$ 123	$ 79	***$ 2,911***
Salt Slough	SJ 09	$ -	$ 1,211	$ 764	$ 613	$ 368	***$ 2,955***
Turner Island	SJ 15	$ 286	$ 1,069	$ 153	$ 76	$ 46	***$ 1,630***
Lathrop/ Sharpe	SJ 33	$ -	$ 973	$ 367	$ 297	$ 248	***$ 1,885***
Merced River	SJ 20	$ 65	$ 370	$ 82	$ 61	$ 47	***$ 626***
Chowchilla Bypass	SJ 05	$ 9	$ 32	$ 193	$ 246	$ 182	***$ 661***
Ash Slough	SJ 13	$ 47	$ 163	$ 22	$ 12	$ 31	***$ 274***
Totals		***$ 995***	***$ 5,702***	***$ 1,816***	***$ 1,428***	***$ 1,000***	***$ 10,942***
% of Total		***9.10%***	***52.11%***	***16.60%***	***13.05%***	***9.14%***	

Table 4-19. Estimated EAD by Flood Event for Phase 1 Project.
All values are in $1000s.

Reach	No.	PHASE 1 - Estimated EAD by Event					
		0.10	0.02	0.01	0.005	0.002	*Totals*
Berenda Slough	SJ 12	$ 589	$ 1,885	$ 236	$ 123	$ 79	***$ 2,911***
Salt Slough	SJ 09	$ -	$ 1,206	$ 762	$ 612	$ 368	***$ 2,948***
Turner Island	SJ 15	$ 286	$ 1,069	$ 153	$ 76	$ 46	***$ 1,630***
Lathrop/ Sharpe	SJ 33	$ -	$ 973	$ 367	$ 296	$ 248	***$ 1,885***
Merced River	SJ 20	$ 65	$ 370	$ 82	$ 61	$ 47	***$ 626***
Chowchilla Bypass	SJ 05	$ 9	$ 32	$ 193	$ 246	$ 182	***$ 661***
Ash Slough	SJ 13	$ 47	$ 163	$ 22	$ 12	$ 31	***$ 274***
Totals		***$ 995***	***$ 5,697***	***$ 1,815***	***$ 1,427***	***$ 1,000***	***$ 10,935***
% of Total		***9.10%***	***52.07%***	***16.58%***	***13.05%***	***9.14%***	

Table 4-20. Estimated EAD by Flood Event for Phase 2/3 Project.
All values are in $1000s.

Reach	No.	PHASE 2/3 - Estimated EAD by Event					
		0.10	0.02	0.01	0.005	0.002	*Totals*
Berenda Slough	SJ 12	$ 589	$ 1,885	$ 236	$ 123	$ 78	***$ 2,911***
Salt Slough	SJ 09	$ -	$ 1,195	$ 759	$ 611	$ 367	***$ 2,932***
Turner Island	SJ 15	$ 286	$ 1,069	$ 153	$ 76	$ 46	***$ 1,630***
Lathrop/ Sharpe	SJ 33	$ -	$ 973	$ 367	$ 296	$ 248	***$ 1,885***
Merced River	SJ 20	$ 65	$ 370	$ 82	$ 61	$ 47	***$ 626***
Chowchilla Bypass	SJ 05	$ 9	$ 32	$ 193	$ 246	$ 182	***$ 661***
Ash Slough	SJ 13	$ 47	$ 163	$ 22	$ 12	$ 31	***$ 274***
Totals		***$ 995***	***$ 5,686***	***$ 1,811***	***$ 1,426***	***$ 1,000***	***$ 10,917***
% of Total		***9.10%***	***51.96%***	***16.55%***	***13.03%***	***9.14%***	

4.2.6 BENEFIT COST ANALYSIS

Table 4-21 shows the B/C ratio generated for this project using assumptions inherent with UNET and FDA and based upon the input files developed for this project. The B/C for Ph1 is 1.86 and for Ph2/3 is 1.98.

Table 4-21. Benefit Cost Analysis of Both Phases under Original and Frequency Shifted Sensitivity Analyses

Phase	Expected Annual Benefits	Present Value of Future Benefits	Present Value of Discounted Costs	Benefit-Cost Ratio
Phase 1	$295,830	$6,636,796	$3,577,384	1.86
Phase 2/3	$490,570	$17,642,485	$8,900,732	1.98

Note: Present value numbers assume 3.75% discount rate and 50-year project life.

4.3 ECONOMIC DISCUSSION SUMMARY

Expected annual damages (EAD) through the study area are estimated at $20M. 73% of those damages are associated with crop losses, with most the remainder (24%) associated with structures, mostly residential (19%), and their contents (Table 4-6). Implementation of the project will reduce EAD by about $300,000 annually for Phase 1 and about $800,000 for Phase 2/3 (Table 4-5).

Historic storm events in 1983, 1986, 1995 and 1997 have resulted in an estimated $1.4B (Table 4-17; 2013 $) in damages along the San Joaquin River (USBR 2005). These storm events are in the range of 5 – 40 year events (Table 4-16; USBR 2005). The FDA model predicted total damage for these four storm events to be between $0.5 – 2.3B (Table 4-17).

In predicting damages to the areas, the FDA model and DWR tools identify the 50- and 100-year storm events as the most damaging (Table 4-12 through Table 4-14; Table 4-18 through Table 4-20). Two reasons underlay this finding. First, total predicted structural damages from a 50-year storm event are over an order of magnitude greater than for a 10-year storm event, but about 80% of a 100-year storm event and 60% of a 500-year storm event (Table 4-10). Second, the 50- and 100-year storm events are relatively frequent compared to the larger storm events. Based upon DWR tools, we estimate the 50- and 100-year storm events contribute to nearly 70% of EAD totals. For those reasons, most EAD are associated with 50- and 100-year storm events (Table 4-20).

Structural damages are the reason for the large increase in damages associated with a 50-year storm event as opposed to a 10-year storm event. Over 75% of total damages for a 10-year storm event are associated with crop damages (Table 4-15). We predicted crop losses of $166,000 for a 10-year storm event. With a 50-year storm event, crop losses increase by 75% from $166,000 to $281,000 (Table 4-15). Increasingly large storm events continue to increase crop losses but those losses are generally linear with the increase in storm events (Figure 4-3). Losses to structures are relatively minor for the 10-year storm event, comprising about 20% of total damages (Table 4-15). However, the 50-year storm event results in losses that are 15X greater, comprising 65% of total damages (Table 4-15). This jump in structure losses between the 10- and 50-year storm events causes total damages to jump 5X between a 10- and 50-year storm event.

The implementation of Phase 1 and Phase 2/3 will reduce costs associated with flood damages. Greatest structural savings are associated with the 10-, 50- and 100-year storm events (Table 4-10). Greatest total EAD savings are expected to occur for the 50- and 100-year storm events as it is for those storm events EAD is greatest under no project and with project conditions (Table 4-18 through Table 4-20). The project will result in a EAD savings of about $300,000 annually for Phase 1 and about $800,000 for Phase 2/3 as discussed earlier (Table 4-5). Benefit costs (B/C) analyses for this project are 1.86 for Phase 1 and 1.98 for Phase 2/3.

5 CONCLUSIONS

Under Phase 1 (Ph 1) and Phase 2 and 3 (Ph 2/3), the studied project will have the capacity to divert 150 and 500 cfs flows from the the Kings River upstream of the James Bypass during flood flow conditions. Flood flows can occur from December into July in the James Bypass, governed by reservoir (Pine Flat Reservoir) and river management to minimize flood risks along the San Joaquin and Kings Rivers. Diverted water will be captured on agricultural lands using a mosaic of flood easement, dual purpose farm / flood lands and farm lands. Ph 1 and Ph 2/3 are not expected to affect flood operations of Kings River structures. In the Kings River North, the limiting flow capacity of 4,750 cfs applies to the entire reach between the Crescent Weir to the beginning of the James Bypass and 4750 cfs is also the assumed capacity through the James Bypass Channel. Any diversions that would occur from the James Bypass as part of the proposed project would, therefore, not result in changes to the operating criteria in the Kings River System. In the San Joaquin River, flood flow control to the Chowchilla Bypass and Reach 2B of the San Joaquin River are controlled by the CBBS. The operating criteria at this structure, as historically practiced, depend on the discharge from the James Bypass via Fresno Slough. Our review of CDEC data indicate the CBBS is generally operated consistent with its operating criteria and that some variance occurs because of local irrigation demands and the goal to minimize flood damage through the flood-control project and protected area. The effect of this project on the CBBS operation is not readily known. For the purpose of this analysis we assumed the project would not affect operation of the CBBS.

The project will affect flows into the Fresno Slough. During Ph 1, up to 150 cfs will be able to be withdrawn during flood flow conditions just upstream of the James Bypass and during Ph 2/3, up to 500 cfs will be able to be withdrawn during flood flow conditions.

The Sacramento/San Joaquin River's Comprehensive Study (Comp Study) (USACE, 2002) identified the design capacity of the James Bypass Channel as 4,750 cfs, and used that discharge rate in Comp Study modeling. Thus, this capacity was assumed for the analyses in this study as well.

To provide input to the flood damage analysis, we performed 1-dimensional (1D) unsteady hydraulic modeling using the USACE UNET modeling software (USACE, 1997). The original unsteady hydraulic (UNET) model of the Sacramento River and San Joaquin River systems was completed for Comp Study. This model was recently updated as part of the CVFPP (DWR, 2012) to account for setback/strengthened levee configurations and modified channel geometry. The majority of the model updates involved adjustment to the likely failure point (LFP) criteria for the levees to reflect recent levee strengthening activities.

The model input files include input hydrographs for the 10-, 25-, 50-, 100-, 200- and 500-year storm events with six storm centerings developed as part of the Comp Study (USACE 2002): 1) San Joaquin River at Friant, 2) San Joaquin River at the latitude of El Nido, 3) San Joaquin River at the latitude of Newman and 4) San Joaquin River at the latitude of Vernalis; 5) Merced River Tributary; and 6) Kings River (Fresno Slough) Tributary. As part of the Comp Study, these model input were substantially reviewed and are well vetted. Historic flow data compare relatively well with the inflow hydrographs. The only modification to the hydrologic model input required for this study was the adjustment to the upstream flow hydrographs in the Fresno Slough under with-project conditions. The CVFPP "no-project" UNET model represented the baseline (no-project) condition model for this study. For Ph1 and Ph2/3 conditions, 150 and 500 cfs was removed from the inflow hydrographs respectively.

For the economic analysis we performed using the HEC-FDA model, we subdivided the San Joaquin River system into 43 damage areas. The HEC-FDA model developed as part of the CVFPP study (DWR 2012) was obtained and used here. UNET results were used to develop representative stage-frequency curves for each damage areas as required inputs to the FDA model (DWR, 2012). CVFPP tools were used to assess the flood depth grid on the landward side of the levees, to develop the interior/exterior stage relationships, and to develop the depth-frequency information for individual parcels. This information was used to develop the HEC-FDA input files. The FDA model used within this study utilized the existing structure inventory and depth-damage functions from the CVFPP. No updates to structure, farm, or business values were performed. Modeling results indicate most project effects occur in reaches near Fresno Slough and effects are much less significant in the downstream reaches of the San Joaquin River system.

Expected annual damages (EAD) through the study area are estimated at $20M. 73% of those damages are associated with crop losses, with most the remainder (24%) associated with structures, mostly residential (19%), and their contents (Table 4-6). Implementation of the project will reduce EAD by about $300,000 annually for Phase 1 and about $800,000 for Phase 2/3 (Table 4-5).

Historic storm events in 1983, 1986, 1995 and 1997 have resulted in an estimated $1.4B (Table 4-17; 2013 $) in damages along the San Joaquin River (USBR 2005). These storm events are in the range of 5 – 40 year events (Table 4-16; USBR 2005). The FDA model predicted total damage for these four storm events to be between $0.5 – 2.3B (Table 4-17).

In predicting damages to the areas, the FDA model and DWR tools identify the 50- and 100-year storm events as the most damaging (Table 4-12 through Table 4-14; Table 4-18 through Table 4-20). Two reasons underlay this finding. First, total predicted structural damages from a 50-year storm event are over an order of magnitude greater than for a 10-year storm event, but about 80% of a 100-year storm event and 60% of a 500-year storm event (Table 4-10). Second, the 50- and 100-year storm events are relatively frequent compared to the larger storm events. Based upon DWR tools, we estimate the 50- and 100-year storm events contribute to nearly 70% of EAD totals. For those reasons, most EAD are associated with 50- and 100-year storm events (Table 4-20).

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The implementation of Phase 1 and Phase 2/3 will reduce costs associated with flood damages. Greatest structural savings are associated with the 10-, 50- and 100-year storm events (Table 4-10). Greatest total EAD savings are expected to occur for the 50- and 100-year storm events as it is for those storm events EAD is greatest under no project and with project conditions (Table 4-18 through Table 4-20). The project will result in a EAD savings of about $300,000 annually for Phase 1 and about $800,000 for Phase 2/3 as discussed earlier (Table 4-5). Benefit costs (B/C) analyses for this project are 1.86 for Phase 1 and 1.98 for Phase 2/3.

6 REFERENCES

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APPENDIX A. UNET MODEL INPUT AND OUTPUT (ON DISC)

APPENDIX B. ECONOMIC TABLES

Table B6-1. Structure Counts by Category from CVFPP

Impact Area		Structure Category Count				
Area	**Name**	**COM**	**IND**	**PUB**	**RES**	**Total**
SJ_01	Fresno	21	8	9	323	361
SJ_02	Fresno Slough East	0	1	6	100	107
SJ_03	Fresno Slough West	2	0	0	40	42
SJ_04	Mendota	7	4	3	318	332
SJ_05	Chowchilla Bypass	0	0	0	66	66
SJ_06	Lone Willow Slough	0	0	0	194	194
SJ_07	Mendota North	0	0	0	6	6
SJ_08	Firebaugh	119	19	14	1,172	1,324
SJ_09	Salt Slough	39	20	364	1,795	2,218
SJ_10	Dos Palos	113	11	104	1,811	2,039
SJ_11	Fresno River	0	0	0	10	10
SJ_12	Berenda Slough	1	3	0	203	207
SJ_13	Ash Slough	1	3	0	104	108
SJ_14	Sandy Mush	0	0	13	28	41
SJ_15	Turner Island	0	0	0	50	50
SJ_16	Bear Creek	1	3	12	89	105
SJ_17	Deep Slough	0	0	10	14	24
SJ_18	West Bear Creek	0	0	76	0	76
SJ_19	Fremont Ford	1	16	16	314	347
SJ_20	Merced River	0	11	15	208	234
SJ_21	Merced River North	1	20	20	398	439
SJ_22	Orestimba	4	1	24	377	406
SJ_23	Tuolumne South	0	0	16	87	103
SJ_24	Tuolumne River	12	1	9	731	753
SJ_25	Modesto	96	71	126	2,718	3,011
SJ_26	3 Amigos	3	0	12	44	59
SJ_27	Stanislaus South	0	0	31	71	102
SJ_28	Stanislaus North	7	4	72	942	1,025
SJ_29	Banta Carbona	1	4	16	435	456
SJ_30	Paradise Cut	3	6	12	186	207
SJ_31	Stewart Tract	3	1	7	6	17
SJ_32	East Lathrop	16	78	13	64	171
SJ_33	Lathrop/ Sharpe	55	72	141	4,838	5,106
SJ_34	French Camp	29	47	49	6,036	6,161
SJ_35	Moss Tract	27	85	27	2,695	2,834
SJ_36	Roberts Island	0	1	13	143	157
SJ_37	Rough and Ready Island	0	3	5	0	8
SJ_38	Drexler Tract	2	1	2	20	25
SJ_39	Union Island	0	2	4	54	60
SJ_40	SE Union Island	0	0	0	8	8
SJ_41	Fabian Tract	2	0	6	20	28
SJ_42	RD 1007	33	18	54	265	370
SJ_43	Grayson	2	0	6	235	243
TOTALS		**601**	**514**	**1,307**	**27,218**	**29,640**

Table B6-2. Depreciated Replacement Value by Category from CVFPP.
(All Values in $1,000's)

Impact Area		Structure Category Count				
Area	**Name**	**COM**	**IND**	**PUB**	**RES**	**Total**
SJ_01	Fresno	3,494	20,646	2,383	51,653	78,176
SJ_02	Fresno Slough East	0	3,314	1,050	8,574	12,938
SJ_03	Fresno Slough West	427	0	0	3,554	3,981
SJ_04	Mendota	569	3,961	516	22,300	27,346
SJ_05	Chowchilla Bypass	0	0	0	3,221	3,221
SJ_06	Lone Willow Slough	0	0	0	10,794	10,794
SJ_07	Mendota North	0	0	0	531	531
SJ_08	Firebaugh	16,000	4,990	4,773	106,881	132,644
SJ_09	Salt Slough	2,898	1,927	36,762	81,569	123,156
SJ_10	Dos Palos	8,778	368	10,898	68,998	89,042
SJ_11	Fresno River	0	0	0	506	506
SJ_12	Berenda Slough	61	863	0	12,159	13,083
SJ_13	Ash Slough	16	590	0	5,946	6,552
SJ_14	Sandy Mush	0	0	1,216	1,117	2,333
SJ_15	Turner Island	0	0	0	1,900	1,900
SJ_16	Bear Creek	98	85	1,218	3,474	4,875
SJ_17	Deep Slough	0	0	1,095	557	1,652
SJ_18	West Bear Creek	0	0	7,871	0	7,871
SJ_19	Fremont Ford	98	689	1,636	12,420	14,843
SJ_20	Merced River	0	499	1,519	9,333	11,351
SJ_21	Merced River North	91	3,204	1,689	35,451	40,435
SJ_22	Orestimba	257	160	1,675	19,474	21,566
SJ_23	Tuolumne South	0	0	723	4,887	5,610
SJ_24	Tuolumne River	2,978	1,944	462	38,262	43,646
SJ_25	Modesto	12,218	119,673	7,568	178,699	318,158
SJ_26	3 Amigos	427	0	511	2,213	3,151
SJ_27	Stanislaus South	0	0	1,688	4,759	6,447
SJ_28	Stanislaus North	1,886	112	3,076	122,176	127,250
SJ_29	Banta Carbona	65	158	732	19,630	20,585
SJ_30	Paradise Cut	479	262	465	14,109	15,315
SJ_31	Stewart Tract	648	34	305	459	1,446
SJ_32	East Lathrop	2,981	2,609	468	4,159	10,217
SJ_33	Lathrop/ Sharpe	16,618	3,609	6,073	640,822	667,122
SJ_34	French Camp	8,524	2,204	2,049	765,390	778,167
SJ_35	Moss Tract	7,238	3,641	1,150	250,731	262,760
SJ_36	Roberts Island	0	45	763	11,123	11,931
SJ_37	Rough and Ready Island	0	106	245	0	351
SJ_38	Drexler Tract	559	34	69	1,562	2,224
SJ_39	Union Island	0	86	182	2,310	2,578
SJ_40	SE Union Island	0	0	0	795	795
SJ_41	Fabian Tract	516	0	210	1,340	2,066
SJ_42	RD 1007	14,693	864	2,161	20,377	38,095
SJ_43	Grayson	179	0	515	11,640	12,334
TOTALS		**102,796**	**176,677**	**103,716**	**2,555,855**	**2,939,044**

Table B6-3. Structure Occupancy Types by Category from CVFPP

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

Table B6-4 Present Value of Expected Annual Damage Benefits – Phase 1

Phase 1: Present Value of Expected Annual Damage Benefits			
(a)	Expected Annual Damage Without Project		$20,179,790
(b)	Expected Annual Damage With Project		$19,883,960
(c)	Expected Annual Benefit	(a) – (b)	$295,830
(d)	Present Value Coefficient		22.43
(e)	Present Value of Future Benefits	(c) x (d)	$6,636,796

Note: Present Value assumes current discount rate of 3.75% and 50-year project life.

Table B6-5. Present Value of Expected Annual Damage Benefits – Phase 2/3

PH 2/3: Present Value of Expected Annual Damage Benefits			
(a)	Expected Annual Damage Without Project		$20,179,790
(b)	Expected Annual Damage With Project		$19,393,390
(c)	Expected Annual Benefit	(a) – (b)	$786,400
(d)	Present Value Coefficient		22.43
(e)	Present Value of Future Benefits	(c) x (d)	$17,642,485

Note: Present Value assumes current discount rate of 3.75% and 50-year project life.

Table B6-6 Present Value of Discounted Costs – Phase 1

Annual Costs of Project						
Time Frame		Total Project Implementation Costs	Annual Costs		Discounting Calculations	
			Operations and Maintenance	Total Costs (a) + (b)	Discount Factor	Discounted Project Costs (c) x (d)
Year	No.	(a)	(b)	(c)	(d)	(e)
2013				0	1.000	**0**
2014				0	0.943	**0**
2015				0	0.890	**0**
2016		4,087,320		4,087,320	0.840	**3,433,349**
2017	**1**		20,000	20,000	0.792	**15,840**
2018	**2**		15,000	15,000	0.747	**11,205**
2019	**3**		10,000	10,000	0.705	**7,050**
2020	**4**		10,000	10,000	0.665	**6,650**
2021	**5**		10,000	10,000	0.627	**6,270**
2022	**6**		10,000	10,000	0.592	**5,920**
2023	**7**		10,000	10,000	0.558	**5,580**
2024	**8**		10,000	10,000	0.527	**5,270**
2025	**9**		10,000	10,000	0.497	**4,970**
2026	**10**		10,000	10,000	0.469	**4,690**
2027	**11**		10,000	10,000	0.442	**4,420**
2028	**12**		10,000	10,000	0.417	**4,170**
2029	**13**		10,000	10,000	0.394	**3,940**
2030	**14**		10,000	10,000	0.371	**3,710**
2031	**15**		10,000	10,000	0.350	**3,500**
2032	**16**		10,000	10,000	0.331	**3,310**
2033	**17**		10,000	10,000	0.312	**3,120**
2034	**18**		10,000	10,000	0.294	**2,940**
2035	**19**		10,000	10,000	0.278	**2,780**
2036	**20**		10,000	10,000	0.262	**2,620**
2037	**21**		10,000	10,000	0.247	**2,470**
2038	**22**		10,000	10,000	0.233	**2,330**
2039	**23**		10,000	10,000	0.220	**2,200**
2040	**24**		10,000	10,000	0.207	**2,070**
2041	**25**		10,000	10,000	0.196	**1,960**
2042	**26**		10,000	10,000	0.185	**1,850**
2043	**27**		10,000	10,000	0.174	**1,740**
2044	**28**		10,000	10,000	0.164	**1,640**
2045	**29**		10,000	10,000	0.155	**1,550**
2046	**30**		10,000	10,000	0.146	**1,460**
2047	**31**		10,000	10,000	0.138	**1,380**
2048	**32**		10,000	10,000	0.130	**1,300**
2049	**33**		10,000	10,000	0.123	**1,230**
2050	**34**		10,000	10,000	0.116	**1,160**
2051	**35**		10,000	10,000	0.109	**1,090**
2052	**36**		10,000	10,000	0.103	**1,030**
2053	**37**		10,000	10,000	0.097	**970**
2054	**38**		10,000	10,000	0.092	**920**
2055	**39**		10,000	10,000	0.087	**870**
2056	**40**		10,000	10,000	0.082	**820**
2057	**41**		10,000	10,000	0.077	**770**
2058	**42**		10,000	10,000	0.073	**730**
2059	**43**		10,000	10,000	0.069	**690**
2060	**44**		10,000	10,000	0.065	**650**
2061	**45**		10,000	10,000	0.061	**610**
2062	**46**		10,000	10,000	0.058	**580**
2063	**47**		10,000	10,000	0.055	**547**
2064	**48**		10,000	10,000	0.052	**516**
2065	**49**		10,000	10,000	0.049	**487**
2066	**50**		10,000	10,000	0.046	**460**
Total Present Value of Discounted Costs (Sum of Column (e))						**3,577,384**

Table B6-7. Present Value of Discounted Costs – Phase 2/3

Annual Costs of Project						
Time Frame		Total Project Implementation Costs	Annual Costs		Discounting Calculations	
			Operations and Maintenance	Total Costs (a) + (b)	Discount Factor	Discounted Project Costs (c) x (d)
Year	No.	(a)	(b)	(c)	(d)	(e)
2013				0	1.000	**0**
2014				0	0.943	**0**
2015				0	0.890	**0**
2016		10,424,639		10,424,639	0.840	**8,756,697**
2017	1		20,000	20,000	0.792	**15,840**
2018	2		15,000	15,000	0.747	**11,205**
2019	3		10,000	10,000	0.705	**7,050**
2020	4		10,000	10,000	0.665	**6,650**
2021	5		10,000	10,000	0.627	**6,270**
2022	6		10,000	10,000	0.592	**5,920**
2023	7		10,000	10,000	0.558	**5,580**
2024	8		10,000	10,000	0.527	**5,270**
2025	9		10,000	10,000	0.497	**4,970**
2026	10		10,000	10,000	0.469	**4,690**
2027	11		10,000	10,000	0.442	**4,420**
2028	12		10,000	10,000	0.417	**4,170**
2029	13		10,000	10,000	0.394	**3,940**
2030	14		10,000	10,000	0.371	**3,710**
2031	15		10,000	10,000	0.350	**3,500**
2032	16		10,000	10,000	0.331	**3,310**
2033	17		10,000	10,000	0.312	**3,120**
2034	18		10,000	10,000	0.294	**2,940**
2035	19		10,000	10,000	0.278	**2,780**
2036	20		10,000	10,000	0.262	**2,620**
2037	21		10,000	10,000	0.247	**2,470**
2038	22		10,000	10,000	0.233	**2,330**
2039	23		10,000	10,000	0.220	**2,200**
2040	24		10,000	10,000	0.207	**2,070**
2041	25		10,000	10,000	0.196	**1,960**
2042	26		10,000	10,000	0.185	**1,850**
2043	27		10,000	10,000	0.174	**1,740**
2044	28		10,000	10,000	0.164	**1,640**
2045	29		10,000	10,000	0.155	**1,550**
2046	30		10,000	10,000	0.146	**1,460**
2047	31		10,000	10,000	0.138	**1,380**
2048	32		10,000	10,000	0.130	**1,300**
2049	33		10,000	10,000	0.123	**1,230**
2050	34		10,000	10,000	0.116	**1,160**
2051	35		10,000	10,000	0.109	**1,090**
2052	36		10,000	10,000	0.103	**1,030**
2053	37		10,000	10,000	0.097	**970**
2054	38		10,000	10,000	0.092	**920**
2055	39		10,000	10,000	0.087	**870**
2056	40		10,000	10,000	0.082	**820**
2057	41		10,000	10,000	0.077	**770**
2058	42		10,000	10,000	0.073	**730**
2059	43		10,000	10,000	0.069	**690**
2060	44		10,000	10,000	0.065	**650**
2061	45		10,000	10,000	0.061	**610**
2062	46		10,000	10,000	0.058	**580**
2063	47		10,000	10,000	0.055	**547**
2064	48		10,000	10,000	0.052	**516**
2065	49		10,000	10,000	0.049	**487**
2066	50		10,000	10,000	0.046	**460**
Total Present Value of Discounted Costs (Sum of Column (e))						**8,900,732**

APPENDIX C. TECHNICAL MEMORANDUM

The included technical memorandum presents an overview of the project operation, infrastructure and strategies.

APPENDIX D. CIG PROJECT FINAL REPORT

APPENDIX E. CIG PROJECT FACT SHEET