HAMILTON CITY FLOOD DAMAGE REDUCTION PROJECT, SACRAMENTO RIVER, CALIFORNIA

Prepared for

U.S. Army Corps of Engineers
Sacramento District
Sacramento, California

Contract Number: W91238-05-D-0009

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HAMCTY3T.DOC

March 2008

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1. INTRODUCTION

1.1 General Background

The Sacramento River flows south from Shasta Dam, through the Sacramento Valley and into San Pablo Bay. Of the 300+ miles of river, the lower 176 miles are bounded by project levees on either side. Without the influence of the project levees, the hydraulics of the upper Sacramento River system become more complex due to water exchange between the main channel and the over bank floodplains. Flow is constrained by natural landforms and a discontinuous series of local and private levees. Throughout this upper reach, the surrounding land typically consists of cultivated fields, orchards, riparian areas, and grassland.

The hydraulic modeling performed for this project focuses on a reach of the Sacramento River from River Mile (RM) 192 to RM 202 as shown in **Figure 1.1**. The U.S. Army Corps of Engineers (USACE) Sacramento District, with the assistance from Ayres Associates, previously completed a feasibility study of a setback of the "J Levee" along the Sacramento River in the vicinity of Hamilton City. From this effort, there is a proposed alignment, an economically justified level of protection, and the associated top of levee profile.

1.2 Purpose and Scope of Project

The purpose of this project was to readdress the appropriate top of levee profile for the proposed setback levee along the Sacramento River in the vicinity of Hamilton City. This effort included updating the previously developed RMA2 hydraulic model, working with the USACE and the local stakeholders to determine the level of protection, developing hydraulic model runs of all alternative simulations, and determine benefits and cost of the project alternatives. The hydraulic model was further refined and recalibrated as part of the current project design phase. This report includes the following tasks:

- *Update Existing RMA2 Hydraulic Model and Without-Project Conditions Runs* – The feasibility model was reviewed and refined at hydraulically important topographic features and at areas of project significance. The model was then calibrated to recent high flows with corresponding high water elevation data.

- *Develop With-Project Conditions Runs* – The alignment determined from the feasibility model was incorporated into the refined mesh. The new top of levee profile was determined based on these new runs and results were compared to the without-project condition runs.

1.3 Acknowledgements

This analysis was authorized by the USACE, Sacramento District. The point of contact for the USACE is Lea Adams. The hydraulic modeling was conducted by Dustin Robinson under the direction of Lyle Zevenbergen, PhD, PE.

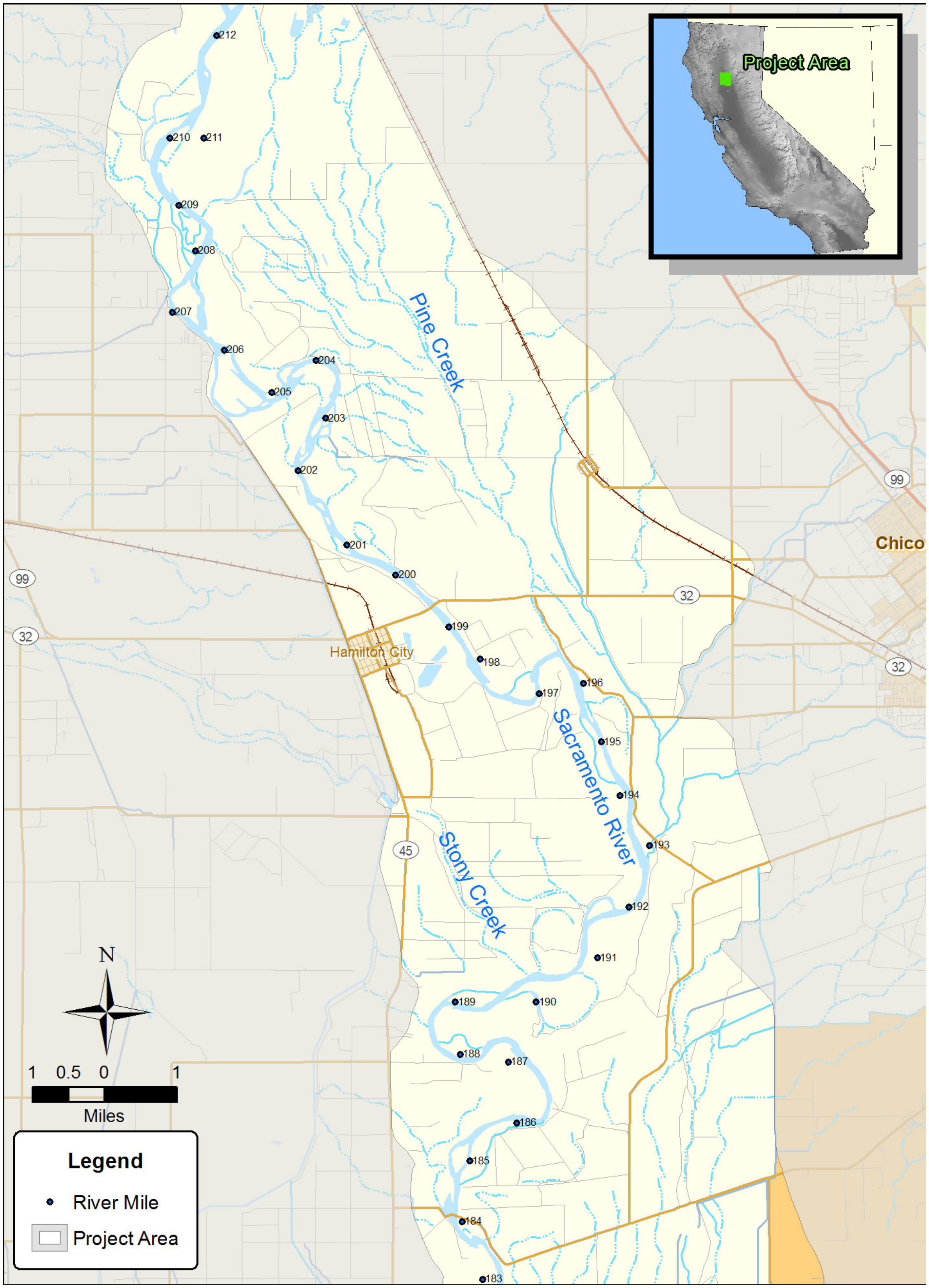

Figure 1.1. Project area.

2. HYDRAULIC MODELING

2.1 General

A two-dimensional model, previously developed for The Nature Conservancy (TNC) (Ayres Associates 2002), and expanded in 2004 for higher flows, was used as the basis for this hydraulic analysis. The SMS program, developed by Brigham Young University, was used to refine and extend the geometric mesh that represents the topographic and bathymetric data through the project reach.

The representation of the project reach was based on 1995 and 1997 topographic conditions. Extensive 2-foot contour mapping of the Sacramento River system was developed by the USACE from hydrographic and aerial photogrammetric surveys. Upstream of RM 194, the mapping data was derived from aerial and hydrographic surveys conducted in 1997. Downstream of RM 194 the mapping was derived from aerial and hydrographic surveys conducted in 1995. The horizontal datum for the survey data is the North American Datum of 1983 (NAD83), State Plane Coordinates. The vertical datum is the National Geodetic Vertical Datum of 1929 (NGVD29). The 2-foot contour mapping covered the limits of the two-dimensional model. The without-project condition of the finite element mesh developed for this project is shown in **Figure 2.1**. The limits of the modeling analysis extend from RM 212 downstream to RM 183.

Flow conditions in the project reach are fairly complex during flood events. The complexity is due to the presence of levees on both banks of the main channel, Hwy 32 that crosses the east floodplain, and multiple off channel levees that impact over bank flow. Levees within the model limits include the J-levee on the west side of the river and the Butte County levees on the east side. All levees and roadways that overtop are assumed to function hydraulically as a broad crested weir.

The RMA-2 program does not accurately simulate rapidly varied flow conditions that occur over the crest of a weir. During the feasibility study attempts were made to manually calculate the flow across the levees and roadways using the weir equation. This was determined to be too tedious and inaccurate. Forcing the model by manually determining flow direction and discharge would have yielded results different from those computed by the model on its own, which more accurately reflect the complex hydraulics within the reach. As a result, it was decided to let RMA-2 compute the flow across the levees on its own. This required increasing the roughness of the levee crest to maintain model stability. While the results across the crest of the levee (local velocities and depths) cannot be taken as accurate, the overall continuity of the model checked well. This methodology was used for all modeling conditions. Because the depths across the levee are not accurate, water surface elevations were compared to detailed project levee elevation profiles to help determine what sections of the levee were dry and therefore should be disabled in the model.

2.2 Model Refinement

The first task was to refine the existing RMA2 hydraulic model. The existing mesh, created during the feasibility study, was refined in areas of hydraulic or project importance. Refinement included representing topographic features better both in alignment and elevation, adding more elements in and around the project area, and including minor hydraulic features in the project area (RM 190 – 202). The following list provides a summary of the areas mesh refinement. For an example of refinement please see **Figure 2.2**.

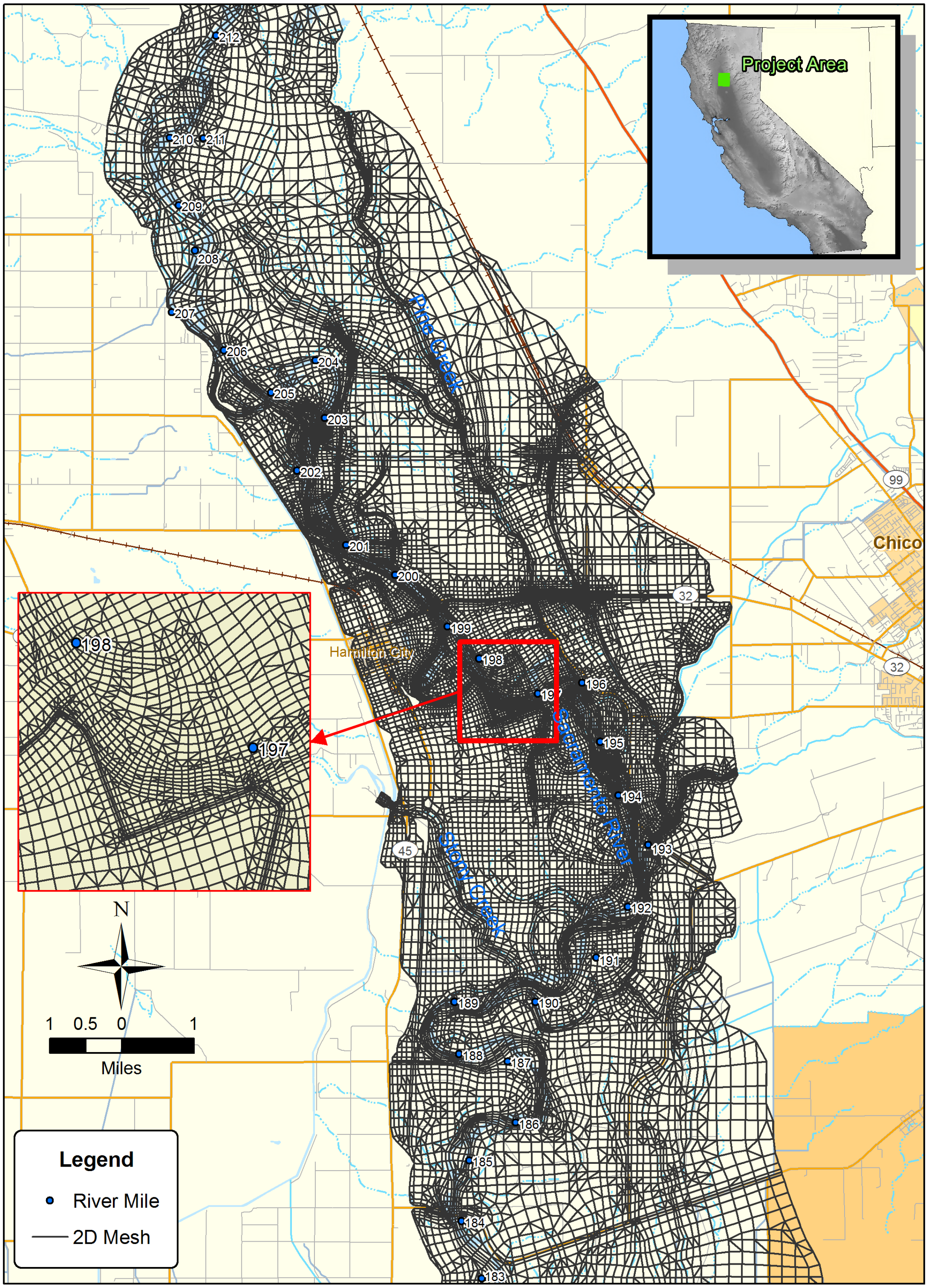

Figure 2.1. Without-project condition finite element mesh.

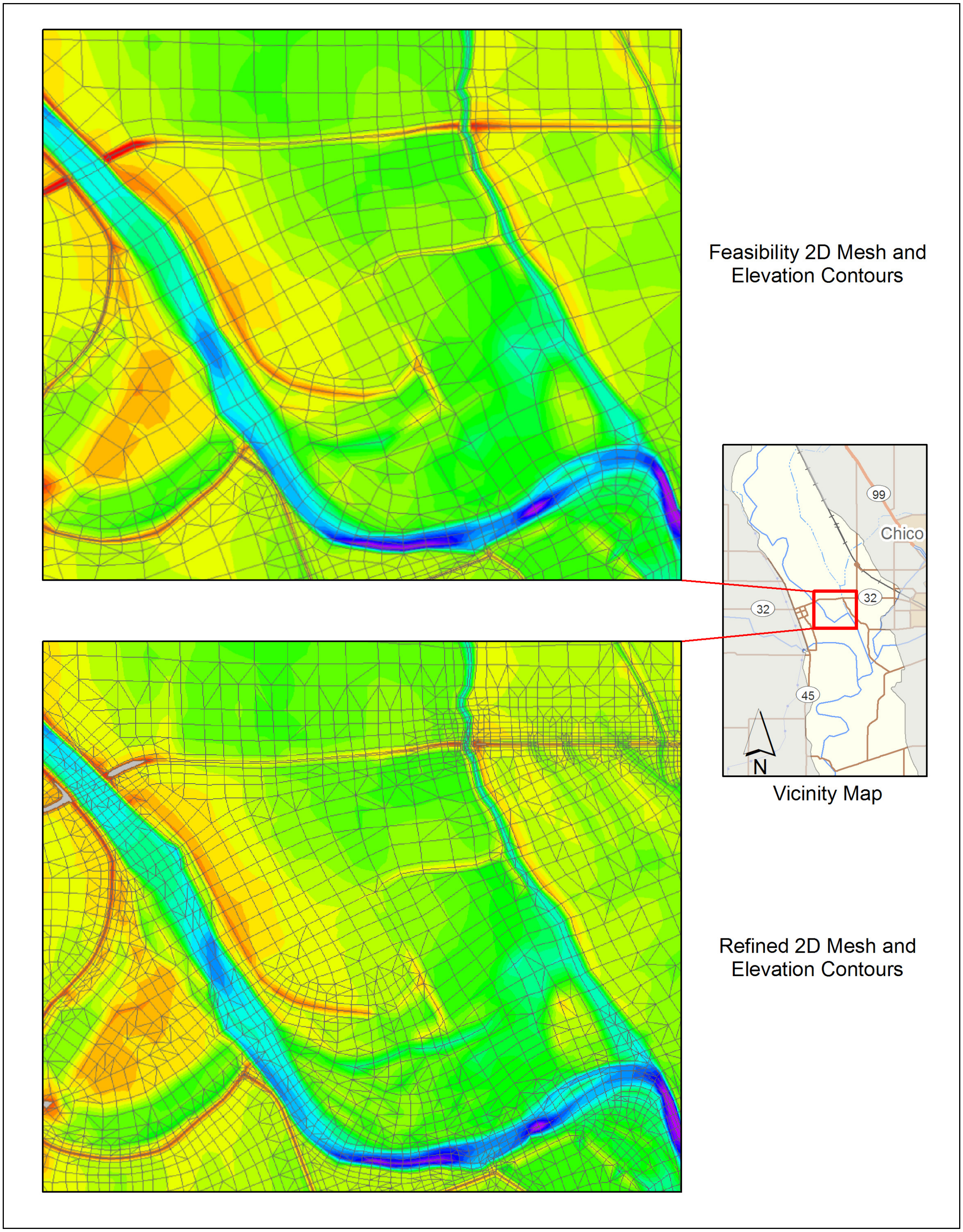

Figure 2.2. Mesh refinement comparison.

Channels

- Sacramento River – Refined entire channel throughout model, including up to top of bank (more detailed between RM 188 and RM 206)
- Dicus Slough
- Pine Creek
- Big Chico Creek
- Stony Creek
- Buck Creek
- Harbeam Slough

Over bank

- Unnamed Levee at north end of model by Dicus Slough
- Wilson Landing Road
- Highway 32
- Pine Creek Levees
- Berm downstream of RM 205
- Levee/Berm downstream of Highway 32
- Butte County Levee
- Area landside of J-Levee
- J-Levee
- Butte Basin Levee

General

- Extended model limits downstream to RM 183
- Reviewed and edited all major roads, embankments, and channels within project area
- Verified and updated n-values
- Refined mesh in restoration areas

The Manning's roughness values used in the modeling are provided in **Table 2.1**. Manning n values for "areas of turbulent flow" are set high to maintain model stability where extreme flow conditions occur in the model, such as at levee crests. Roughness values used in the previous studies were preserved in the calibration of this model with the exception of the Orchard material type. The reason for these changes is discussed in the calibration section (see **Figure 2.3** for a figure of the without-project conditions n values used in the model).

The Sacramento River and tributary inflows used in the two-dimensional modeling simulations are shown in **Table 2.2**. The peak flows were provided by the USACE and were derived from the Sacramento and San Joaquin river Basin Comprehensive Study UNET model. The Stony Creek inflows were changed from the feasibility study in order to represent a more realistic flow condition in relation to the peak flow in the Sacramento River.

Table 2.1. Roughness Coefficients used in Two-Dimensional Model.		
Element #	Land Use	n value
1	Levee/Road	0.025
2	Main Channel	0.035
3	Cultivated Field	0.035
4	Pasture/Grassland	0.035
5	Creek Bed	0.035
6	Pine Creek Bed	0.035
7	Sand/Gravel	0.04
8	Stony Creek Bed	0.04
9	Savannah (pr)	0.05
10	Scrub (pr)	0.10
11	Orchard	0.10 - 0.15
12	Forest/Riparian	0.14
13	Urban	0.20
14	Area of low turbulent flow	0.20
15	Area of high turbulent flow	0.50
16	Weir Flow/Overtopping	0.50
17	Valley Oak Woodland	0.05
18	Valley Oak Eld. Savanna	0.05
19	Valley Oak Rip. Forest	0.16
20	Cottonwood Rip. Forest	0.16
21	Elderberry Savannah	0.05
22	Shaded Riverine Aquatic Habitat	0.16
23	Mixed Riparian Forest	0.16
24	Valley Wild rye Grassland	0.035
25	Valley Needle grass Grassland	0.035

Table 2.2. Two-Dimensional Model Boundary Conditions.			
Flood Event (yr)	Sacramento Inflow (cfs)	Stony Creek Inflow (cfs)	Tailwater Elevation (ft)
2	97,500	5,000	111.7
5	137,000	9,100	112.5
10	160,600	12,450	113.0
25	206,575	14,700	113.8
50	237,829	14,950	114.3
75	260,000	14,950	114.6
100	275,910	14,950	114.9
200	315,965	24,640	115.6
320	342,600	39,760	116.2
500	424,511	60,460	117.5

Downstream water surface elevation boundary conditions were referenced from previous two-dimensional modeling conducted for the Butte Basin reach of the Sacramento River (Ayres Associates 1997). The Butte Basin model covered the Sacramento River south of the Hamilton City project area reach, and provided enough overlap to be used as a reference for the tail water elevation for this modeling effort. A rating curve was developed as shown in **Figure 2.3** based on the computed water surface elevation and discharge from the Butte Basin model at the location of the downstream limit of the current model (approx. RM 183). The lowest flow modeled in the Butte Basin model was the 1995 flood event, with a total inflow in the Sacramento River of 195,000 cfs at the downstream location of the current model.

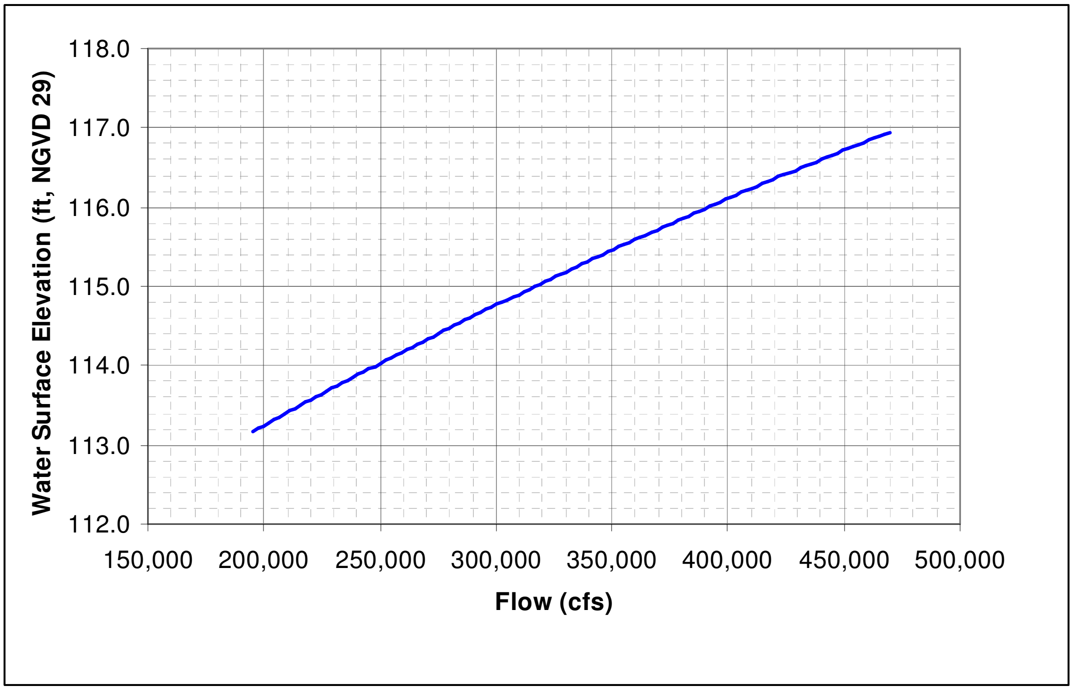

Figure 2.3. Rating curve for the downstream water surface elevation boundary condition.

2.3 Model Calibration

Once the two-dimensional hydraulic model was refined, it was calibrated against measured high water marks from the January 2006 flood event, as well as one other lower flood event during December 2005. The peak flow data used for both of these events was obtained from the California Data Exchange Center, CDEC, (http://cdec.water.ca.gov/), at the Hamilton City Gage, Sacramento River. The boundary conditions used in the two-dimensional modeling calibration are shown in **Table 2.3**.

Table 2.3. Two-Dimensional Model Boundary Conditions.

Flood Event (yr)	Sacramento Inflow (cfs)	Tail water Elevation (NGVD29, ft)
Dec-05	109,322	111.8
Jan-06	134,638	112.3

Water surface elevations from the calibration models were compared to elevations from surveyed high water marks and from the stages recorded at the CDEC Hamilton City gage and Ord Ferry Gage. The locations of the gages and surveyed high water marks are shown in **Figure 2.4**. A comparison of the models and the recorded values is provided in **Table 2.4**.

During the initial calibration run of the 2006 flood event, the model was overestimating the water surface elevations compared to the surveyed high water marks in the over bank area. Adjusting the Orchard material type roughness value had the greatest effect on the water surface elevation for this calibration model. Based on the results of this effort, the Orchard material type will be set a 0.10 for the 2-, 5-, and 10-year flood events, and 0.15 for the 20-year and higher flood events. This accounts for water surface elevation reaching the approximate canopy of the Orchard during the higher flow events. The model is still high compared to the over bank high water marks.

One other high flow event was run to check additional high water mark data. The model is overestimating the water surface elevations compared to the high water mark and the two gages.

This calibration effort was a difficult task due to the data available and dynamic nature and hydraulic complexity of the river in this area. Based on our professional judgment and experience with previous hydraulic models on the Sacramento River, the following observations have been made to explain the calibration model and results:

- Topographic data for this model is based off of survey data from 1995-1997. This reach of the river has experienced several high flow events since this survey, resulting in major channel alignment changes and possible bathymetric changes. Based on the original calibration work performed during the feasibility study for this model (Ayres 2002), we know that the water surface elevations are sensitive to changes in the channel.

- The hydrology used for the calibration events are peak flow events during a fluctuating dynamic flood. The modeled event assumes a steady state, non-dynamic flood.

- During these flow events there is flood flow in the over bank areas at the gage locations which may or may not be accounted for at the gage locations.

- The size of this model limits the detail of the finite element mesh. Even though the mesh was refined, specifically in the project area, there may still be local hydraulic effects not accounted for in the model due to the limited detail and from possible changes in topography over the last 12 years.

- Gages in these locations are known to be unreliable.

In general the model is overestimating the water surface elevation, but is within reasonable amounts. This will provide a conservative but acceptable elevation for the final levee design.

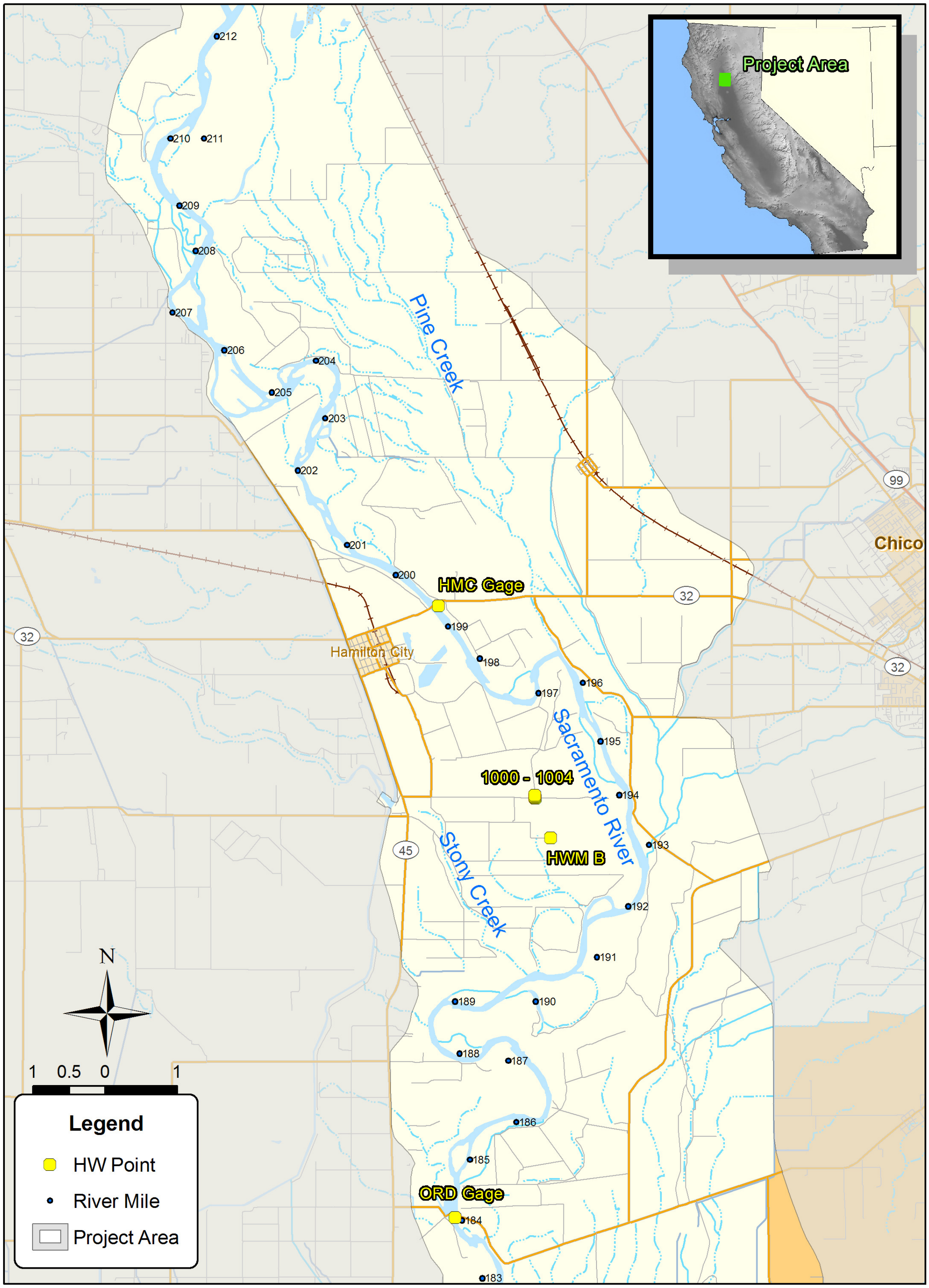

Figure 2.4. Surveyed high water mark locations.

Table 2.4. Two-dimensional Model Calibration Points.					
January 1, 2006 flow event (134,638 cfs)					
Pt Name	Location (NAD83, CASPZ 2, ft)		Elevation (NGVD29, ft)		
	Easting	Northing	Measured	Model	Difference
HMC Gage	6562956.0	2399679.5	146.84	146.27	-0.57
ORD Gage	6564194.6	2354862.9	115.24	116.54	1.30
1000	6570062.3	2385595.6	134.4	134.6	0.2
1001	6570068.3	2385602.3	134.2	134.6	0.4
1002	6570048.5	2385664.6	134.2	134.7	0.5
1003	6570044.2	2385704.6	134.2	134.7	0.5
1004	6570031.8	2385808.5	134.2	134.8	0.6
December 29, 2005 flow event (109,322 cfs)					
HMC Gage	6562956.0	2399679.5	144.05	145.1	1.1
ORD Gage	6564194.6	2354862.9	113.19	115.6	2.4
HWM B	6571209.4	2382679.2	131.95	132.5	0.6

2.4 Without-Project Conditions Hydraulic Model

The without-project conditions hydraulic model represents the land use and river configuration that existed following the 1995 flood events. This model uses the topographic and hydrographic mapping data developed by the USACE following that event. The land use within two areas was updated to match restoration planting that has occurred since the feasibility modeling. These areas are the U.S. Fish and Wildlife Service Parcel and the Department of Fish and Game Parcel (see **Figure 2.5** for a comparison of the without-project conditions and project conditions roughness coefficients in the vicinity of the setback levee area). For the without-project conditions, the existing J-levee was assumed to contain flows up to the 100-year event, as indicated by flood fighting reports and agreements from the local Hamilton City landowners. The flood fighting efforts extend along the J-levee from its upper terminus, downstream to the elbow directly west of RM 195. For events greater than the 100-year flow, the J-levee was modeled with a crest equal to the 100-year water surface elevation.

2.5 Project Conditions Hydraulic Model

The project conditions model represents the setback levee and training dike configuration determined from the feasibility study. The details of the project conditions model are illustrated in **Figure 2.6**. The proposed levee is set at the 320-year flood profile to a point that is roughly 5,000 feet upstream of County Road 23. At that location, the levee transitions into a "training levee" set at the 100-year flood profile for roughly 3,000 feet. From this point it drops to an elevation that is 2.1 feet below the project 100-year water surface elevation, which is roughly equivalent to the 20-year flood profile. Two project conditions were modeled as part of this study. The only difference between the two scenarios is the length of the transition of the "training levee" from the 100-year flood elevation to the 2.1 feet below the 100-year flood elevation. In Project A this transition is approximately 25 feet long, and in Project B it is approximately 3,400 feet long. It was assumed that the J levee would be completely removed for the with-project condition. The riparian restoration condition with corresponding roughness coefficients for the setback areas were included in this run.

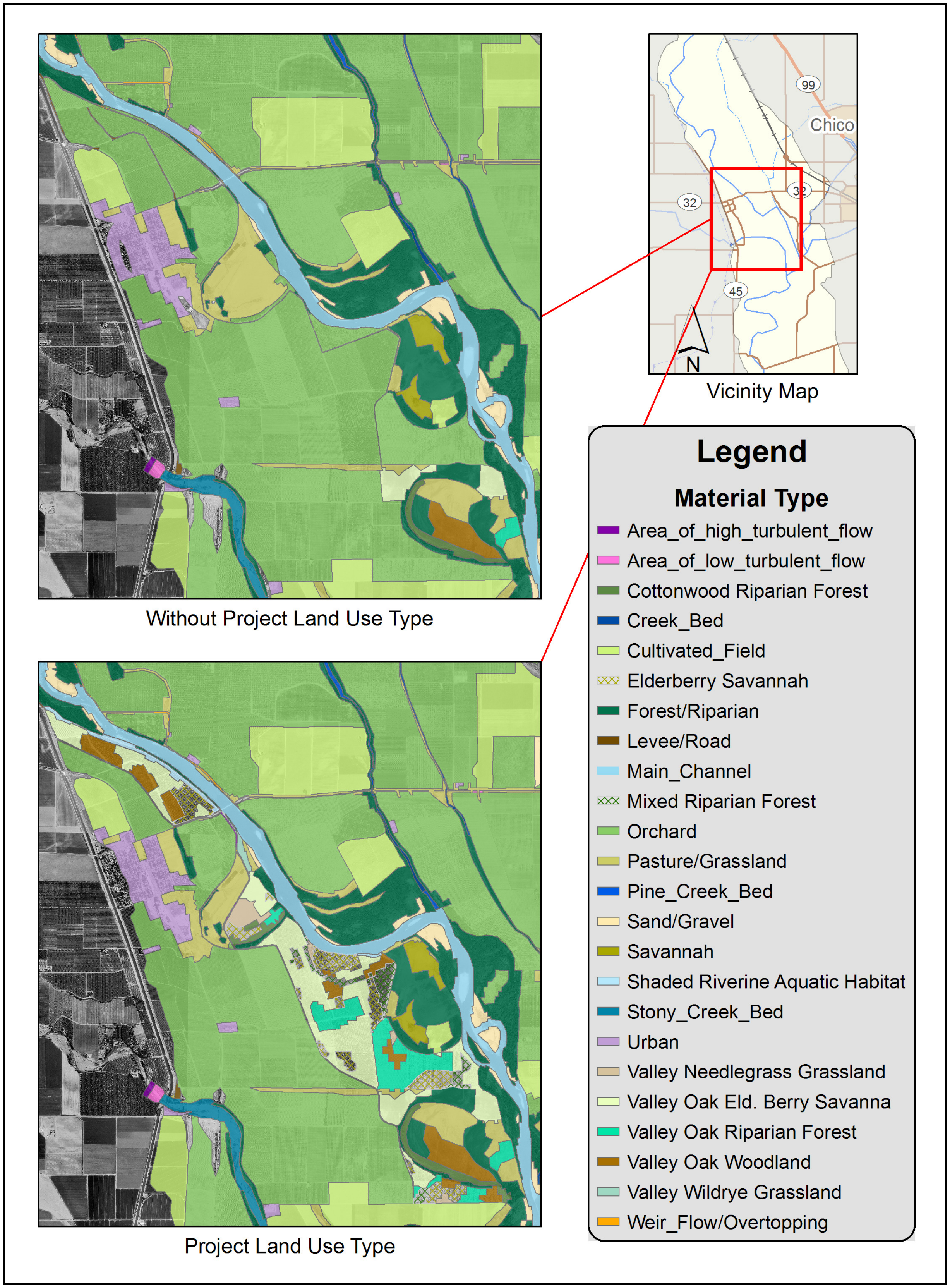

Figure 2.5. Project area roughness changes.

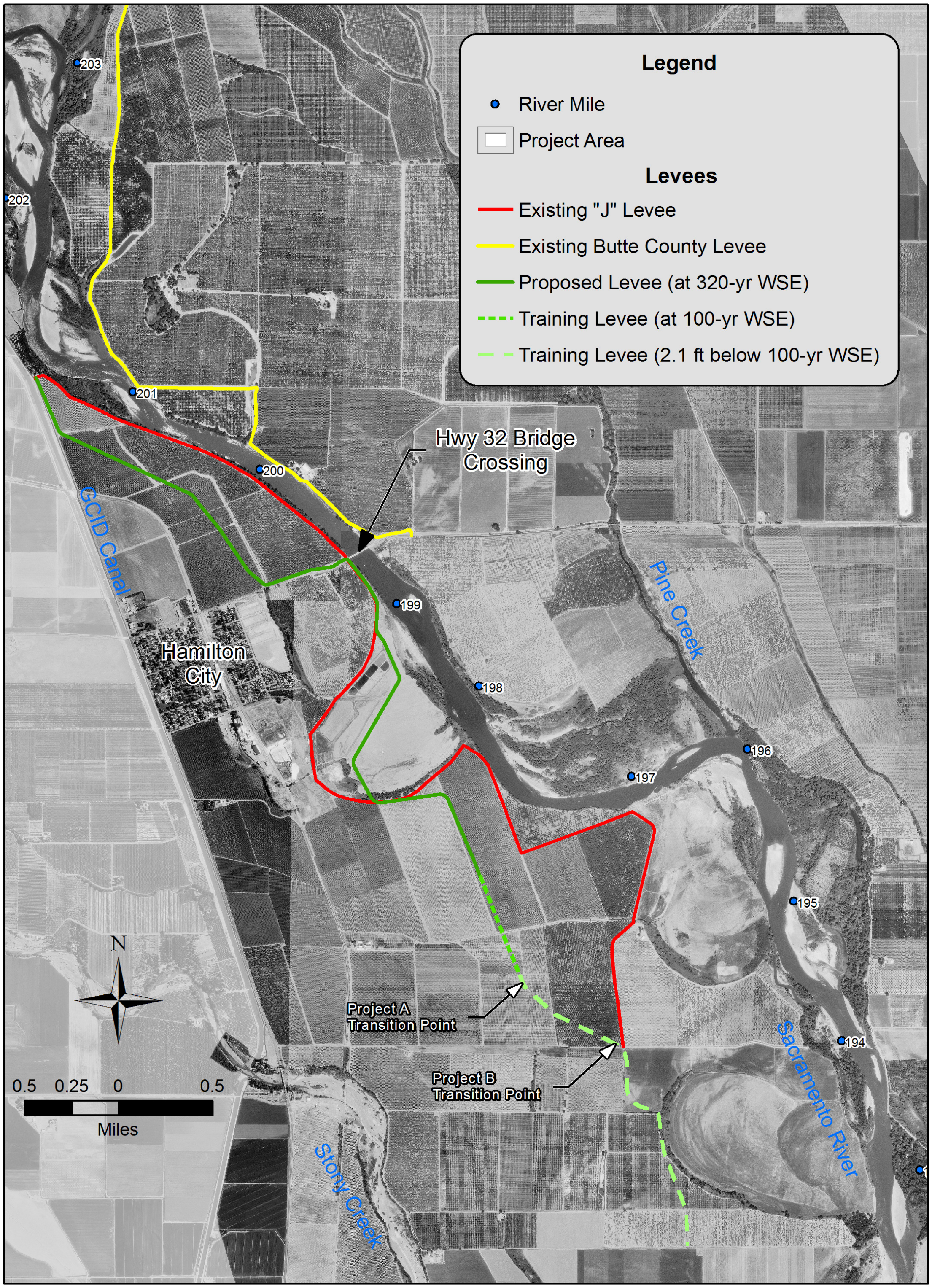

Figure 2.6. Project levee configuration.

3. DISCUSSION OF MODELING RESULTS

A list of all modeling completed for this project is summarized in **Table 3.1**. All plots referenced in the table and following discussion are included in the attachments. The results of the without-project conditions run were used as a baseline to compare changes in velocity and depth. General observations concerning the modeling are summarized below, as well as more detailed results for each modeled flow.

Table 3.1. Summary of Modeling.

Model Scenario	Flood Event	Figure Included[1]	Model Name[2]
Calibration	January 1, 2006	No Plots	C1b07
	December 29, 2005	No Plots	C2d09
Without-Project Condition	2-year	D, V	Ex_002i07
	5-year	D, V	Ex_005f06
	10-year	D, V	Ex_010b07
	25-year	D, V	Ex_025b07
	50-year	D, V	Ex_050c07
	100-year	D, V	Ex_100g07
	200-year	D, V	Ex_200b09
	500-year	D, V	Ex_500e13
Project Condition A	2-year	D, V, WSE, ΔD, ΔV	PA_002d07
	5-year	D, V, WSE, ΔD, ΔV	PA_005b06
	10-year	D, V, WSE, ΔD, ΔV	PA_010e06
	25-year	D, V, WSE, ΔD, ΔV	PA_025f07
	50-year	D, V, WSE, ΔD, ΔV	PA_050d10
	75-year	No Plots	PA_075e07
	100-year	D, V, WSE, ΔD, ΔV	PA_100d06
	200-year	D, V, WSE, ΔD, ΔV	PA_200b09
	320-year	No Plots	PA_320e07
	500-year	D, V, WSE, ΔD, ΔV	PA_500b09
Project Condition B[3]	25-year	D, V, WSE, ΔD, ΔV	PB_025b09
	50-year	D, V, WSE, ΔD, ΔV	PB_050a06
	75-year	No Plots	PB_075a07
	100-year	D, V, WSE, ΔD, ΔV	PB_100b01
	200-year	D, V, WSE, ΔD, ΔV	PB_200a06
	320-year	No Plots	PB_320a11
	500-year	D, V, WSE, ΔD, ΔV	PB_500a06
Sensitivity Runs	100-year	No Plots	SR_100a08
	320-year	No Plots	SR_320a07

[1]D = Depth, V = Velocity, WSE = Water surface elevation, ΔD = Change in depth verses without-project condition, ΔV = change in velocity verses without-project condition

[2]Includes SMS project file *.sms and all sub-file formats

[3]The difference between Project A and B does not affect the 2-, 5-, and 10-year flood events, therefore these flows were not modeled for Project B

3.1 General Observations

- *Upstream of Hwy 32 Bridge Crossing* – In this reach immediately upstream of the bridge crossing the proposed levee alignment is set-back from the river's edge where the J levee is currently located. This opens a small floodplain for the right bank providing relief to flow. Less flow is in the main channel approaching the bridge. This results in a slight decrease in velocity and increase in depth in the main channel in comparison to the without-project condition. This increase in water surface elevation continues upstream to between RM 200 and RM 201, depending on the flow condition. This increase is local to the main channel and does not increase the flood inundation area except where the levee is set back. Therefore, this increase is not an adverse impact.
- *Downstream of Dunning Slough* – This is the area most impacted by the removal of the J levee and the location of the proposed levee alignment. There is a local area of increase in water surface elevation on the river-side of the setback levee, land-side of the current levee. This area was dry or a backwater area under the without-project conditions, but will be inundated under the with-project conditions. On the landward side of the new levee, between the training dike and the GCID canal there is a decrease in the water surfaces.
- *Between Dunning Slough and the GCID Canal (Hamilton City Area)* – For flows below the 100-year event there is no impact in this area. For the 200-year event, the proposed levee removes the flooding that occurs when the J levee overtops and allows flow through this area. For the 500-year event, the proposed levee reduces the flooding that occurs in this area.
- *East Floodplain Downstream of Hwy 32* – The increased conveyance provided by the set-back alignment of the proposed levee results in a decrease in water surface elevation extending into the east floodplain between County Road 23 and Hwy 32.
- *East Floodplain Upstream of Hwy 32* – The decrease in water surface elevation in the east floodplain continues upstream of Hwy 32.
- *Big Chico Creek / Butte Basin Overflow* – The eastern edge of the model follows Big Chico Creek where it connects to the Sacramento. Along this edge flow overtops a natural levee feature and goes into the Butte Basin overflow area. Due to the widening of the floodplain by the set-back alignment of the proposed levee the water surface elevation along this edge decreases. This results in a slight decrease in the amount of flow spilling into Butte Basin.

3.2 500-Year Flood Event

- See attached plots titled: "500-Year Flood Event"
- Flow in Sacramento River is 424,511 cfs; flow in Stony Creek is 60,460 cfs
- Upstream of the Hwy 32 bridge crossing, there is a slight increase in water surface elevation of roughly 0.2 to 0.4 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of 2 - 3 feet where the levee is set-back. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.

- Flow is reduced by 1 - 2 feet in the Hamilton City area under the project condition, assuming no levee failure.
- Downstream of Hwy 32 there is a decrease in water surface elevation of 1 - 2 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.8 feet carries upstream of Hwy 32.
- Water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek decreases slightly by 0.1 - 0.5 feet

3.3 200-Year Flood Event

- See attached plots titled: "200-Year Flood Event"
- Flow in Sacramento River is 342,600 cfs; flow in Stony Creek is 39,760 cfs
- Upstream of the Hwy 32 bridge crossing, there is a slight increase in water surface elevation of roughly 0.2 to 0.4 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of 2 - 4 feet where the levee is set-back. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.
- Flow is removed from the Hamilton City area under the project condition
- Downstream of Hwy 32 there is a decrease in water surface elevation of 1 – 1.5 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.8 feet carries upstream of Hwy 32.
- Water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek decreases slightly by 0.1 - 0.4 feet
- Changes at the eastern upstream area of the model are caused by local changes made in the model from the without-project conditions to the project conditions and is not an impact from the project itself

3.4 100-Year Flood Event

- Flow in Sacramento River is 275,910 cfs; flow in Stony Creek is 14,950 cfs
- Upstream of the Hwy 32 bridge crossing, there is a slight increase in water surface elevation of roughly 0.2 to 0.3 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back
- Downstream of Hwy 32, there is a decrease in water surface elevation of 0.8 – 1.5 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.4 feet carries upstream of Hwy 32.
- Water surface elevation along the eastern edge of the model in the vicinity of Big Chico creek decreases by as much as 0.6 feet

- On the landward side of the new setback levee there is a decrease in the water surface elevation of 1 – 2 feet

3.5 50-Year Flood Event

- Flow in Sacramento River is 237,829 cfs; flow in Stony Creek is 14,950 cfs
- Upstream of the Hwy 32 bridge crossing there is a slight increase in water surface elevation of roughly 0.1 to 0.2 feet in the channel
- Downstream of Dunning Slough there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.
- Downstream of Hwy 32 there is a decrease in water surface elevation of 0.8 – 1.3 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.8 feet carries upstream of Hwy 32
- Water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek decreases by less than 0.4 feet upstream of its confluence with Mud Creek
- On the landward side of the new setback levee there is a decrease in the water surface elevation of 1 – 2 feet
- There is no overflow to Butte Basin under the without-project condition. The project condition does not change this.

3.6 25-Year Flood Event

- Flow in Sacramento River is 206,575 cfs; flow in Stony Creek is 14,700 cfs
- Upstream of the Hwy 32 Bridge crossing, there is a slight increase in water surface elevation of roughly 0.1 feet in the channel
- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.
- Downstream of Hwy 32, there is a decrease in water surface elevation of 0.7 – 1 feet in the floodplain east of the river channel. A decrease of 0.1 to 0.8 feet carries upstream of Hwy 32.
- There is no change in the water surface elevation along the eastern edge of the model in the vicinity of Big Chico Creek
- On the landward side of the new setback levee there is a decrease in the water surface elevation of 1 – 2 feet

3.7 10-Year Flood Event

- Flow in Sacramento River is 160,600 cfs; flow in Stony Creek is 12,450 cfs

- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 4 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.
- Downstream of Hwy 32, there is a decrease in water surface elevation of 0.4 – 0.8 feet in the floodplain east of the river channel. A decrease of less than 0.2 feet carries upstream of Hwy 32.
- Increase in water surface caused by the levee at 2.1 feet below the 100-year wsel causes a slight increase of less than 0.2 feet in the vicinity of Big Chico Creek
- On the landward side of the new setback levee there is a decrease in the water surface elevation of 1 – 1.5 feet
- There are two areas that are the result of local changes made in the model from the without-project conditions to the project conditions and is not an impact from the project itself. These areas are seen east of the Butte County Levee near RM 202 and near the eastern edge of the model at Hwy 32.

3.8 5-Year Flood Event

- Flow in Sacramento River is 137,000 cfs; flow in Stony Creek is 9,100 cfs
- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 3 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.
- Downstream of Hwy 32, there is a decrease in water surface elevation of 0.3 – 0.8 feet in the floodplain east of the river channel. A decrease of less than 0.2 feet carries upstream of Hwy 32.
- On the landward side of the new setback levee there is a decrease in the water surface elevation of 1 – 1.5 feet

3.9 2-Year Flood Event

- Flow in Sacramento River is 97,500 cfs; flow in Stony Creek is 5,000 cfs.
- Downstream of Dunning Slough, there is a local increase in water surface elevation of greater than 1 - 3 feet. This is in an area that is under backwater conditions for the without-project condition that is now inundated due to the levee set-back. There is a similar increase in depth in the west floodplain immediately upstream of the Hwy 32 Bridge where the levee is set-back.
- Downstream of Hwy 32, there is a decrease in water surface elevation of 0.1 – 0.3 feet in the floodplain east of the river channel
- On the landward side of the new setback levee there is a decrease in the water surface elevation of less than 1 foot
- Changes at the southern downstream area of the model are caused by local changes made in the model from the without-project conditions to the project conditions and is not an impact from the project itself

4. REFERENCES

Ayres Associates, 1997. Hydrodynamic Modeling of the Sacramento River and Butte Basin from RM 174 to RM 194, Sacramento River Bank Protection Project (SRBPP), Sacramento River and Tributaries, prepared for the U.S. Army Corps of Engineers, Sacramento District, Sacramento, CA, December.

Ayres Associates, 2002. Two-Dimensional Hydraulic Modeling of the Upper Sacramento River, RM 194 to RM 202, Including Riparian Restoration, Two Setback Levee Alternatives, and East Levee Removal, Glenn and Butte Counties, CA, prepared for the Nature Conservancy, October.

APPENDIX

Two-Dimensional Hydraulic Model Results and Comparison Plots

Two-Dimensional Hydraulic Model Results and Comparison Plots.		
Model Condition	Plot Name	File Name
Existing	2 yr Flood Event, Flow: 97,500 cfs, Depth, Without Project Conditions	Existing_002_Depth.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Velocity, Without Project Conditions	Existing_002_Velocity.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Depth, Without Project Conditions	Existing_005_Depth.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Velocity, Without Project Conditions	Existing_005_Velocity.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Depth, Without Project Conditions	Existing_010_Depth.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Velocity, Without Project Conditions	Existing_010_Velocity.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Depth, Without Project Conditions	Existing_025_Depth.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Velocity, Without Project Conditions	Existing_025_Velocity.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Depth, Without Project Conditions	Existing_050_Depth.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Velocity, Without Project Conditions	Existing_050_Velocity.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Depth, Without Project Conditions	Existing_100_Depth.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Velocity, Without Project Conditions	Existing_100_Velocity.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Depth, Without Project Conditions	Existing_200_Depth.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Velocity, Without Project Conditions	Existing_200_Velocity.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Depth, Without Project Conditions	Existing_500_Depth.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Velocity, Without Project Conditions	Existing_500_Velocity.pdf
Project A	2 yr Flood Event, Flow: 97,500 cfs, Depth, With Project Conditions	ProjectA_002_Depth.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Velocity, With Project Conditions	ProjectA_002_Velocity.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Water Surface Elevation, With Project Cond.	ProjectA_002_wse.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Depth, With Project Conditions	ProjectA_005_Depth.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Velocity, With Project Conditions	ProjectA_005_Velocity.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Water Surface Elevation, With Project Cond.	ProjectA_005_wse.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Depth, With Project Conditions	ProjectA_010_Depth.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Velocity, With Project Conditions	ProjectA_010_Velocity.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Water Surface Elevation, With Project Cond.	ProjectA_010_wse.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Depth, With Project Conditions	ProjectA_025_Depth.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Velocity, With Project Conditions	ProjectA_025_Velocity.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Water Surface Elevation, With Project Cond.	ProjectA_025_wse.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Depth, With Project Conditions	ProjectA_050_Depth.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Velocity, With Project Conditions	ProjectA_050_Velocity.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Water Surface Elevation, With Project Cond.	ProjectA_050_wse.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Depth, With Project Conditions	ProjectA_100_Depth.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Velocity, With Project Conditions	ProjectA_100_Velocity.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Water Surface Elevation, With Project Cond.	ProjectA_100_wse.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Depth, With Project Conditions	ProjectA_200_Depth.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Velocity, With Project Conditions	ProjectA_200_Velocity.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Water Surface Elevation, With Project Cond.	ProjectA_200_wse.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Depth, With Project Conditions	ProjectA_500_Depth.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Velocity, With Project Conditions	ProjectA_500_Velocity.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Water Surface Elevation, With Project Cond.	ProjectA_500_wse.pdf
Project A Compared to Existing	2 yr Flood Event, Flow: 97,500 cfs, Change in Depth, Project Conditions A	Difference_002_Depth.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Change in Velocity, Project Conditions A	Difference_002_Velocity.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Change in Depth, Project Conditions A	Difference_005_Depth.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Change in Velocity, Project Conditions A	Difference_005_Velocity.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Change in Depth, Project Conditions A	Difference_010_Depth.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Change in Velocity, Project Conditions A	Difference_010_Velocity.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Change in Depth, Project Conditions A	Difference_025_Depth.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Change in Velocity, Project Conditions A	Difference_025_Velocity.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Change in Depth, Project Conditions A	Difference_050_Depth.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Change in Velocity, Project Conditions A	Difference_050_Velocity.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Change in Depth, Project Conditions A	Difference_100_Depth.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Change in Velocity, Project Conditions A	Difference_100_Velocity.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Change in Depth, Project Conditions A	Difference_200_Depth.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Change in Velocity, Project Conditions A	Difference_200_Velocity.pdf
	500 yr Flood Event, Flow: 424,911 cfs, Change in Depth, Project Conditions A	Difference_500_Depth.pdf
	500 yr Flood Event, Flow: 424,911 cfs, Change in Velocity, Project Conditions A	Difference_500_Velocity.pdf

Two-Dimensional Hydraulic Model Results and Comparison Plots (continued).		
Model Condition	Plot Name	File Name
Project B	2 yr Flood Event, Flow: 97,500 cfs, Depth, With Project Conditions B	ProjectB_002_Depth.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Velocity, With Project Conditions B	ProjectB_002_Velocity.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_002_wse.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Depth, With Project Conditions B	ProjectB_005_Depth.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Velocity, With Project Conditions B	ProjectB_005_Velocity.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_005_wse.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Depth, With Project Conditions B	ProjectB_010_Depth.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Velocity, With Project Conditions B	ProjectB_010_Velocity.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_010_wse.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Depth, With Project Conditions B	ProjectB_025_Depth.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Velocity, With Project Conditions B	ProjectB_025_Velocity.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_025_wse.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Depth, With Project Conditions B	ProjectB_050_Depth.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Velocity, With Project Conditions B	ProjectB_050_Velocity.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_050_wse.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Depth, With Project Conditions B	ProjectB_100_Depth.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Velocity, With Project Conditions B	ProjectB_100_Velocity.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_100_wse.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Depth, With Project Conditions B	ProjectB_200_Depth.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Velocity, With Project Conditions B	ProjectB_200_Velocity.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_200_wse.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Depth, With Project Conditions B	ProjectB_500_Depth.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Velocity, With Project Conditions B	ProjectB_500_Velocity.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Water Surface Elevation, With Project Cond. B	ProjectB_500_wse.pdf
Project B Compared to Existing	2 yr Flood Event, Flow: 97,500 cfs, Change in Depth, Project Conditions B	PB-Difference_002_Depth.pdf
	2 yr Flood Event, Flow: 97,500 cfs, Change in Velocity, Project Conditions B	PB-Difference_002_Velocity.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Change in Depth, Project Conditions B	PB-Difference_005_Depth.pdf
	5 yr Flood Event, Flow: 137,000 cfs, Change in Velocity, Project Conditions B	PB-Difference_005_Velocity.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Change in Depth, Project Conditions B	PB-Difference_010_Depth.pdf
	10 yr Flood Event, Flow: 160,600 cfs, Change in Velocity, Project Conditions B	PB-Difference_010_Velocity.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Change in Depth, Project Conditions B	PB-Difference_025_Depth.pdf
	25 yr Flood Event, Flow: 206,575 cfs, Change in Velocity, Project Conditions B	PB-Difference_025_Velocity.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Change in Depth, Project Conditions B	PB-Difference_050_Depth.pdf
	50 yr Flood Event, Flow: 237,829 cfs, Change in Velocity, Project Conditions B	PB-Difference_050_Velocity.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Change in Depth, Project Conditions B	PB-Difference_100_Depth.pdf
	100 yr Flood Event, Flow: 275,910 cfs, Change in Velocity, Project Conditions B	PB-Difference_100_Velocity.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Change in Depth, Project Conditions B	PB-Difference_200_Depth.pdf
	200 yr Flood Event, Flow: 315,965 cfs, Change in Velocity, Project Conditions B	PB-Difference_200_Velocity.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Change in Depth, Project Conditions B	PB-Difference_500_Depth.pdf
	500 yr Flood Event, Flow: 424,511 cfs, Change in Velocity, Project Conditions B	PB-Difference_500_Velocity.pdf