TECHNICAL MEMORANDUM

Broadway Bridge Feasibility Study Preliminary Hydraulics Study

PREPARED FOR:	City of West Sacramento, in cooperation with the City of Sacramento
PREPARED BY:	WRECO

Introduction

The purpose of this technical memorandum is to summarize the preliminary hydrologic and hydraulic analyses of the Sacramento River at the project site, and the preliminary scour analysis of the proposed Broadway Bridge over the Sacramento River.

Proposed Bridge

The hydraulic and scour analyses were performed for the south alignment double-leaf bascule bridge and vertical lift bridge. However, the hydraulic analyses of double-leaf bascule bridge was not further performed after the preliminary two-dimensional (2D) hydraulic analyses and scour analyses were performed. Therefore, not all of the sections in this technical memorandum discuss the outputs from the hydraulic and scour analyses of the double-leaf bascule bridge. A 72-foot bridge width was chosen as the baseline assumption for the hydraulic analysis, which is reflected in the attached figures. An updated analysis will be completed in the environmental/preliminary engineering phase once a preferred bridge alternative is selected.

Double-Leaf Bascule Bridge

The proposed double-leaf bascule bridge over the Sacramento River would be an 820-foot-long, 75.5-foot-wide bridge and include two 12-foot-wide traffic lanes, two 8-foot-wide bicycle lanes, two 10-foot-wide sidewalks, and a 12-foot-wide median (**Figure 1**). The span between Bents 2 and 3 would be 230 feet long and leafs can swing upwards to provide sufficient horizontal and vertical clearance for the vessels traveling the river.

Vertical Lift Bridge

The proposed vertical lift bridge over the Sacramento River would be an 820-foot-long, 75.5-foot-wide bridge and include two 12-foot-wide traffic lanes, two 8-foot-wide bicycle lanes, two 10-foot-wide sidewalks, and a 12-foot-wide median (**Figure 2**). The span between Bents 3 and 4 would be 220 feet long and could be lifted vertically to provide sufficient horizontal and vertical clearance for the vessels traveling the river.

Bridge Design Standards

The proposed Broadway Bridge over the Sacramento River would need to comply with the criterion for the hydraulic design of bridges set by the Federal Highway Administration (FHWA), California Department of Transportation (Caltrans), Central Valley Flood Protection Board (CVFPB), and U.S. Coast Guard (USCG).

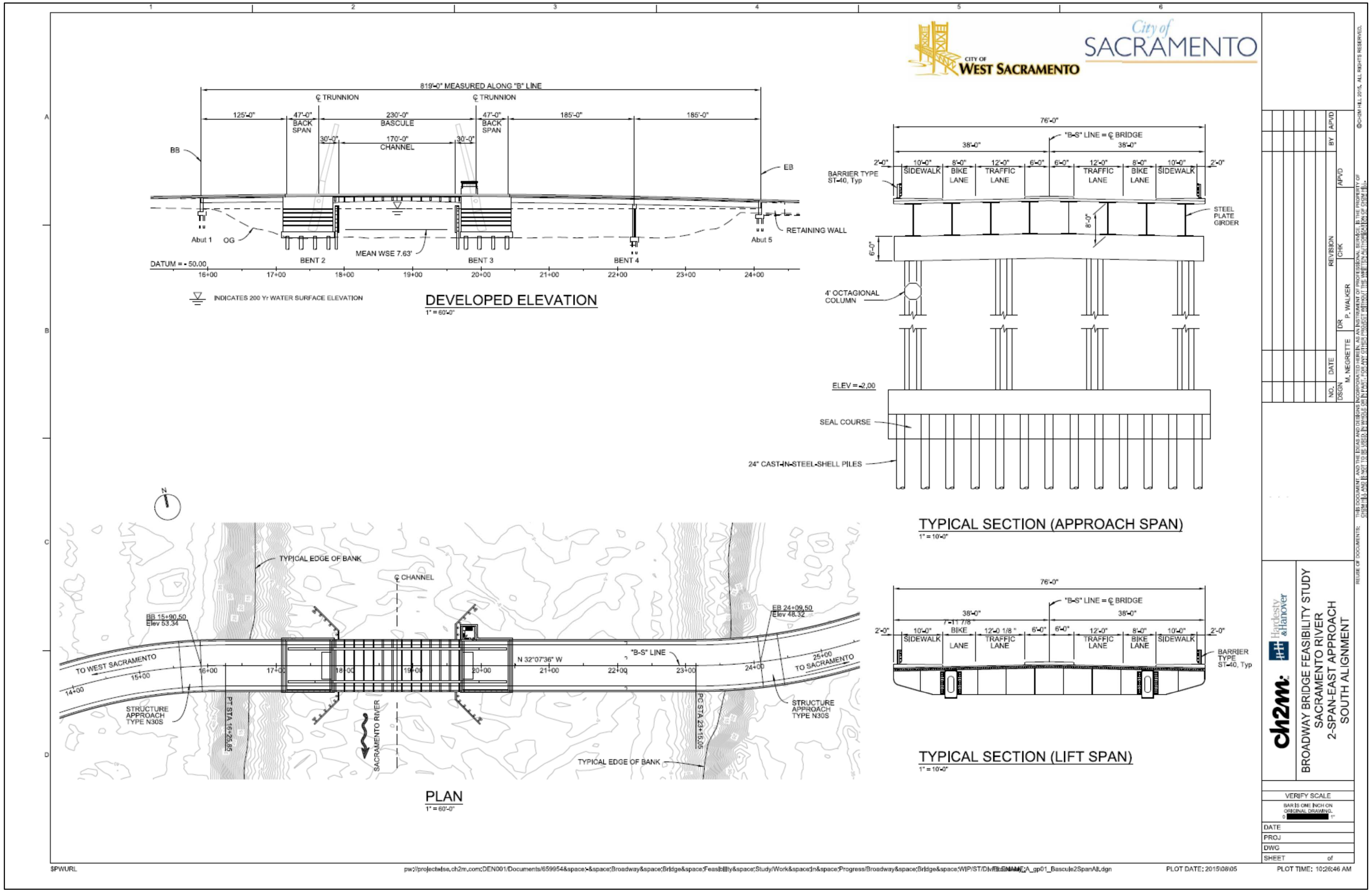

Figure 1. Proposed Bridge General Plan, Double-Leaf Bascule Bridge

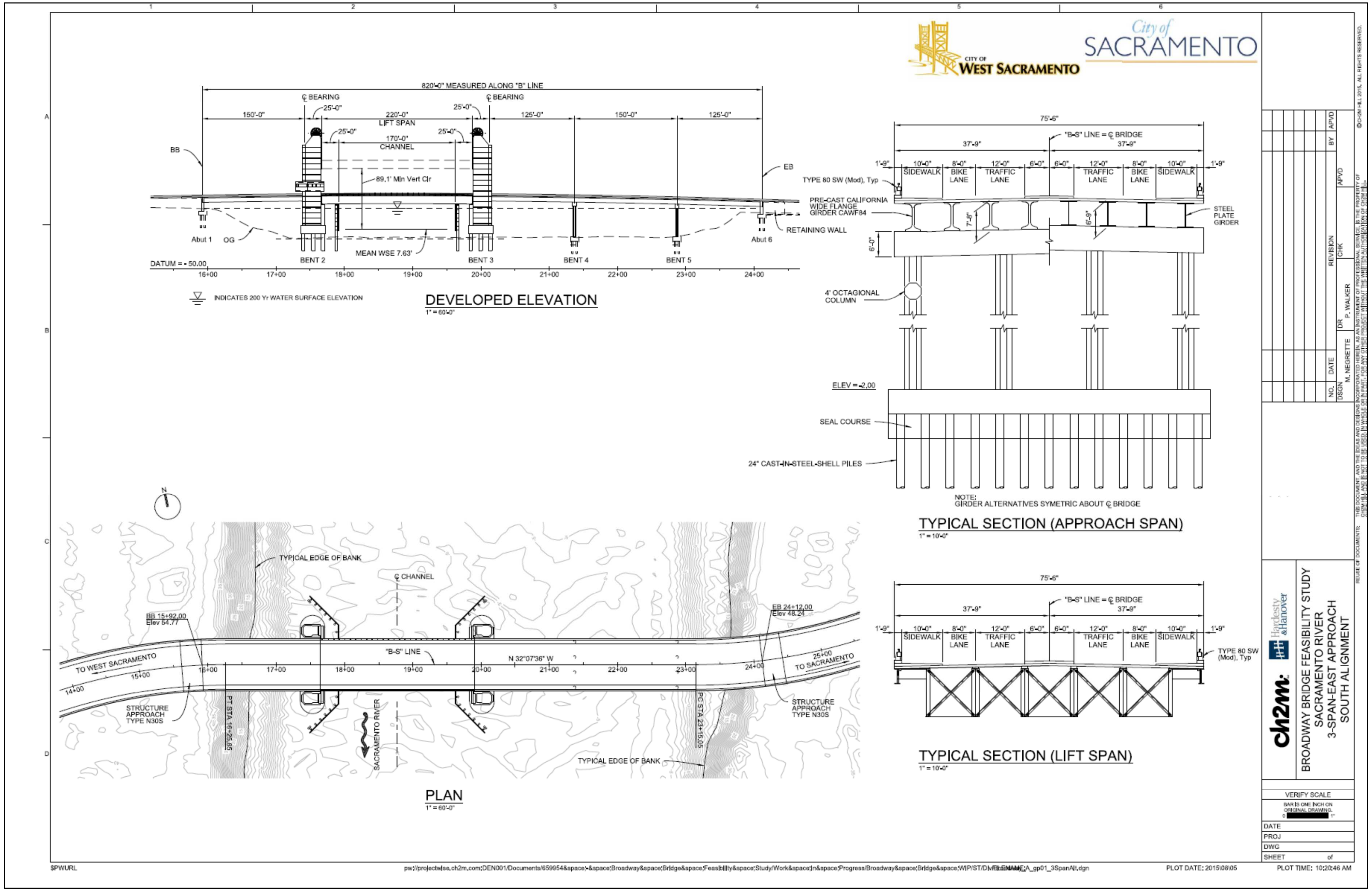

Figure 2. Proposed Bridge General Plan, Vertical Lift Bridge

FHWA Standards

The FHWA criterion for the hydraulic design of bridges is that they be designed to pass the 2 percent probability of annual exceedance flow (50-year recurrence interval design discharge) with adequate freeboard, where practicable, to account for debris and bedload.

Caltrans Standards

The Caltrans criteria for the hydraulic design of bridges is that they be designed to pass the 2 percent probability of annual exceedance flow (50-year design discharge) or the flood of record, whichever is greater, with adequate freeboard to pass anticipated drift. Two feet of freeboard is commonly used in bridge designs. The bridge should also be designed to pass the 1 percent probability of annual exceedance flow (100-year design discharge, or base flood). No freeboard is added to the base flood.

CVFPB Standards

Streams regulated by the CVFPB must adhere to the design criteria from Title 23 of the California Code of Regulations. CVFPB's list of regulated streams includes the Sacramento River at the project location, and they maintain nonpermissible work periods during the flood season from November 1 through April 15. CVFPB may allow work to be done during the flood season if provided forecasts for weather and river conditions are favorable.

The bridge freeboard criteria for the CVFPB are determined by the design capacity and number of residents in the project vicinity. The soffit of the proposed bridge must be at least 3 feet above the design flood profile for major streams (channel capacity greater than 8,000 cubic feet per second [cfs]). The required freeboard can be reduced to 2 feet on minor streams (design capacity less than 8,000 cfs) where significant amounts of stream debris are unlikely. CVFPB will be requiring a 200-year level of protection starting in 2025 for urban and urbanizing areas in the California Central Valley. A design flood can be the 100-year flow in nonurban areas.

The proposed project is in the urban/urbanizing area and the Sacramento River at the project location is classified as major stream with a capacity greater than 8,000 cfs. The proposed bridge would be designed for the 200-year flow with a minimum 3 feet of freeboard.

USCG Standards

The Sacramento River at the project site is under the jurisdiction of the USCG and is classified as navigable waterway. The proposed bridge would be required to meet the horizontal and vertical clearances set by the USCG. The minimum horizontal clearance required for the proposed bridge is 170 feet. The minimum vertical clearance required for the proposed bridge is 89.1 feet above the mean water surface elevation (WSE) level.

Hydrologic Analysis

WRECO reviewed the available hydrologic data of the Sacramento River to develop design discharges at the project location. The hydrologic data in the project vicinity were available from the U.S. Army Corps of Engineers (USACE), Federal Emergency Management Agency (FEMA), and City of West Sacramento.

USACE

USACE's *Sacramento and San Joaquin River Basins Comprehensive Study* – Technical Studies Appendix D, Hydraulic Technical Documentation provided the design flow capacity of the Sacramento River between Shasta and Collinsville. The proposed Broadway Bridge over the Sacramento River is within the watercourse segment between the Sacramento Weir and Sutter Slough. The design flow capacity of the Sacramento River between the Sacramento Weir and Sutter Slough is shown in **Table 1**. The limits of the watercourse segment are shown in **Figure 3**.

Table 1. Design Flow Capacity of Sacramento River

Watercourse Segment in Sacramento River	Design Flow Capacity (cfs)
Sacramento Weir to Sutter Slough	110,000

Source: USACE

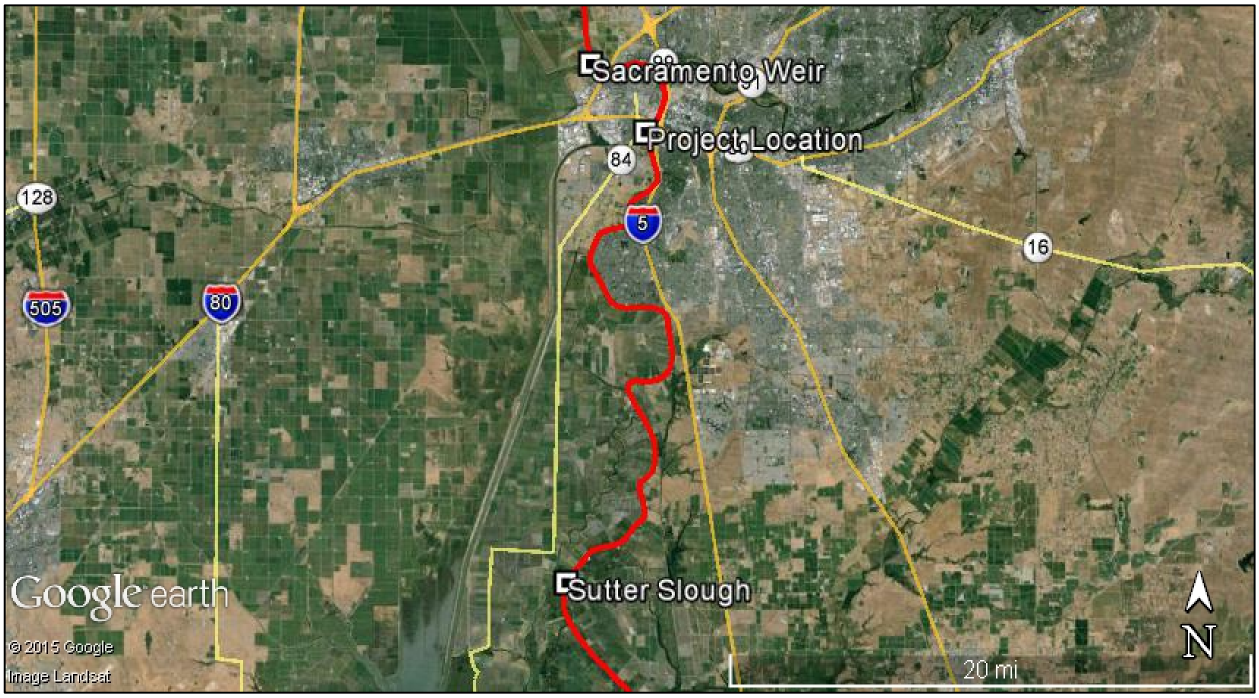

Figure 3. Limits of the Watercourse Segment
Source: Google Earth

FEMA

The FEMA Flood Insurance Study (FIS) for Sacramento County and incorporated areas (effective August 2012) and FEMA FIS for Yolo County and incorporated areas (effective May 2012) provided the 100-year peak discharge of the Sacramento River at I Street, located approximately 1.4 miles north-northeast of the project location (**Figure 4**). The design 100-year flow and corresponding 100-year water surface from the Sacramento County FIS and Yolo County FIS were identical; the number is shown in **Table 2**.

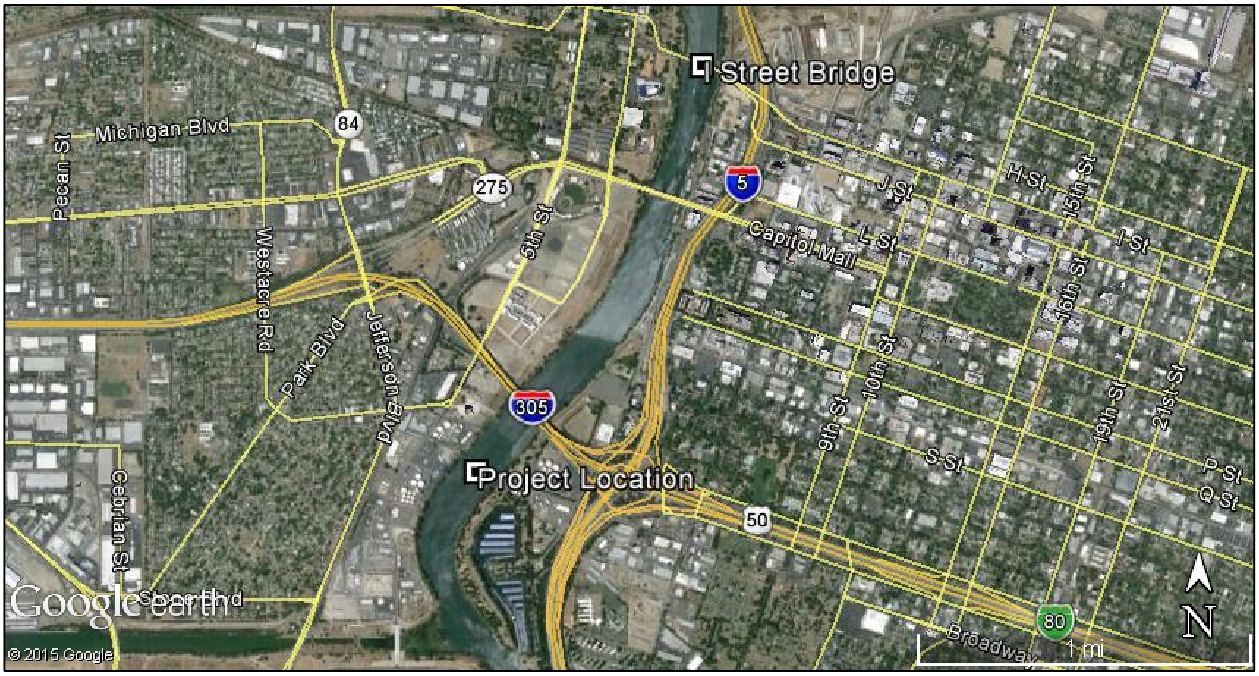

Figure 4. FEMA FIS Flood Source Location
Source: Google Earth

Table 2. FEMA FIS Hydrologic Data Summary

Flood Source and Location	Peak 100-year flow Discharge (cfs)
Sacramento River at I Street	120,000

Notes:
cfs = cubic feet per second
Source: FEMA

City of West Sacramento

The City of West Sacramento's *West Sacramento Levee Improvement Program CHP Academy and The Rivers Early Implementation Projects Final – 408 Permission Environmental Impact Statement/Environmental Impact Report, Appendix D – Flood Control and Geomorphic Conditions Technical Appendix* provided 100- and 200-year flows of the Sacramento River at the I Street bridge (see Figure 4 for location). The design flows from City of West Sacramento are summarized in **Table 3**.

Table 3. City of West Sacramento Hydrologic Data Summary

Flood Source and Location	Peak 100-year flow Discharge (cfs)	Peak 200-year flow Discharge (cfs)
Sacramento River at I Street	135,600	143,300

Source: City of West Sacramento

Design Flow for Hydraulic Assessment

The design flows from the City of West Sacramento provided the most conservative design 100- and 200-year flows from the available data. Therefore, hydrologic information available from the City of West Sacramento was used in the 1D and 2D hydraulic analyses.

1D Hydraulic Analysis

Design Tools

The 1D hydraulic analyses of the Sacramento River were performed based on a standard step backwater calculation using USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 4.1 to provide the flow characteristics of the river at the project location. The hydraulic analysis assumed steady-state flow, fixed channel bed, and no sediment inflow/outflow. The analyses were performed for the existing and proposed conditions.

Cross-section Data

The channel cross sections in the hydraulic model were developed from the bathymetry data of the Sacramento River and ground elevation of overbank areas provided by CH2M and the California Department of Water Resources (DWR). The length of the hydraulic model is approximately 8,500 feet, extending 5,000 feet upstream and 3,500 feet downstream of the proposed Broadway Bridge over the Sacramento River.

Manning's Roughness Coefficient

Manning's roughness coefficients were used in the hydraulic model to estimate energy losses in the flow due to friction. Manning's roughness coefficients were selected to best describe the existing and proposed channel characteristics of the Sacramento River at the project location, based on the channel geometry data, and aerial imagery. The Manning's n value used for the channel is 0.035.

Expansion and Contraction Coefficients

Expansion and contraction coefficients were used to describe transitions between cross sections. The expansion and contraction coefficients used in the channel were 0.3 and 0.1, respectively. They represent a waterway with a gradual transition between cross sections. Expansion and contraction coefficients of 0.5 and 0.3, respectively, were used at cross sections upstream of the proposed Broadway Bridge and US 50 bridge to represent impacts to the flow field caused by the existing and proposed bridge structures.

Modeled Hydraulic Structures

The HEC-RAS hydraulic model for the existing and proposed conditions included the proposed Broadway Bridge (proposed condition only) and US 50 bridge (both conditions). The design of the US 50 bridge was based on the as-builts and bridge inspection reports (BIR). The design of the proposed Broadway Bridge in the hydraulic model was based on the bridge general plans provided by CH2M.

Downstream Control Water-surface Elevations

The City of West Sacramento's study provided the 100- and 200-year WSEs of the Sacramento River from the hydraulic analysis based on the 100- and 200-year design flows. **Table 4** shows the maximum 100- and 200-year WSEs from their study closest to the Project location that was used as the downstream control WSE for the existing and proposed condition hydraulic analyses.

Table 4. City of West Sacramento Hydrologic Data Summary

Flood Source and Location	100-year WSE (feet NAVD 88)	200-year WSE (feet NAVD 88)
Sacramento River at RM 59.695 (approximately 0.3 mile downstream of project location)	34.67	36.37

Water-surface Elevations

A comparison of the 100- and 200-year WSEs for the existing and proposed conditions in the vicinity of the proposed Broadway Bridge over the Sacramento River are summarized in **Table 5** and **Table 6**, respectively.

The outputs from the HEC-RAS hydraulic analysis showed that the vertical lift bridge would increase the 100- and 200-year WSEs and the WSEs by approximately 0.09 foot upstream of the proposed bridge location. The double-leaf bascule bridge would increase the 100- and 200-year WSEs and the WSEs by approximately 0.13 foot upstream of the proposed bridge location. Because the double-leaf bascule bridge would have wider piers supporting the movable-bridge structure than the vertical lift bridge, the flow obstruction would be greater and would increase the 100- and 200-year WSEs more than the vertical lift bridge. For both proposed bridge design, the increase in 100- and 200-year WSEs would not attenuate at 5,000 feet upstream of the proposed bridge location.

Table 5. Sacramento River 100-Year Water-surface Elevations

Flood Source and Location	**Existing Condition (feet NAVD 88)**	**Proposed Condition: Vertical Lift Bridge (feet NAVD 88)**	**Proposed Condition: Double-Leaf Bascule Bridge (feet NAVD 88)**
Upstream limit of the hydraulic model (approximately 5,000 feet upstream of the proposed Broadway Bridge)	36.06	36.15	36.18
Immediately upstream of US 50 Bridges	35.39	35.48	35.52
Immediately downstream of US 50 Bridges	35.38	35.47	35.51
Immediately upstream of Broadway Bridge	35.36	35.29	35.49
Upstream face of Broadway Bridge	-	35.27	35.20
Downstream face of Broadway Bridge	-	35.25	35.18
Immediately downstream of Broadway Bridge	35.35	35.25	35.35
Downstream limit of hydraulic model (approximately 3,500 feet downstream of the proposed Broadway bridge)	34.67	34.67	34.67

Table 6. Sacramento River 200-Year Water-surface Elevations

Flood Source and Location	Existing Condition (feet NAVD 88)	Proposed Condition: Vertical Lift Bridge (feet NAVD 88)	Proposed Condition: Double-Leaf Bascule Bridge (feet NAVD 88)
Upstream limit of the hydraulic model (approximately 5,000 feet upstream of the proposed Broadway Bridge)	37.73	37.82	37.85
Immediately upstream of US 50 Bridges	37.06	37.15	37.19
Immediately downstream of US 50 Bridges	37.05	37.14	37.18
Immediately upstream of Broadway Bridge	37.05	36.97	37.18
Upstream face of Broadway Bridge	-	36.95	36.86
Downstream face of Broadway Bridge	-	36.94	36.88
Immediately downstream of Broadway Bridge	37.03	36.93	37.03
Downstream limit of hydraulic model (approximately 3,500 feet downstream of the proposed Broadway bridge)	36.37	36.37	36.37

2D Hydraulic Analysis

2D hydraulic analyses of the Sacramento River at the project site were performed using Aquaveo's Surface-water Modeling System (SMS) version 11.2 with the Finite Element Surface-water Modeling System (FESWMS). SMS is a graphical user interface used for the pre- and post-processing of the model that includes developing a finite element mesh representing the creek geometry, setting model parameters, running the model, and visualizing the results. FESWMS is a hydrodynamic modeling code developed with funding by the FHWA, suited for modeling regions involving flow-control structures.

The 2D hydraulic analysis of the double-leaf bascule bridge was not performed after the preliminary 2D hydraulic analyses when the smaller model footprint was performed. Therefore, this section only discusses existing condition and the proposed condition with the vertical lift bridge.

Model Inputs

A 3D finite element mesh for the existing and proposed conditions was created in SMS by importing the bathymetry data of the Sacramento River and ground elevation of overbank areas provided by CH2M and the DWR. The upstream and downstream limits of the hydraulic model are approximately 1,700 feet upstream and 1,000 feet downstream from the proposed south alignment bridge (see Figure 1). The eastern limits of the hydraulic model are the existing railroad tracks in the City of Sacramento. The western limit of the hydraulic model is the end of the overbank slope. The finite-element mesh was composed of triangles and quadrilaterals with edge lengths varying from approximately 4 feet to 15 feet. The finite element mesh for the existing and proposed conditions model is composed of approximately 8,000 triangles and 10,000 quadrilaterals.

The existing and proposed hydraulic structures within the limit of the hydraulic model are the US 50 bridge and the proposed south alignment lift bridge. The design of the proposed lift bridge in the hydraulic model was based on the bridge general plans provided by CH2M. The design of the US 50 bridge in the hydraulic model was based on the Caltrans' Bridge Inspection Reports and as-builts. Flow obstruction from bridge piers, abutments, and fenders were represented in the hydraulic model as a void space. This hydraulic analysis assumed both the US 50 bridge and proposed lift bridge would have sufficient clearance during the 200-year storm event.

The 2D hydraulic model was set to a steady-state hydraulic condition (**Figure 5**). The inflows to the model and downstream control WSE were same as the inputs for the HEC-RAS hydraulic analysis (see Table 3 and Table 4).

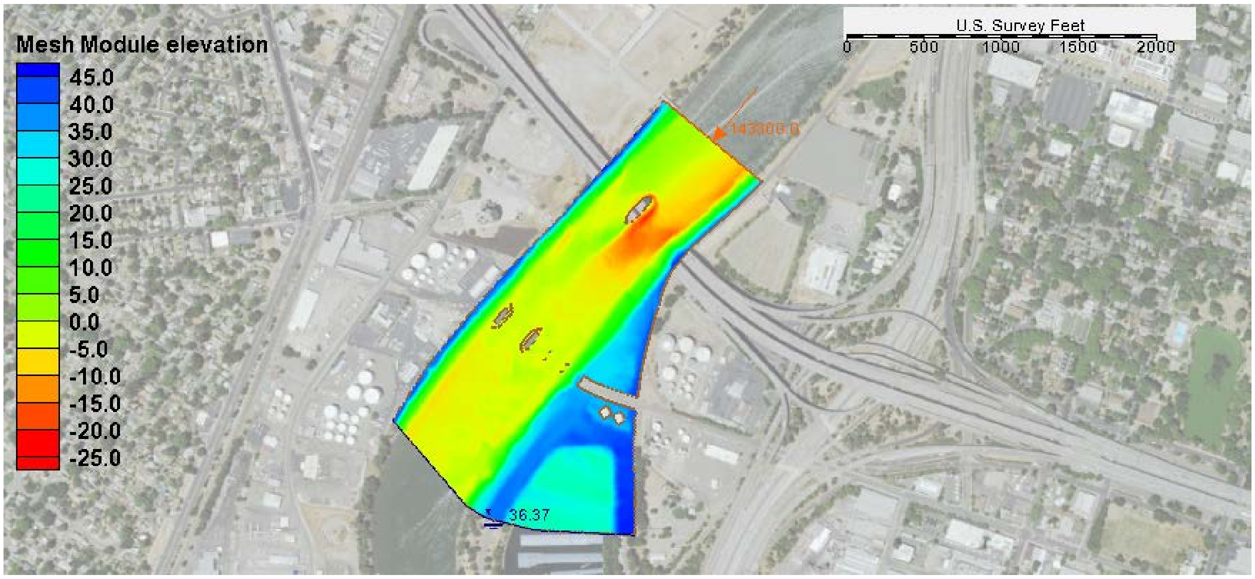

Figure 5. 2D Model Limits

A Manning's roughness coefficient was assigned to the individual finite-element mesh in the hydraulic model. The Manning's roughness coefficients assigned to the mesh are summarized in **Table 7**.

Table 7. Manning's Roughness Coefficients

Surface Type	Manning's Roughness Coefficient
General area below waterline	0.035
Below waterline, impacted by fender	0.045
General area above waterline	0.045
Paved surface	0.020

Model Outputs – Water-surface Elevation

Six cross sections were taken within this reach to present the water-surface elevation variation along the reach. **Figure 6** presents the locations of the cross sections. **Figures 7 and 8** present the spatial representation of the existing and proposed condition 100-year WSEs in the model reach. **Figures 9 and 10** present spatial representations of the existing and proposed condition 200-year WSEs in the model reach. **Figures 11-16** show the WSEs at an exaggerated scale at each of the six cross section locations. **Figure 17** shows a cross section in a more typical scale at cross section 1.

The hydraulic analysis shows the proposed lift bridge creates an increase of approximately 0.1 foot in the 100- and 200-year WSE throughout the length of the 2D model domain upstream of the proposed lift bridge.

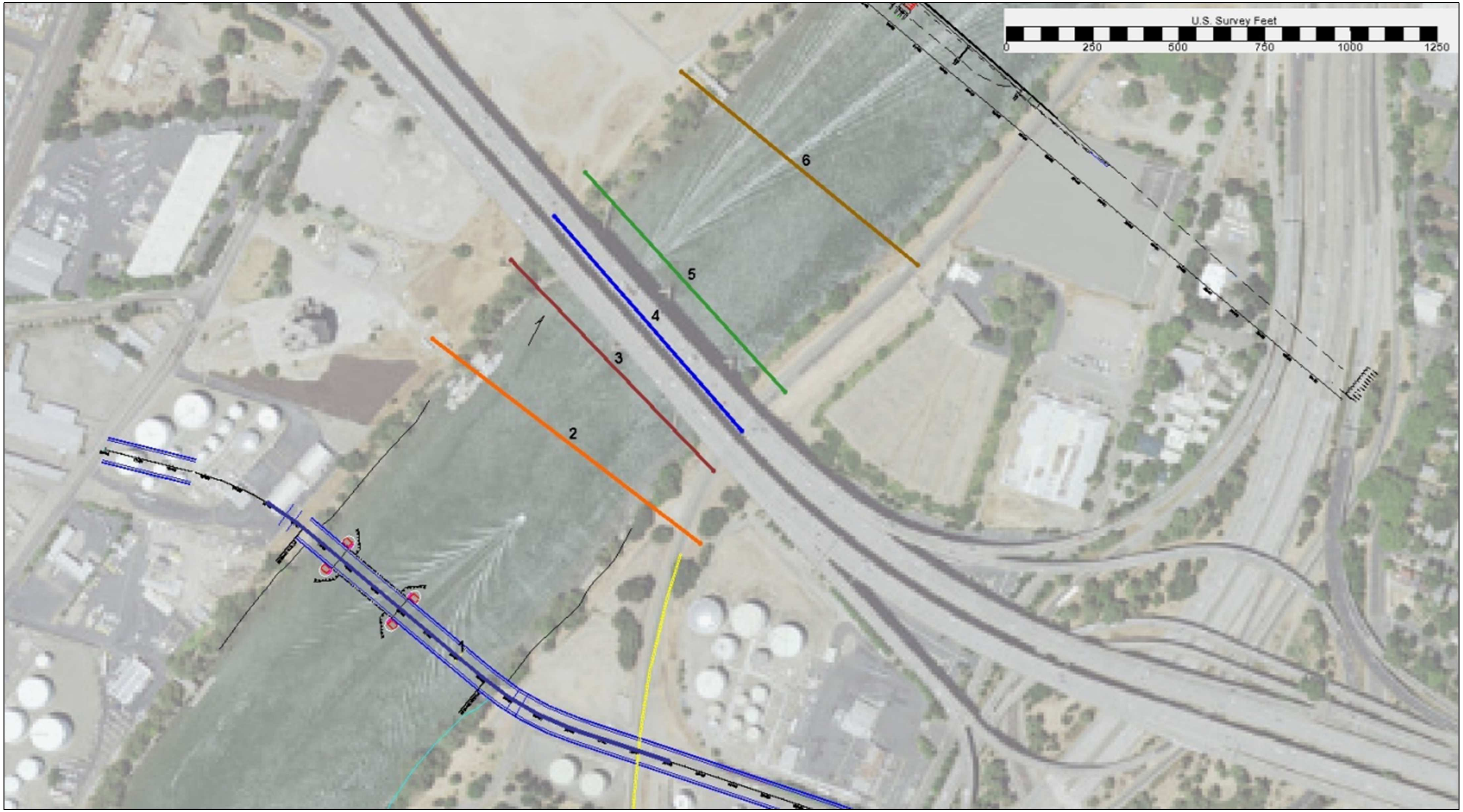

Figure 6. Cross Section Locations

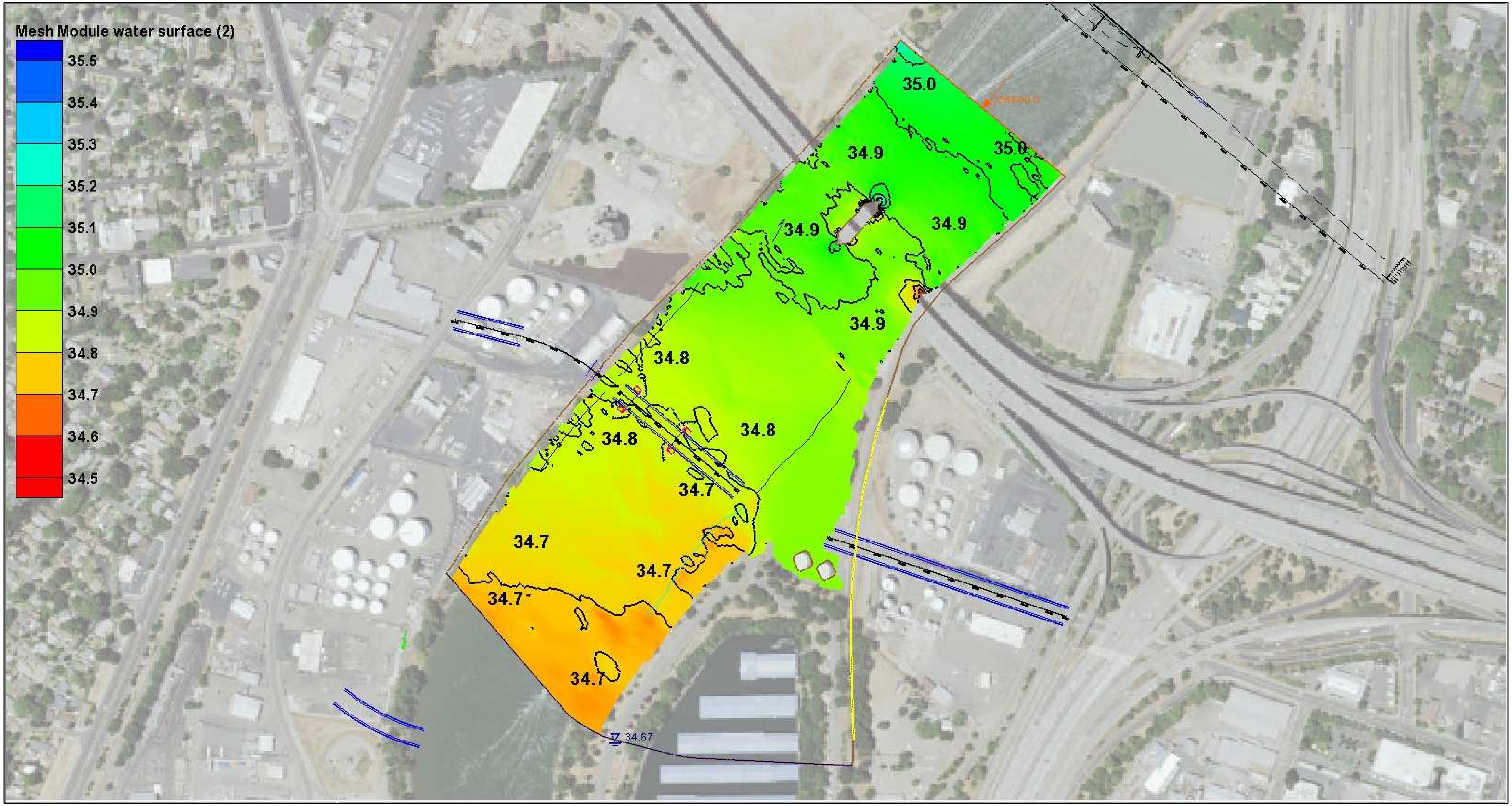

Figure 7. Existing Condition Model Output: Water Surface Elevations, Q100

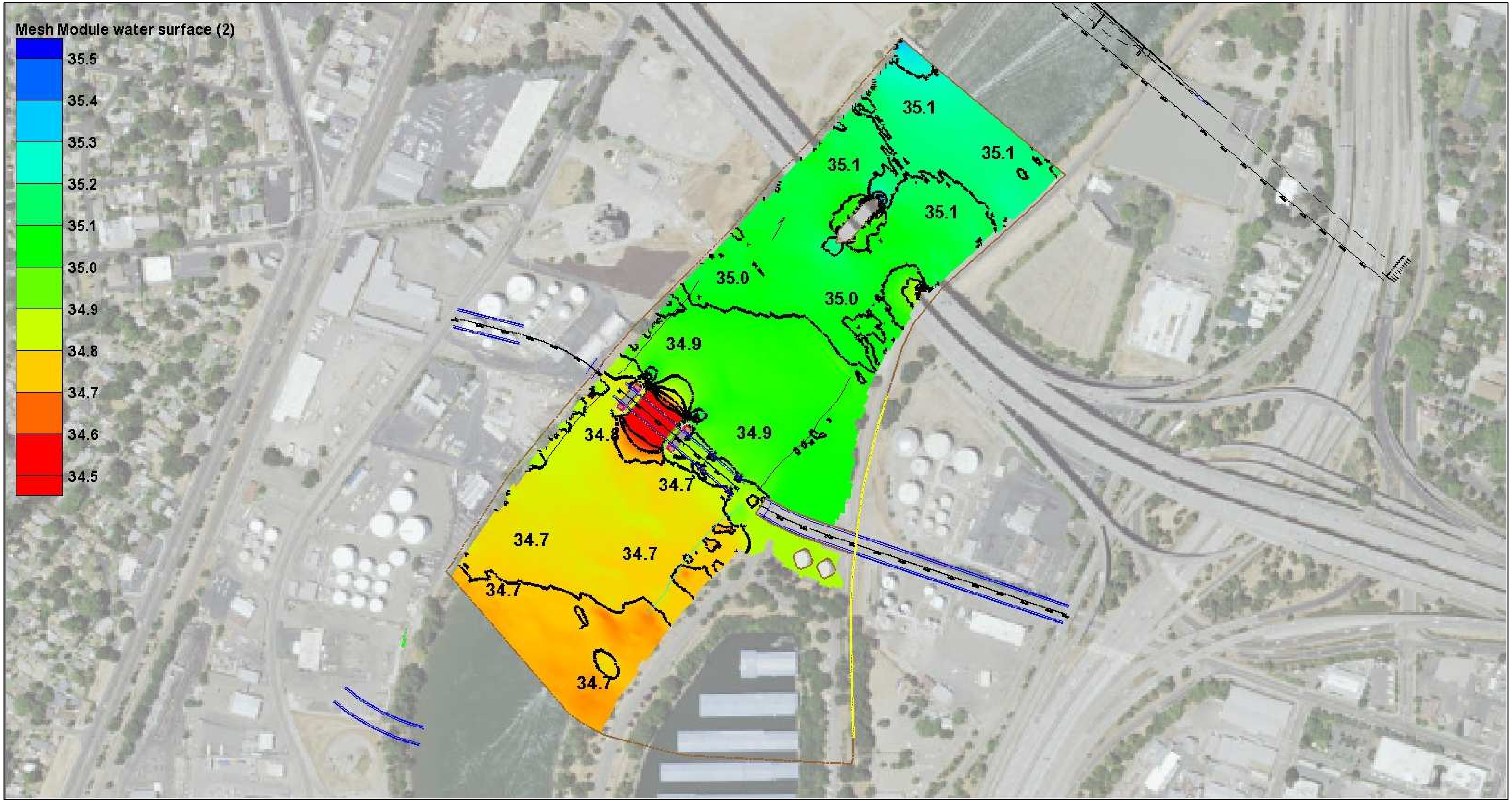

Figure 8. Proposed Condition Model Output: Water Surface Elevations, Q100

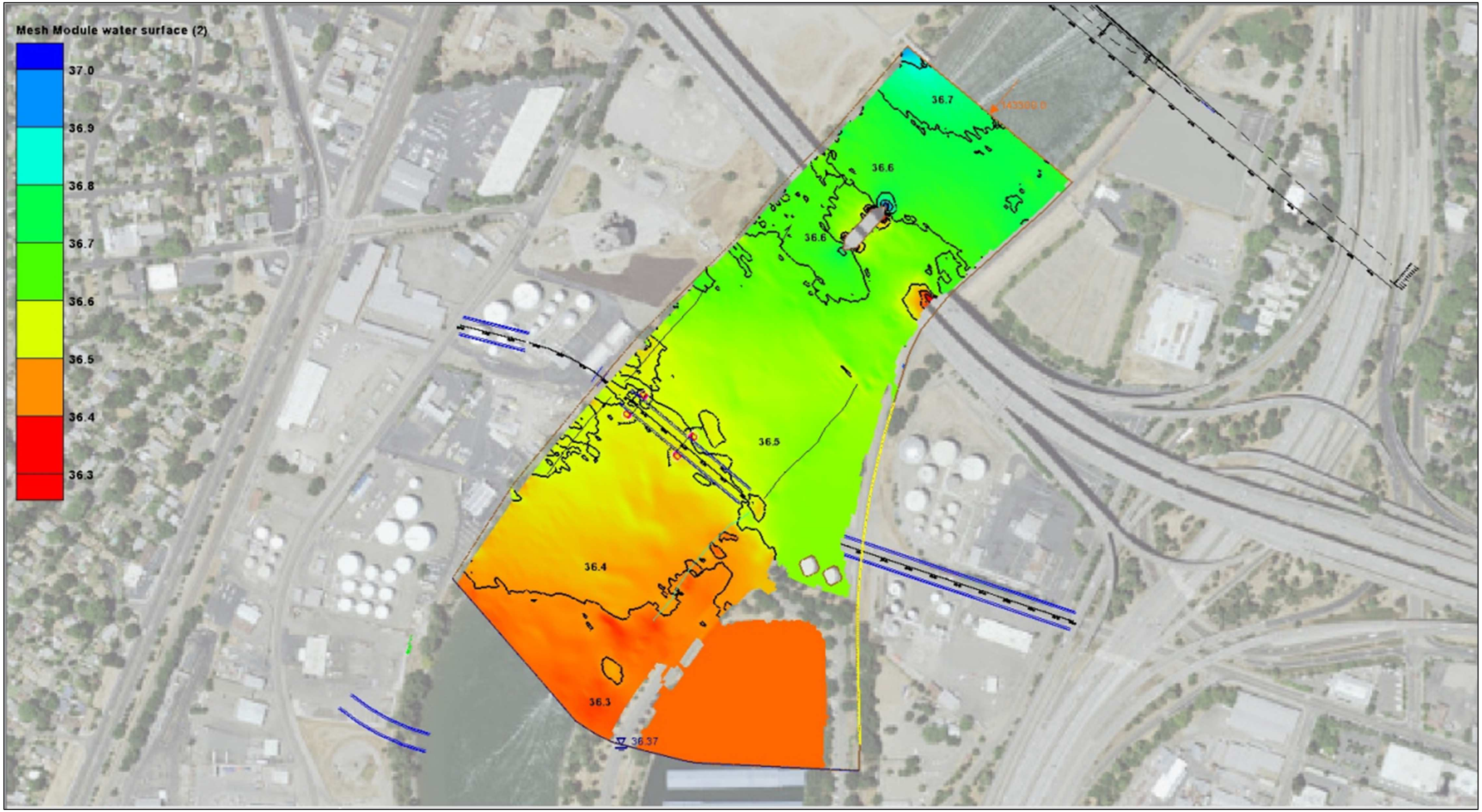

Figure 9. Existing Condition Model Output: Water Surface Elevations, Q200

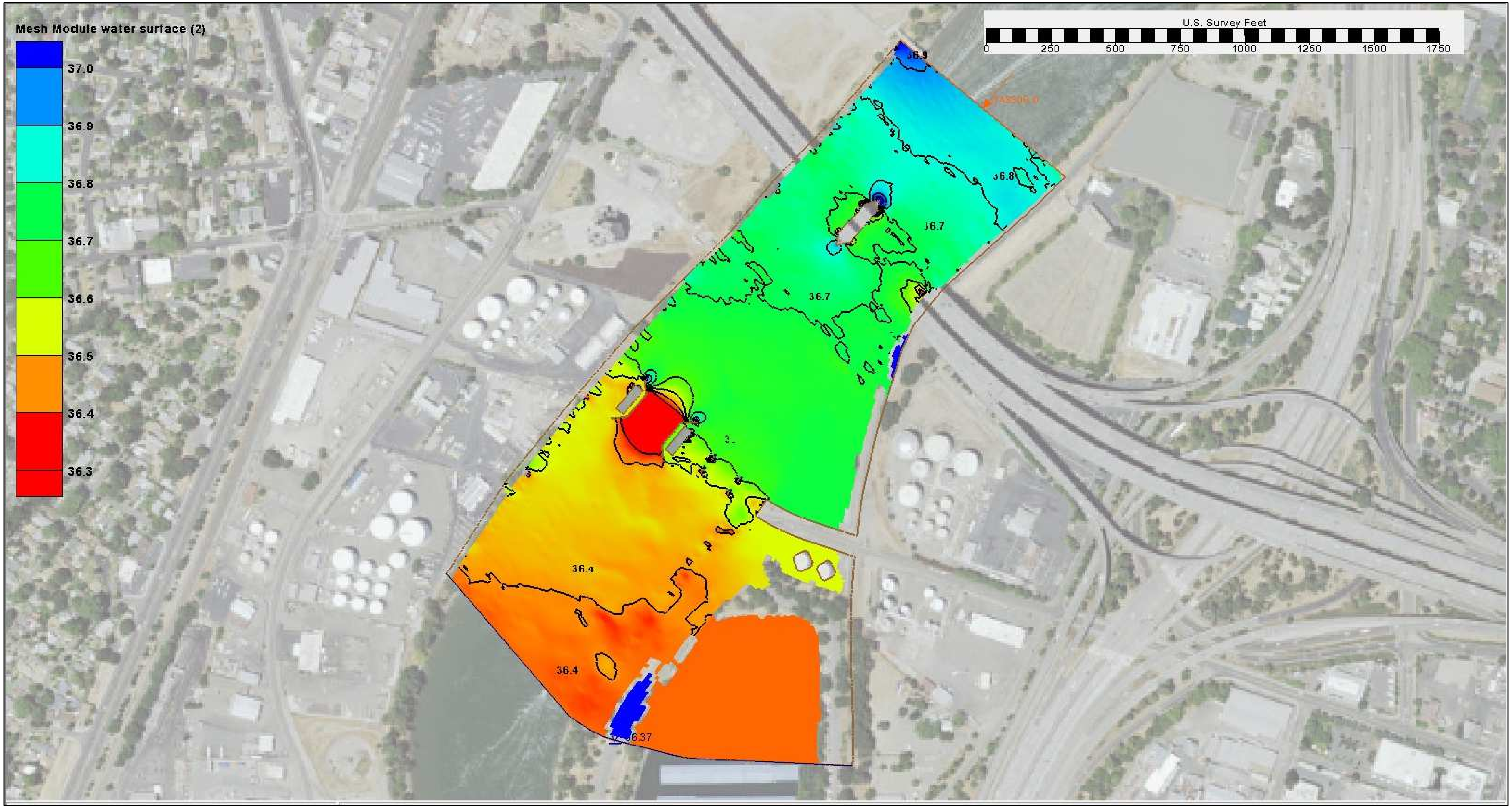

Figure 10. Proposed Lift Bridge Condition Model Output: Water Surface Elevations, Q200

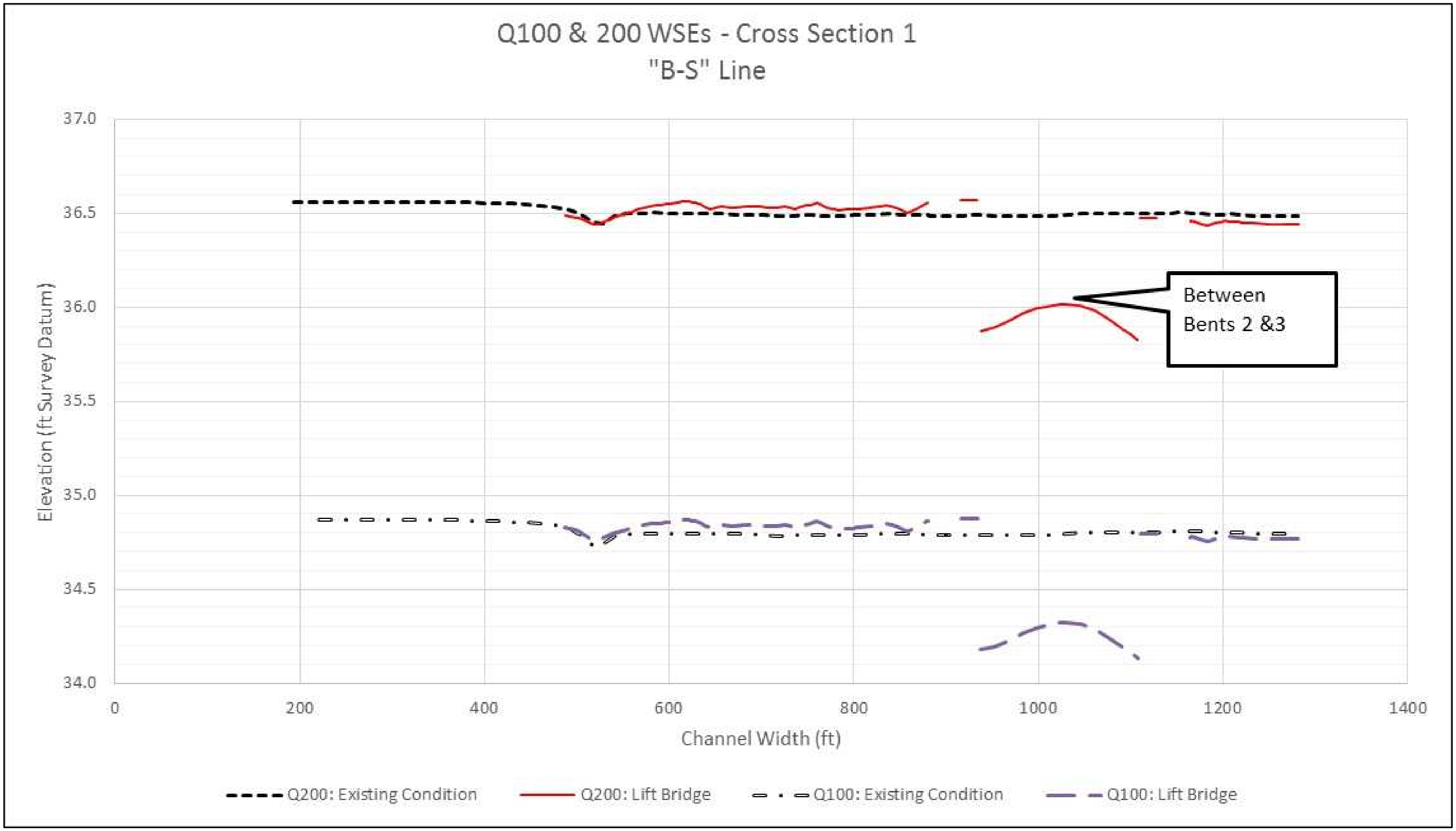

Figure 11. Cross Section 1, exaggerated scale to show WSE difference

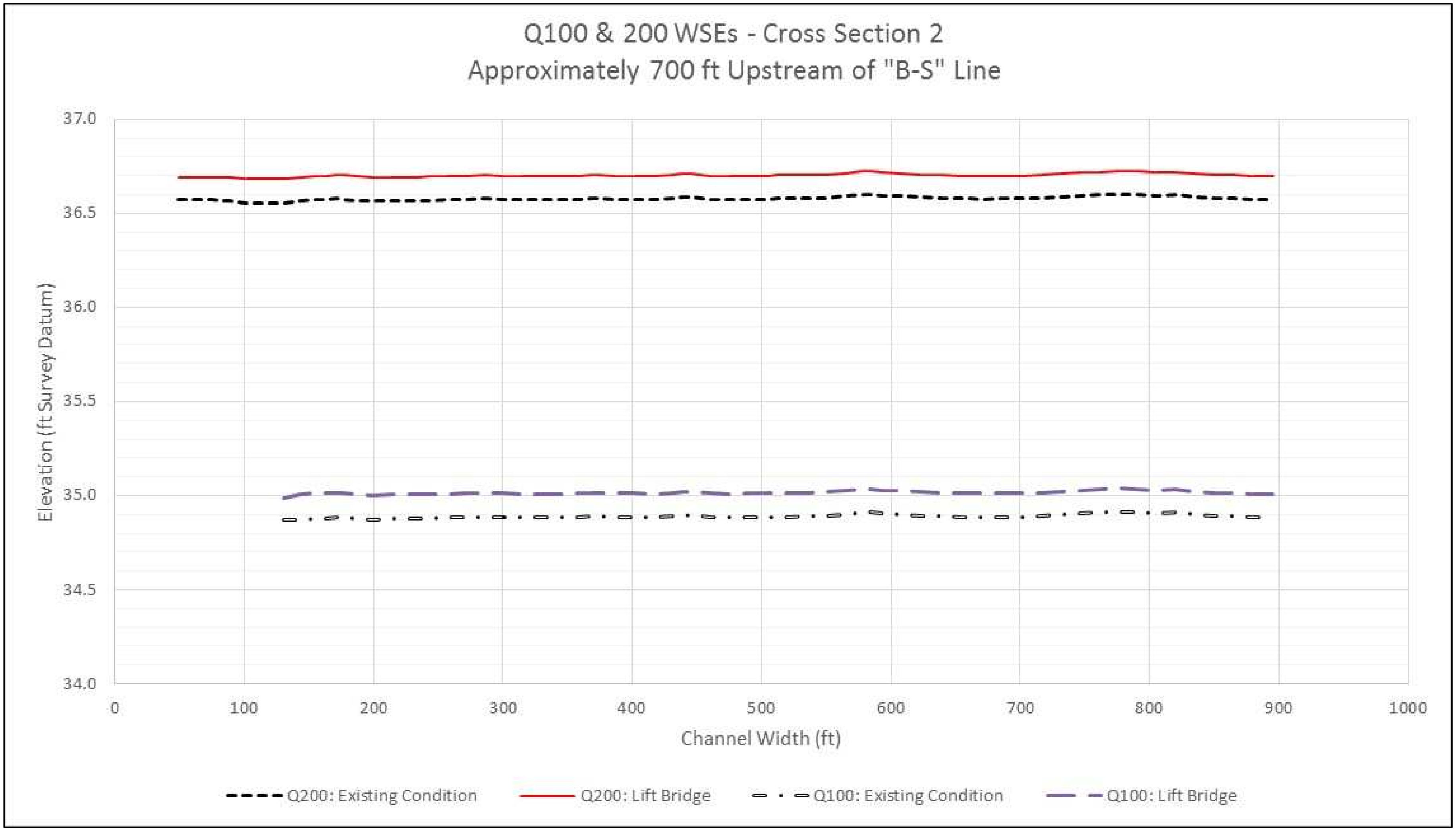

Figure 12. Cross Section 2, exaggerated scale to show WSE difference

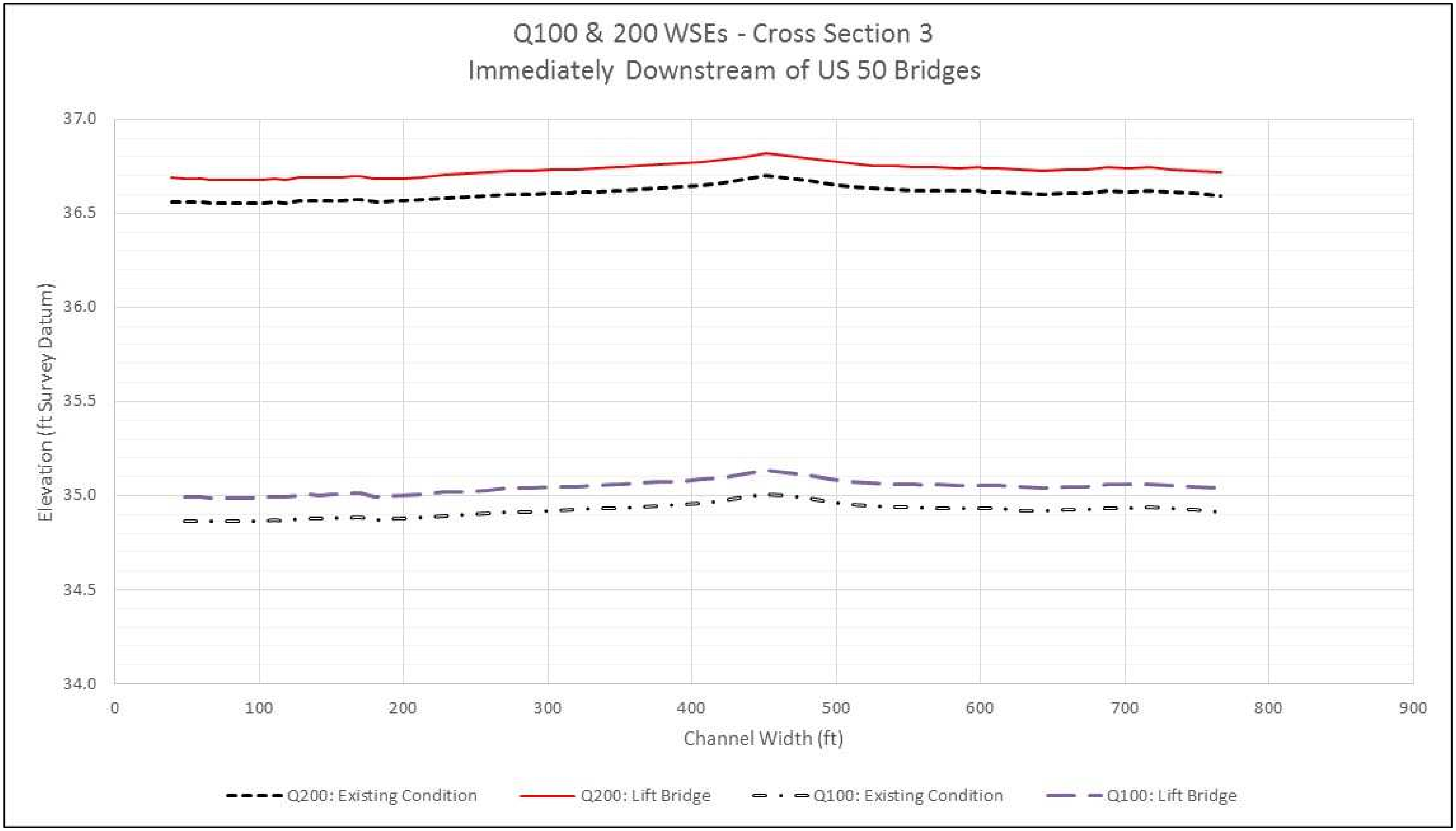

Figure 13. Cross Section 3, exaggerated scale to show WSE difference

Figure 14. Cross Section 4, exaggerated scale to show WSE difference

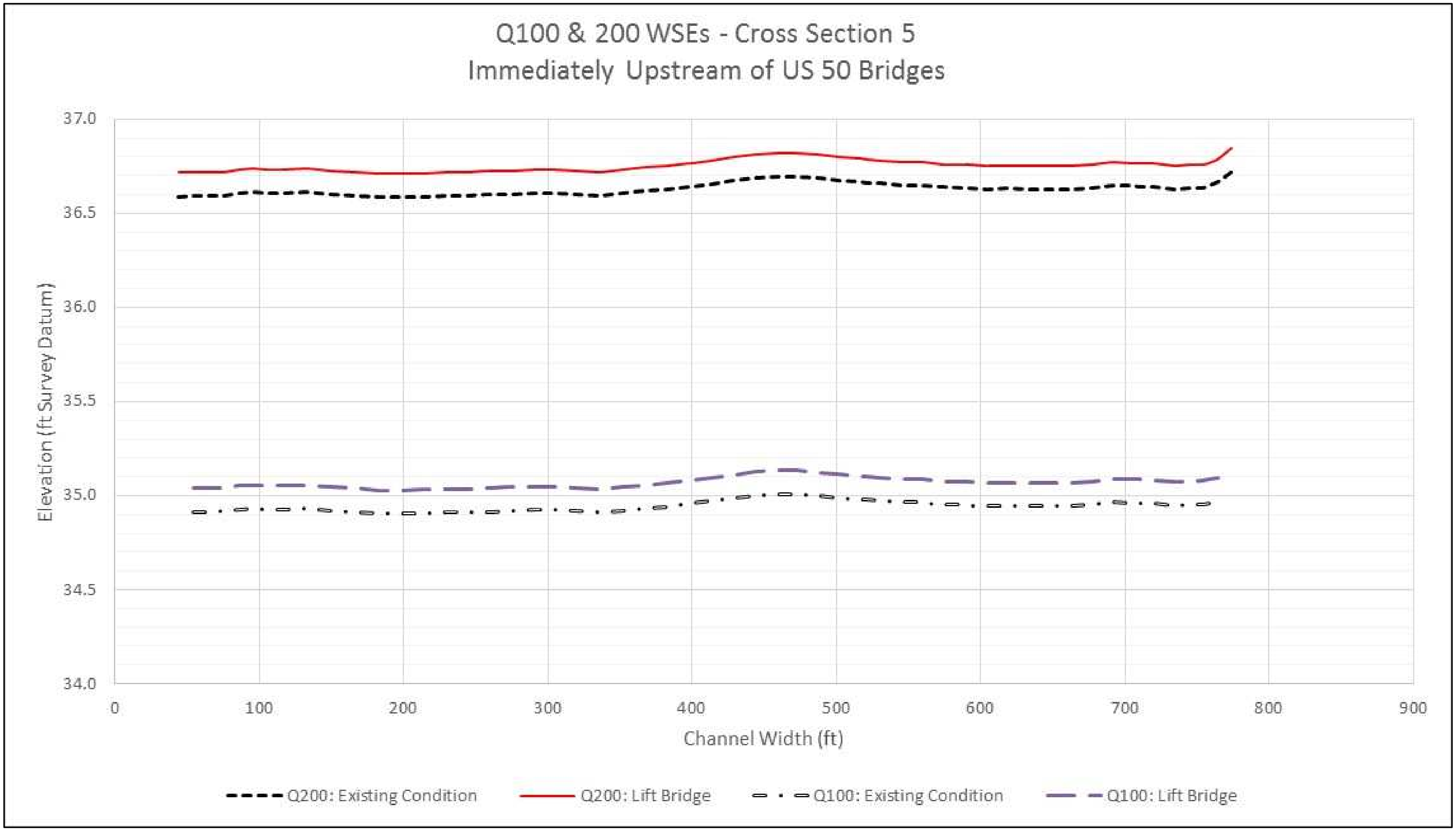

Figure 15. Cross Section 5, exaggerated scale to show WSE difference

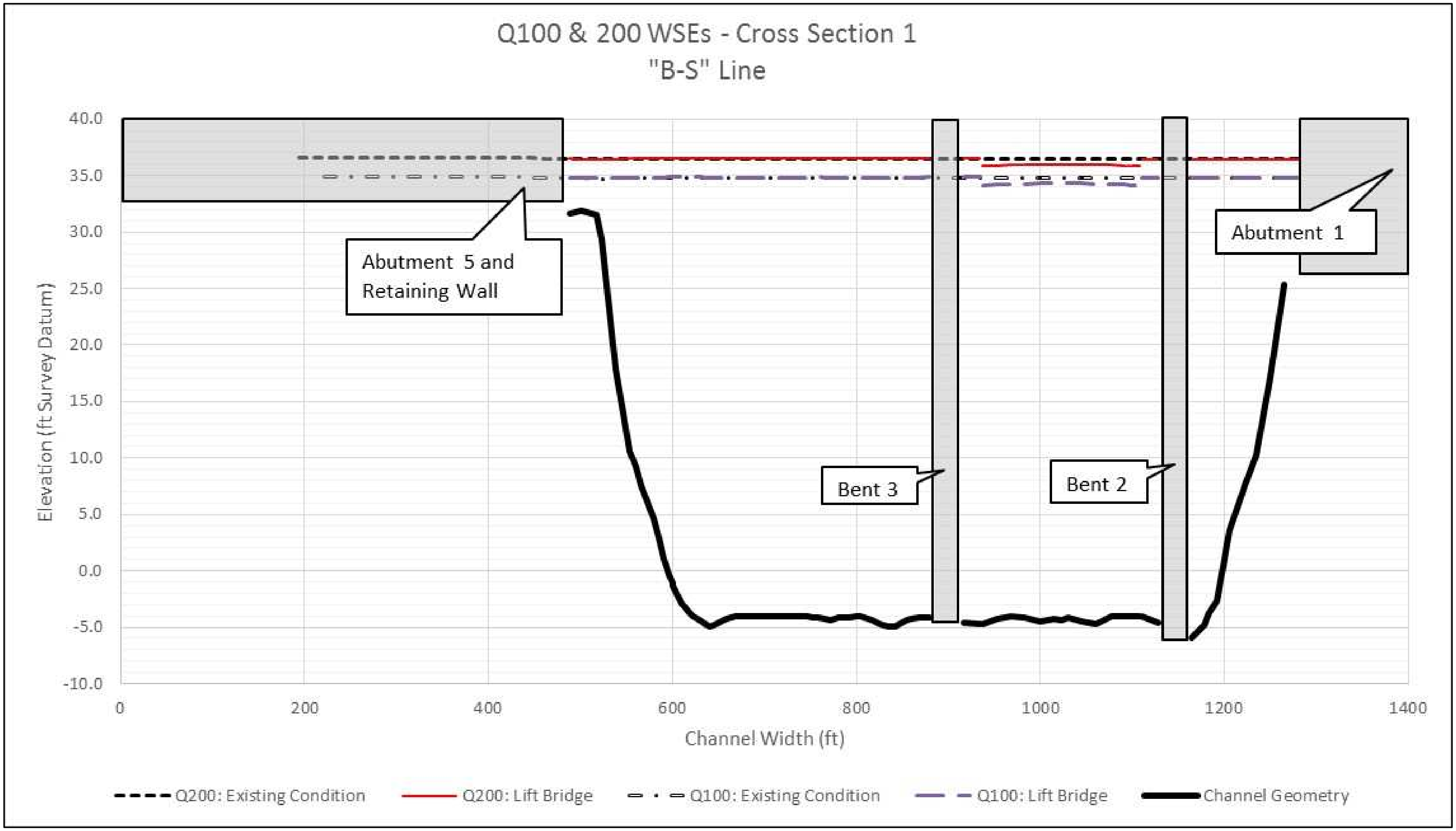

Figure 17. Cross Section 1

Scour Analysis

The evaluation of potential scour at the proposed bridge followed the criteria described in the FHWA's Hydraulic Engineering Circular No. 18 (HEC-18) *Evaluating Scour at Bridges* (Fifth Edition). The evaluation of potential scour was based on the hydraulic characteristics of the 100-year design discharge from the 2D hydraulic model. The total scour was estimated based on the cumulative effects of the long-term bed elevation change, general (contraction) scour, and local scour. The channel bed and bank materials at the project location was assumed to be erodible when computing the scour depths. The life expectancy of the bridge was considered in determining the long-term bed elevation change of the waterway; it was based on an assumed 75-year design life for a new replacement bridge.

The scour analyses for the double-leaf bascule bridge was not performed after the preliminary scour analyses based on the outputs from the preliminary 2D hydraulic analyses when the smaller model footprint was performed. The preliminary scour calculation for the double-leaf bascule bridge was only performed for Bents 2 and 3. Therefore, except for the section for pier scour, scour analysis in this technical memorandum only discusses proposed condition with the vertical lift bridge.

Existing Channel Bed

The median particle size of channel bed material was not available in this phase of the project. For this study, a median particle diameter of 0.2 mm was assumed to perform the scour analysis. The bed material was also assumed to be cohesionless. The scour calculation will be revised when the median particle size of channel bed material became available.

Long-term Bed Elevation Change

There are no historical channel cross sections available at the proposed bridge location. The long-term bed elevation change was not analyzed in this phase of this project.

Contraction Scour

Contraction scour occurs when the flow area of a stream is reduced by 1) the natural contraction of the stream channel; 2) a bridge structure; or 3) the overbank flow forced back to the channel. Based on the aerial imagery and outputs from the hydraulic analysis, there are no natural contraction of the stream channel. However, the proposed bridge structure and the overbank flow forced back to the channel would potentially cause channel contraction to occur at the project site.

The ratio of shear velocity and fall velocity was determined using the hydraulic model of the proposed bridge. If the critical velocity (Vc) is less than the mean channel flow velocity, live-bed contraction scour will be assumed. If the Vc is greater than the mean channel flow velocity, clear-water scour will be assumed. The critical velocity was calculated using equation 6.1 in HEC-18, and was less than the mean channel flow velocity. Therefore, the live-bed contraction scour equation (Equation 6.2, HEC-18) was selected to estimate the contraction scour the proposed Broadway Bridge. The result of the contraction scour calculations for the proposed bridge was a scour depth of approximately 3.1 feet.

Pier Scour

Pier scour is caused by vortices forming at the base of the pier. The scour depth at the pier is influenced by pier design, flow characteristics (flow rate and local velocity at the pier), and sediment particle size distribution. For piers in cohesionless materials, the HEC-18 manual recommends the Colorado State University (CSU) equation to determine pier scour. For this analysis, the live-bed equation was selected to estimate pier scour (Equation 7.1, HEC-18). The scour calculations for Bents 2 and 3 were based on the pier width of 35 feet to account for the potential flow obstruction from the fender system. The pier widths of Bents 4 and 5 were set to 4 feet as shown in the proposed bridge general plans. The computed scour depths for proposed bridge piers are summarized in **Table 8**.

Table 8. Pier Scour Summary, Vertical Lift Bridge

Proposed Bridge Component	Pier Width (feet)	Local Flow Depth (feet)	Approach Flow Velocity (feet/second)	Scour Depth (feet)
Bent 2	35.0	40.1	4.3	32.4
Bent 3	35.0	41.3	4.6	33.5
Bent 4	4.0	38.9	5.3	8.6
Bent 5	4.0	39.0	4.8	8.2

Note:
Values in this table are rounded to the nearest 0.1 foot or 0.1 foot/second.

The preliminary scour calculation for the double-leaf bascule bridge was only computed for Bents 2 and 3 supporting the bascule structure. The computed scour depths for Bents 2 and 3 for the double-leaf bascule bridge are summarized in **Table 9**.

Table 9. Pier Scour Summary, Double-Leaf Bascule Bridge

Proposed Bridge Component	Pier Width (feet)	Local Flow Depth (feet)	Approach Flow Velocity (feet/second)	Scour Depth (feet)
Bent 2	76.0	39.8	4.1	58.3
Bent 3	76.0	40.5	4.1	58.6

Notes:
Scour calculation was only performed for Bents 2 and 3.
Values in this table are rounded to the nearest 0.1 foot or 0.1 foot/second.

Abutment Scour

Abutment scour occurs when the bridge abutments and roadway embankment block approaching flow. According to HEC-18, local scour at the bridge abutment is commonly evaluated using either the Froehlich or HIRE live-bed scour equation. The Froehlich equation (Equation 8.1, HEC-18) is applicable when the ratio of the projected abutment length to the flow depth is less than 25. The HIRE equation (Equation 8.2, HEC-18) is applicable when the ratio of the projected abutment length to the flow depth is greater than 25. Both equations assume that the bed material around bridge abutment is erodible during the 100-year storm event.

According to the outputs from the FESWMS for the proposed condition 100-year storm event, Abutment 1 would not be in contact with the 100-year flow. Therefore, local scour at the abutment was not computed for Abutment 1. Abutment 2 and the proposed retaining wall on the approach area would obstruct the 100-year flow on the overbank area. The projected length of obstruction and average flow depth at the obstructed area were approximately 274 feet and 4.6 feet, respectively. Because ratio of the projected abutment length to the flow depth is greater than 25, HIRE equation was selected to calculate the local abutment scour at Abutment 6. The result of the local scour calculations for the proposed bridge Abutment 6 was a scour depth of approximately 11.4 feet.

Total Scour

Total scour is the sum of contraction scour, local scour, and long-term bed elevation change. The scour calculations are summarized in **Table 10**.

Table 10. Total Scour Summary

Proposed Bridge Component	Contraction Scour (feet)	Local Scour (feet)	Long-Term Bed Elevation Change (feet)	Computed Total Scour Depth (feet)	Scour Hole Elevation (feet NAVD 88)
Abutment 1[a]	-	-	N/A	-	-
Bent 2	3.1	32.4	N/A	35.5	-41.7
Bent 3	3.1	33.5	N/A	36.6	-42.8
Bent 4	3.1	8.6	N/A	11.7	-17.9
Bent 5	3.1	8.2	N/A	11.3	-17.5
Abutment 6	3.1	11.4	N/A	14.5	16.0

Notes:

N/A = Not Available

[a] Values in this table are rounded to the nearest 0.1 foot.

Scour depth and scour hole elevation for Abutment 1 was not computed because Abutment 1 is located outside of the 100-year floodplain. The scour hole elevation for Bents 2, 3, 4, and 5 reference the thalweg elevation of -6.2 feet NAVD 88 at Bent 3. The scour hole elevation for Abutment 6 references the ground elevation of 30.5 feet NAVD 88 at Abutment 6.

Conclusions

Hydraulic Impacts

The WSE impacts from the proposed Broadway Bridge with lift structure extend throughout the length of the 2D reach, and likely would extend approximately 2.2 miles upstream of the project site to the confluence of the American River, because of high tailwater at the downstream end of the reach. Although the extent of the hydraulic impact extends for approximately 2.2 miles, the magnitude of the WSE impact is small. Figure 17 illustrates the small magnitude of the WSE impact in comparison with overall channel depth within the reach. The existing channel is approximately 50 feet deep at Cross Section 6. The increase in WSE of approximately 0.1 foot is an approximate increase of only 0.2 percent of the total depth of the Sacramento River at Cross Section 1.

Potential Mitigation of Hydraulic Impacts

Potential mitigation measures for the hydraulic impacts of the proposed bridge include construction of new levees, improvement of existing levees, dredging within the channel reach, and revision of the design of the bridge.

New Levee Construction. Construction of new levees would require coordination with the Sacramento Area Flood Control Agency (SAFCA), USACE, CVFPB, and the responsible party for maintenance of the proposed levee improvement (Reclamation District). New levee construction would require a USACE 408 permit to ensure the existing levee prism is maintained and the hydraulic capacity of the system is not compromised. The existing operation and maintenance (O&M) manual for the levee system would need to be reviewed, and the new system would need to adhere to any maintenance standards set forth in the O&M manual. Permits are likely needed to be issued from the CVFPB, Regional Water Quality Control Board, and California Department of Fish and Wildlife.

Improvement of Existing Levees. Improvement of existing levees would require coordination with SAFCA, USACE, and the responsible party for maintenance of the proposed levee improvement (Reclamation District). Based on information presented at the Project Development Team meeting on

September 23, 2015, the existing levees in the vicinity of the project site do not provide protection up to the 200-year storm event, as required by the CVFPB. Because the existing levees are out of compliance with the CVFPB, it is likely that some form of compensation toward a future levee improvement project would be acceptable as a mitigation measure for the impacts of the proposed bridge.

Dredging. WRECO developed an HEC-RAS model of the specified reach within the project area in order to evaluate selective dredging as a potential mitigation measure. **Figure 18** shows the proposed dredging area. However, because the WSE is controlled by high tailwater at the downstream end of the model domain, dredging this area proved to be mostly ineffective, causing only a 0.03 foot decrease in WSE throughout the model reach using the 200-year peak storm flows.

Revised Design. The bridge design may be revised to create a smaller foundation area within the water. However, it should be noted that because of high tailwater at the downstream end of the project area, any foundation structure will likely create blockage and, therefore, have at least a minimal WSE impact.

Suggested Mitigation of Hydraulic Impacts

Because the impact to WSE in the vicinity of the project is approximately 0.1 foot, corresponding to only 0.2 percent of the total depth of the channel, consultation with SAFCA on compensation for the hydraulic impacts should be investigated. Construction of a new levee within the project limits may also be investigated if desired. Construction of 2.2 miles of levee along the Sacramento River upstream of the project site is not feasible.

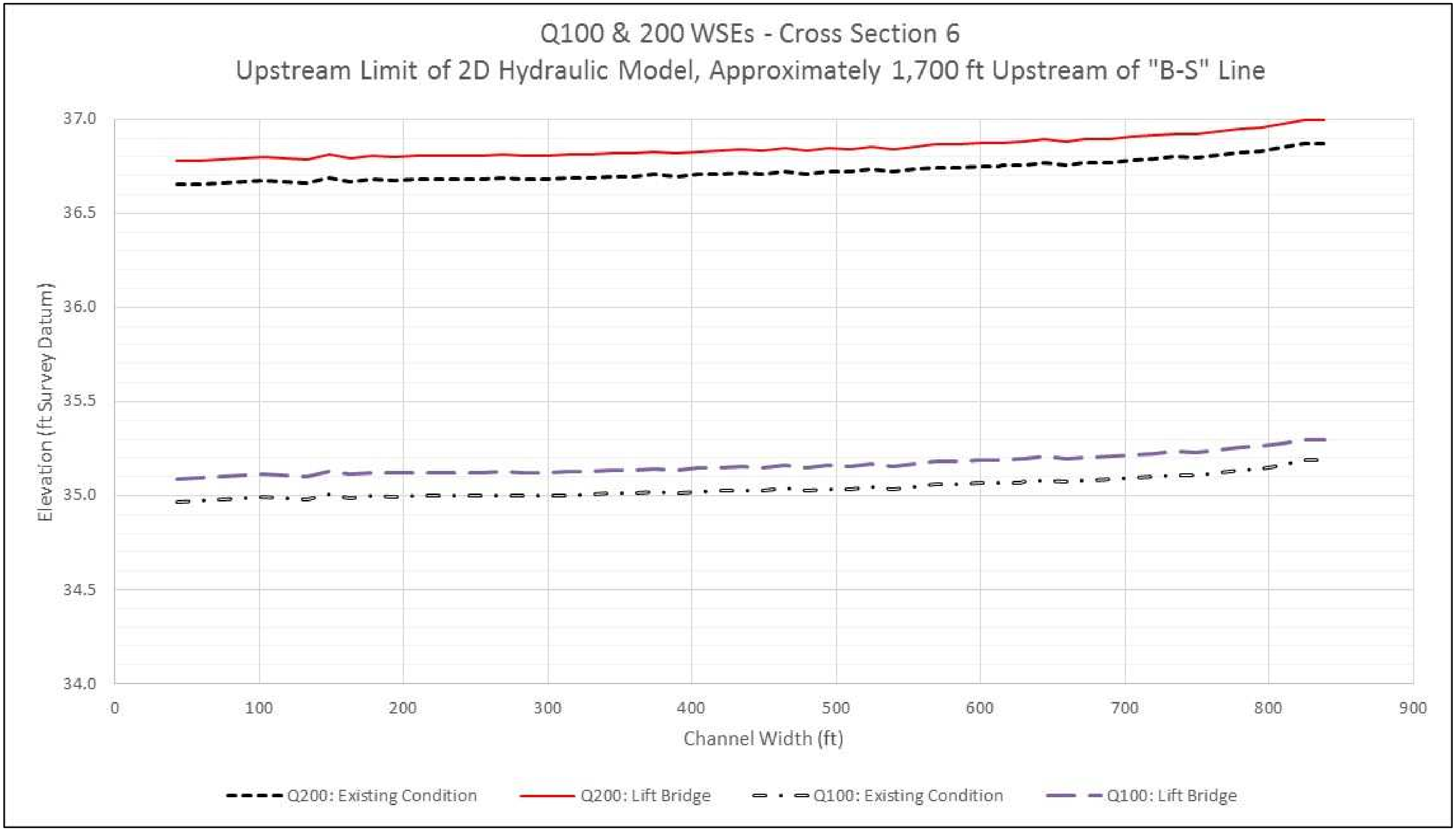

Figure 16. Cross Section 6, exaggerated scale to show WSE difference