Appendix I

Flood Hydrologic and Hydraulic System Analysis Technical Memorandum

(Revised)

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

Flood Hydrologic and Hydraulic System Analysis Technical Memorandum

Prepared for
California Department of Water Resources

September 2019 (Rev. August 2020)

ESA

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Flood Hydrologic and & Hydraulic System Analysis Technical Memorandum

1 Purpose

The purpose of this technical memorandum is to summarize the modeling assumptions and data sources used to perform a hydrologic and hydraulic system performance analysis to determine potential changes to the performance of State-Federal flood control system that could result from the proposed Tisdale Weir Rehabilitation and Fish Passage Project (Project). The Project is being developed by the California Department of Water Resources as a multi-benefit project designed to improve the reliability of the State-Federal flood control system while also reducing fish stranding in the Tisdale Weir energy dissipation basin, and improving fish passage in the Sacramento River system. The Project includes structural rehabilitation of the existing spillway and abutments and proposes to modify the Tisdale Weir to incorporate a notch with an operable gate to improve fish passage between the Sacramento River and the Tisdale Bypass.

2 Background

The Tisdale Weir, completed in 1932 by the U.S. Army Corps of Engineers (USACE) as part of the Sacramento River Flood Control Project (SRFCP), is located along the left bank of the Sacramento River about ten miles southeast of the town of Meridian and about 56 miles north of Sacramento (River Mile 119, as measured upstream from the Sacramento–San Joaquin Delta) (**Figure 1**). The primary purpose of the weir is to release overflow waters of the Sacramento River into the Sutter Bypass via the Tisdale Bypass. Typically, the Tisdale Weir is the first of the five weirs in the SRFCP to overtop, and continues to spill for the longest duration. The adjoining levees provide direct protection to agricultural lands in the surrounding area (USACE, 1955).

The current form of the weir was constructed with what would typically be a 50-year design life and is now more than 35 years beyond that design life. Because of the structure's age and frequent use, it has sustained damage that, if the weir is not rehabilitated, could eventually result in failure of the weir. Failure of the weir would likely result in flooding, damage to property, and possible loss of lives.

SOURCE: California Department of Water Resources, 2019. Tisdale Weir and Bypass Program: A Road Map for Multi-Benefit Flood and Ecosystem Management, May.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 1
Tisdale Weir and Bypass Vicinity Map

2.1 Weir Rehabilitation

The weir is a 1,150-foot long reinforced concrete structure, with appurtenances including a concrete apron and cobble revetments. The weir has a crest elevation of approximately 44 feet (NAVD 88) and an authorized project design flow of 38,000 cubic feet per second (cfs). Immediately downstream of the weir is a concrete energy dissipation basin that is 3 feet deep and 12 feet wide that provides protection from the erosive forces of high velocity water being discharged over the weir. The Tisdale Weir is often the first weir in the Sacramento River Flood Control System to overtop, and typically continues to spill for the longest duration (DWR, 2010).

Downstream of the weir, the north and south levees of the Tisdale Bypass are turf-covered earthen structures, varying in height from approximately 16 feet at the weir to approximately 21 feet at the transition to the Sutter Bypass (DWR, 2010). The Tisdale Bypass provides flood protection to the Sutter and Colusa Basins, including the towns of Knights Landing, Meridian, and Robbins; Reclamation Districts 108, 1660, and 1500; and portions of State Routes 45 and 113. Structures crossing the Tisdale Bypass include Tisdale Weir at the head of the bypass and two bridges, Garmire Road and Reclamation Road.

The Tisdale Weir has overflowed one or more times each year from water years 1934-2010, except during 1976, 1977, 1990, and 1994 (DWR, 2010). Overflow events during these years most commonly happened between January and March, but occurred as early in the water year as November and as late as June (DWR, 2010). During wet years the weir can spill for prolonged periods. For example, during the 2016-2017 water year, the Sacramento River flows overtopped Tisdale Weir five times, totaling 102 days with a peak overtopping flow of 25,100 cfs on January 24, 2017 (DWR, 2019).

Existing problems with the weir structure were identified in a 2015 inspection (DWR, 2015), a 2017 inspection (DWR, 2017), a 2018 inspection and site reconnaissance (DWR, 2018); these problems are summarized below:

1. Concrete surfaces – Spalling, scaling, and cracking and other signs of damage to the concrete and rebar are present throughout the structure. There are potentially internal voids in the existing weir due to missing annual space grouting due to the deterioration of original wooden piles. In the 2018 Structure Summary Report (DWR, 2018), concrete surfaces were the only item rated unacceptable by the DWR Sutter Maintenance Yard.

2. Weir foundation – A 2015 Tisdale Weir Structure Assessment indicated that settlement of the weir has occurred. A review of field-surveyed elevations along the weir sill, as part of this feasibility study, indicates the crest elevation varies within approximately +0.1 foot from the documented 44.0-foot NAVD88 crest elevation, except for the northern end of the weir at the abutment where the elevation is approximately 0.1 foot below this elevation. This suggests the 2015 assessment was perhaps visual or was specifically to the abutments or other smaller, isolated areas of the weir. Geophysical investigations were performed between November 27 and December 2, 2018 (AECOM, 2019), to identify the lateral extent of potential voids underlying the concrete crest slab and the potential presence of air-filled voids, and corresponding loss of the sub-slab support was identified along a portion of the weir.

3. Weir abutments – A 9-foot-long west segment of the south abutment wall is displaced out of plane and extensive horizontal and vertical cracks are visible (**Figure 2**). The wall of the north abutment has about a foot of missing concrete across the entire face with exposed rebar, and the concrete wing walls are falling apart. There is vertical and horizontal cracking throughout the walls. At the south end of the energy dissipation basin (basin) near the south abutment wall, there are large boulders and rocks covering the basin.

4. Weir sill – The weir sill concrete has eroded and exhibits exposed aggregate, spalls, cracks, and many patches; some locations show signs of exposed rebar. The cold joint above the energy dissipation basin (basin) wall appears to have some cracking and spalling along the entire length of the joint. The basin along the east side of the weir is badly damaged on the north end with concrete deterioration and exposed rebar and a buttress wall is missing.

5. Energy dissipation basin (basin) – Numerous buttress walls in the basin (40 short and 4 tall) are missing or badly damaged, and the basin concrete is showing signs of light erosion (**Figure 3**). Sediment, including large rocks, and vegetation routinely collect in the basin and are removed during annual maintenance. This recurring collection and removal of sediment contributes to the collective damage of the basin.

6. Revetment – The stone revetment adjacent to (and upstream of) the top of the concrete weir sill is shown to be inconsistent throughout the length of the weir. The original stone revetment appears to be depleted throughout. The revetment appears to be eroded away from the weir sill and transported and dispersed all around the area, including inside the basin.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 2
Vertical and Horizontal Cracking of the South Abutment Wall

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 3
Deterioration of Energy Dissipation Basin and Buttress Walls

A number of maintenance activities are required annually to ensure that the weir and its appurtenances continue to perform as designed. Annual maintenance activities include major erosion repairs, removal of sediment deposits in the energy dissipation basin and the Tisdale Bypass, and removal of large wood debris that deposits along the crest of the weir, in the basin, or in the bypass immediately downstream of the weir during flood season. Typically, maintenance is performed in the late spring or early summer months after the last spill event recedes.

Rehabilitation of the weir would include improvements to the Tisdale Bypass side of the weir to improve ease of maintenance and reduce potential for erosion. The existing energy dissipation basin would be replaced with a wider concrete energy dissipation and fish collection basin that can be more easily accessed and maintained by DWR maintenance staff to address sediment deposition, debris collection, and, if necessary, fish rescue.

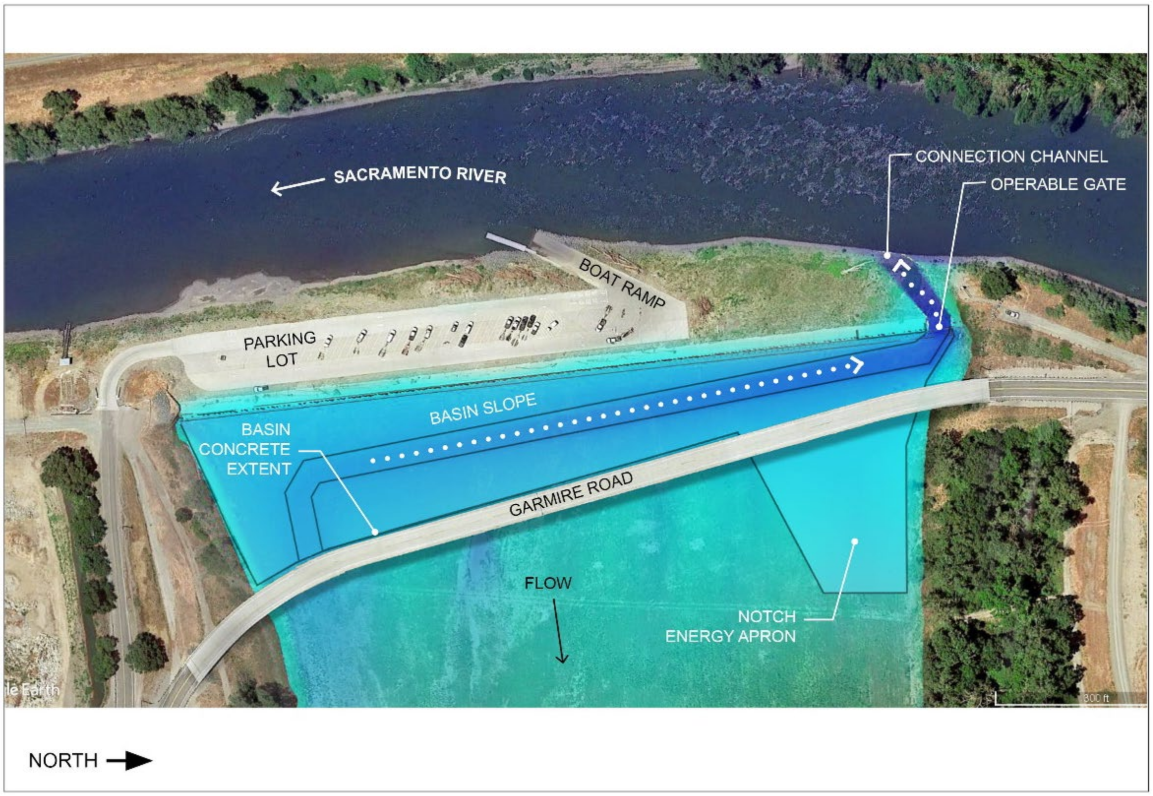
2.2 Fish Passage Improvement

At the Tisdale Weir and Sacramento River, four federally-listed anadromous fish species may be present: Sacramento River winter-run Chinook salmon *Oncorhynchus tshawytscha*, Central Valley spring-run Chinook salmon *O. tshawytscha,* California Central Valley steelhead Distinct Population Segment (DPS) *O. mykiss*, and Southern DPS of North American Green Sturgeon

Acipenser medirostris. Adult Chinook salmon, steelhead, sturgeon and other fish may become isolated and subsequently stranded in the Tisdale Bypass after overtopping of the Tisdale Weir (Beccio, 2016). When flows recede below the top of the Tisdale Weir, these and other fish species can become stranded in the Tisdale Weir apron area below the weir and in various residual pools (scoured holes and swales) within the Tisdale Bypass (Beccio, 2016).

Fish passage improvements at the Tisdale Weir has been identified as key priorities for Chinook salmon and Green Sturgeon recovery and resiliency in the Central Valley. The annual Work Plan for the Central Valley Project Improvement Act (CVPIA) includes improving access for spring-run Chinook salmon and Green Sturgeon through the Tisdale Bypass as a Core Team priority with the goal of reducing or eliminating stranding opportunities (CVPIA, 2017). The National Marine Fisheries Service (NMFS) Recovery Plan for Central Valley salmonids also includes an action (SAR 1.12) to implement short- and long-term solutions to minimize loss of Chinook salmon and Steelhead in the Sutter-Butte Basin (NMFS, 2014). Lastly, the Sacramento Valley Salmon Resiliency Strategy (CNRA, 2017) includes a Sutter Bypass improvements action (including Tisdale Weir modifications) to improve Chinook salmon passage as part of their suite of actions necessary to improve the immediate and long-term resiliency of Sacramento Valley salmonids (ESA, 2018).

Proposed alterations to the Tisdale Weir to improve fish passage include a 33-foot-wide by 11-foot-deep notch in the northern end of the existing weir (**Figure 4**). The notch would provide flow from the river to the bypass at depths and velocities in the range of suitability to allow for upstream passage of sturgeon and salmon. Flow through the notch opening would be regulated by a bottom-hinged gate actuated by an inflatable air bladder. The notch would be connected to the Sacramento River via a concrete lined trapezoidal channel, and would facilitate fish passage from the Tisdale Bypass to the Sacramento River when the gate is in the open position. A single bottom hinged gate would be formed by two gate assemblies bolted together, with gaskets on each side and in between to improve water sealing. Individual air bladders would actuate under the two gate sections but would always be operated in unison as a single gate. The existing energy dissipation basin will be replaced with a new, wider energy dissipation and fish collection basin sloped from south to north to facilitate drainage towards notch opening, encouraging any remaining fish behind the Tisdale Weir to swim towards the notch opening as elevations in the Sacramento River begin to recede.



SOURCE: California Department of Water Resources, 2019. Tisdale Weir and Bypass Program: A Road Map for Multi-Benefit Flood and Ecosystem Management, May.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 4
Tisdale Weir with Proposed Notch Alterations

3 Analysis

The proposed Tisdale Weir fish passage gate is currently proposed to operate in the closed position during flood conditions exceeding the 10-percent annual chance exceedance (ACE), or 10-year, design storm, and the gate is not anticipated to have a significant impact on the performance of the SRFCP system during normal operations. However, recognizing that debris impingement or equipment failure could temporarily preclude closing the gate, hydraulic analyses have been performed to understand potential implications resulting from a hypothetical condition where the gate would be operated in the fully open position during a flood event. This represents a worst-case condition and provides the most conservative estimate of the Project's potential impacts to the performance of the SRFCP system. For purposes of this analysis, this will be referred to as the "with-Project" condition.

3.1 Hydraulic Modeling Tools

Environmental Science Associates (ESA) performed the hydraulic analysis using the USACE's Common Features HEC-RAS model Release 5 (USACE, 2014). The hydraulic analyses were performed using HEC-RAS Version 4.2 (July 2013 Beta). Each of the storm events listed in the USACE's n-year events runs were modeled to consider a full range of hydraulic loadings. The storm events used include the 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual chance exceedance

(ACE) events. Information from the California Department of Water Resources' (DWR) Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS model of the Sacramento River Basin (Wood Rodgers, 2015) was used to update the Common Features model geometry to reflect the 2008 bridge improvements downstream of the weir at Garmire Road. All elevations used in these models are expressed in units of feet and referenced to the North American Vertical Datum of 1988 (NAVD 88).

3.2 System Performance Assumptions

Per USACE Engineering Circular 1165-2-220, Appendix F, Section F-3.f (USACE, 2018), all project features are assumed to be stable and functional to the top of containment in this analysis. Levees are not assumed to breach or otherwise malfunction in the analysis of without- and with-Project conditions. Levees are allowed to overtop and spill water to storage areas adjacent to levees without failing. The Project also is assumed to be stabilized to the authorized condition, and based on this assumption, system response curves are not required to complete the analysis.

3.3 Index Points

Eight index points were identified to assess changes in system performance resulting from the with-Project condition. Index points were selected at the following locations:

- Sacramento River upstream of Tisdale Bypass at River Station 125.5, near Grimes; and at River Station 119.25, near CDEC gauge TIS
- Sacramento River downstream of Tisdale Bypass at River Station 118, near CDEC gauge WLK; and at River Station 111.25, near Boyer's Landing
- Sutter Bypass upstream of Tisdale Bypass at River Station 84.87, near CDEC gauge SB3
- Sutter Bypass, downstream of Tisdale Bypass at River Station 77.7 9, near CDEC gauge SB2; and at River Station 69.38, near CDEC gauge SB1
- Tisdale Bypass, upstream of the Reclamation Road bridge at River Station 2.07

These locations are summarized in **Table 1** and can be seen in **Figure 5**.

TABLE 1
INDEX POINT LOCATIONS AND ASSOCIATED HEC-RAS RIVER STATION

Index Point	River Station	Description
1	125.5	Near Grimes
2	119.25	Near CDEC gauge TIS
3	118	Near CDEC gauge WLK
4	111.25	Near Boyer's Landing
5	84.87	Near CDEC gauge SB3
6	77.79	Near CDEC gauge SB2
7	69.38	Near CDEC gauge SB1
8	2.07	Upstream of Reclamation Road bridge

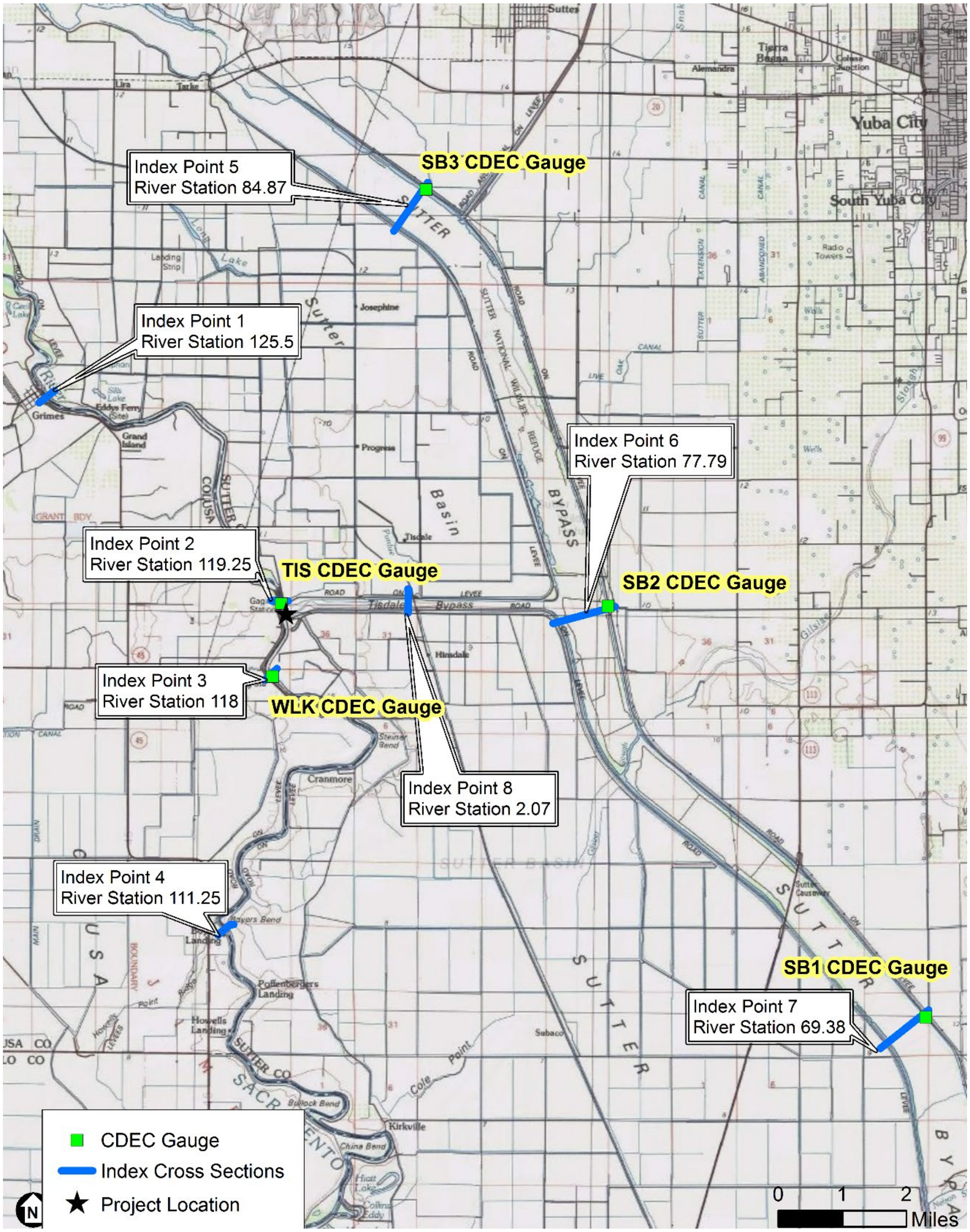


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Figure 5
Index Point Locations

3.4 Hydrology

Steady-state design hydrology as well as unsteady-state hydrology developed by the USACE were used to support the hydraulic analyses. The 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent ACE events were used. This hydrology is based on the synthetic event hydrology prepared for the Sacramento-San Joaquin Rivers Comprehensive Study, with some changes to flood routing through Folsom Dam (USACE, 2014). The alterations to the flood routing through Folsom Dam were performed to account for the recent changes, including construction of a new auxiliary spillway, raising the dam itself, and associated changes in dam operations (USACE, 2015). As the proposed project does not modify either the drainage area or the hydrologic properties of tributary watersheds, this data set was considered to be appropriate for use as-is for analyzing both without- and with-Project conditions.

3.5 Hydraulic Analysis

The hydraulic analysis was conducted in two phases. The first phase (Phase 1) analyzed the system to determine any potential flooding impacts resulting from the fish passage notch gate remaining in the open position under a range of hydraulic loadings (50- to 0.2 percent ACE). The Phase 1 analysis was conducted for the without- and with-Project "gate open" conditions using unsteady state hydraulic loadings to determine the project's potential to transfer risk to other parts of the system. These potential flooding risks were accounted for by analyzing the potential change in water surface elevation (WSEL) during flood peaks for the with- and without- project conditions.

The second phase (Phase 2) of the hydraulic analysis was conducted to investigate whether the project would adversely impact the system's hydraulic performance under the system's authorized design flow. The Phase 2 analysis used a steady-state hydraulic analysis.

For purposes of the hydraulic analysis, weir flow was assumed for areas in which floodwaters exceed the system's capacity (such as overtopping banks or levees). It was assumed that no levee failures or breaches of the system occur during without- or with-Project conditions and that the system, and any proposed alterations, are functional and stable to the top of the containment.

3.5.1 Without-Project Conditions Geometry Update

The Garmire Road bridge was originally constructed on top of the Tisdale Weir in 1935. The roadway and the piers proved to be a major maintenance challenge, particularly with respect to large wood debris carried by the Sacramento River during high water events. The bridge was replaced in 2008, at which time the original structure was demolished, and a new bridge was constructed east of the Tisdale Weir. The new bridge offered several advantages over the old bridge. The new bridge was constructed downstream within the Tisdale Bypass, reducing direct interactions with the operation of the weir and improving the ease of maintenance. Additionally, the new bridge has fewer piers, which reduces the potential for debris impingement at the current location.

The Common Features HEC-RAS model Release 5 has not been updated to reflect the Garmire Road bridge replacement project in 2008. To best reflect the without-Project condition at the

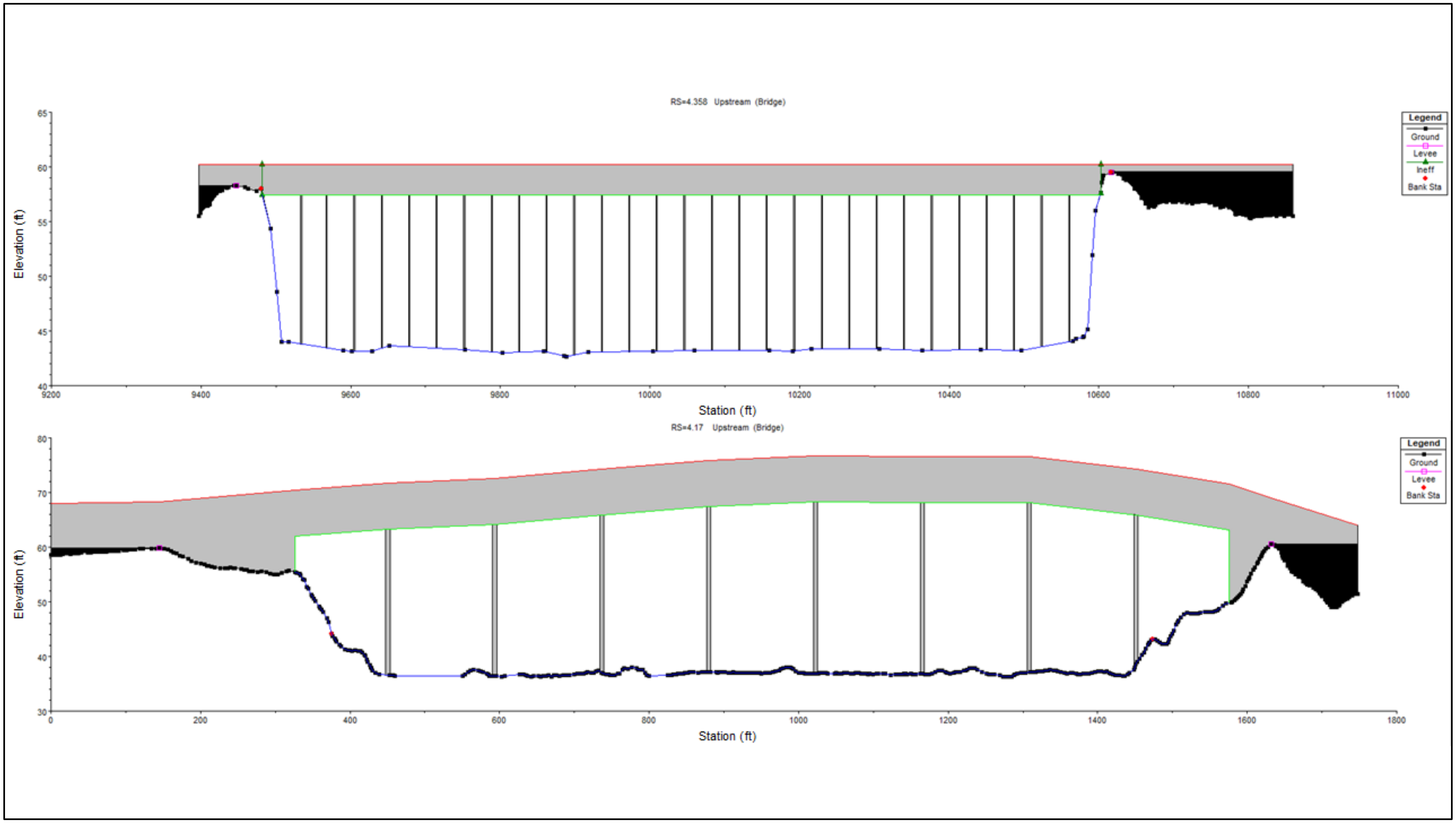
Tisdale Weir, it was necessary to update the model geometry files to reflect the present day Garmire Road bridge geometry. The Garmire Road bridge geometry was obtained from an existing HEC-RAS model of the Tisdale Bypass developed for DWR's CVFED Program (Wood Rodgers, 2015). **Figure 6** shows the previous model's bridge geometry and the updated geometry used for the without-Project condition baseline.

The Common Features HEC-RAS model Release 5 does not include geometry for the Tisdale weir and represents the flow split between the Sacramento River and the Tisdale Bypass by use of a lateral diversion rating curve. The lateral diversion rating curve was removed and replaced with a lateral structure to represent the Tisdale weir using data from the CVFED HEC-RAS system model.

The geometry modifications noted above are considered to provide a better representation of present day hydraulic conditions in the vicinity of the Tisdale Weir. Representing the Tisdale Weir as a lateral diversion structure also facilitates more direct comparisons of how the proposed gate may affect the overall system performance in the with-Project condition.

3.5.2 With–Project Condition

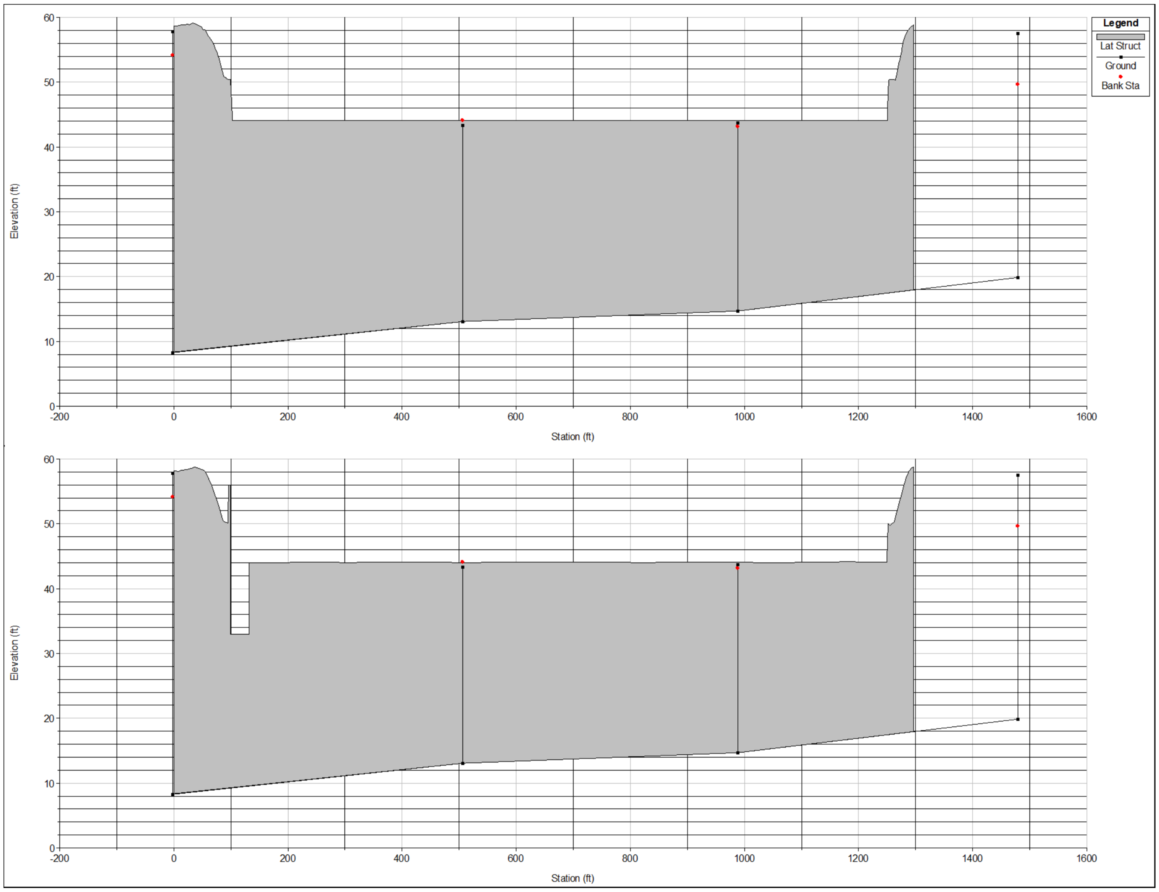
For the with-Project conditions, ESA developed an updated HEC-RAS geometry file to reflect the proposed geometry of the Tisdale Weir notch. The Project proposes to make a notch in the weir approximately 33 feet wide, 11 feet tall, located at the northern abutment of the weir. **Figure 7** shows the without- and with-Project HEC-RAS weir geometries.



Note: Top graphic shows the old bridge geometry. The bottom graphic has updated pier geometry to more accurately capture the existing bridge conditions.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 6
Garmire Road at Tisdale Weir HEC-RAS Bridge Geometry



Note: The top graphic shows the without-project conditions, and the bottom graphic shows the with-project conditions with the notch included.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 7
Tisdale Weir HEC-RAS Geometries

3.5.3 HEC-RAS Plan Names

A summary of the scenarios modeled for both the without- and with-Project conditions are shown in **Table 2**.

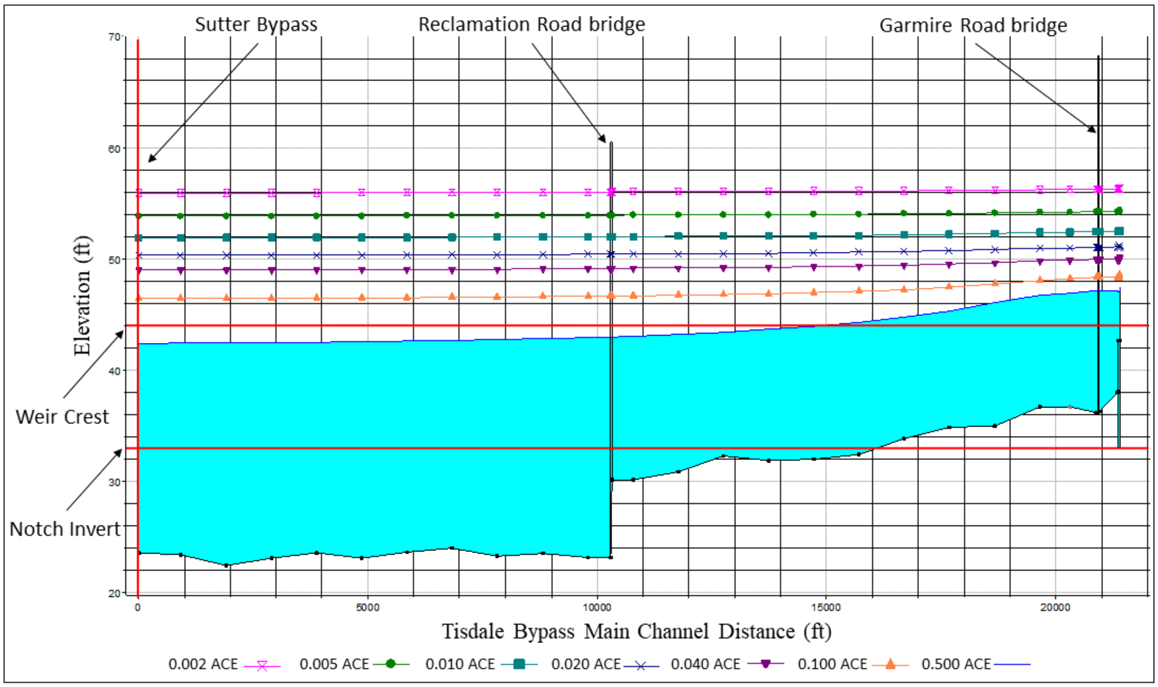
TABLE 2
HEC-RAS PLAN SUMMARY INCLUDING SCENARIO AND PLAN NAME

Scenario	ACE	Plan Name
Without-Project	50.0 %	002SAC_WO-PRJ
	10.0 %	010SAC_WO-PRJ
	4.0 %	025SAC_WO-PRJ
	2.0 %	050SAC_WO-PRJ
	1.0 %	100SAC_WO-PRJ
	0.5 %	200SAC_WO-PRJ
	0.2 %	500SAC_WO-PRJ
With-Project	50.0 %	002SAC_W-PRJ
	10.0 %	010SAC_W-PRJ
	4.0 %	025SAC_W-PRJ
	2.0 %	050SAC_W-PRJ
	1.0 %	100SAC_W-PRJ
	0.5 %	200SAC_W-PRJ
	0.2 %	500SAC_W-PRJ

3.5.4 Phase 1 – Hydrologic and Hydraulic Performance Results

Any alterations to the bypass system spillway hydraulics within the State-Federal system must be carefully examined to avoid adversely affecting performance in other parts of the system. Under certain conditions, operating the gates in the open position will increase diversion from the Sacramento River into the Tisdale Bypass. However, during periods where the existing weir is overtopped, hydraulics in the Tisdale Bypass are generally governed by the high tailwater conditions in the Sutter Bypass (**Figure 8**). In addition to submerging the hydraulic jump downstream of the weir, this condition controls the hydraulic conveyance of the notch opening during flood events. Any changes in flood conveyance through the notch itself are also offset by minor changes in the water surface profile on the upstream side of the weir.

The metric used in this analysis is assurance of design performance, also referred to as the conditional non-exceedance probability (CNP), or the probability of non-exceedance of the levee crest elevation under a given flood condition. For purposes of this analysis, the magnitude of the change in CNP is simply assessed as the change in water surface elevation for the events being analyzed relative to the baseline without-Project condition. As shown in **Table 3**, the proposed Project alterations result in negligible adverse impacts to CNP at the identified index locations for the range of hydrologic loadings analyzed. The distribution of flow between the Sacramento River and Tisdale Weir were also reviewed and changes were found to be negligible (**Table 4**). There are a few minor increases in computed water surface elevations at several index points downstream of the Project in the Tisdale Bypass and Sutter Bypass. These increases in stage do not exceed 0.01 feet. Additionally, there are minor stage reductions at several locations on the Sacramento River. These reductions in stage do not exceed 0.03 feet. These changes in system performance would only occur if the gate experienced a mechanical failure and are not deemed significant enough to warrant detailed system performance calculations using HEC-FDA. The deterministic analysis conducted for the Project is considered sufficient for describing the overall system performance for the without- and with-Project conditions and verifies that the reduction in assurance is negligible.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 8
With-Project Water Surface Profiles at Tisdale Bypass

TABLE 3
SUMMARY OF CHANGE IN ASSURANCE AT RESPECTIVE INDEX POINTS

Index Point	1957 Design WSEL (ft, NAVD 88)	Design Freeboard (feet)	Existing Top of Levee Elevation[1] Left Bank (ft, NAVD 88)	Existing Top of Levee Elevation[1] Right Bank (ft, NAVD 88)	CNP	ACE	WSEL (ft, NAVD 88)		
							Without-Project	With-Project	Change
1	57.58	3	62.85	65.97	0.500	50.0%	53.42	53.41	-0.01
					0.100	10.0%	54.76	54.75	-0.01
					0.040	4.0%	55.68	55.66	-0.02
					0.020	2.0%	56.61	56.6	-0.01
					0.010	1.0%	57.63	57.62	-0.01
					0.005	0.5%	59.05	59.04	-0.01
					0.002	0.2%	61.23	61.22	-0.01
2	51.92	3	58.12	58.90	0.500	50.0%	49.08	49.08	0.00
					0.100	10.0%	49.11	49.09	-0.02
					0.040	4.0%	50.41	50.38	-0.03
					0.020	2.0%	51.38	51.35	-0.03
					0.010	1.0%	52.6	52.58	-0.02
					0.005	0.5%	54.19	54.17	-0.02
					0.002	0.2%	56.14	56.12	-0.02
3	51.56	3	57.20	58.92	0.500	50.0%	48.26	48.26	0.00
					0.100	10.0%	48.97	48.94	-0.03
					0.040	4.0%	50.25	50.23	-0.02
					0.020	2.0%	51.22	51.2	-0.02
					0.010	1.0%	52.39	52.38	-0.01
					0.005	0.5%	53.87	53.86	-0.01
					0.002	0.2%	55.69	55.68	-0.01
4	48.94	3	54.09	55.37	0.500	50.0%	44.62	44.62	0.00
					0.100	10.0%	45.97	45.95	-0.02
					0.040	4.0%	47.45	47.43	-0.02
					0.020	2.0%	48.38	48.37	-0.01
					0.010	1.0%	49.46	49.44	-0.02
					0.005	0.5%	50.57	50.55	-0.02
					0.002	0.2%	51.78	51.78	0.00
5	53.82	6	59.66	58.00	0.500	50.0%	47.15	47.15	0.00
					0.100	10.0%	50.75	50.75	0.00
					0.040	4.0%	52.76	52.77	0.01
					0.020	2.0%	54.39	54.39	0.00
					0.010	1.0%	56.06	56.06	0.00
					0.005	0.5%	58.21	58.21	0.00
					0.002	0.2%	60.1	60.1	0.00

TABLE 3
SUMMARY OF CHANGE IN ASSURANCE AT RESPECTIVE INDEX POINTS

Index Point	1957 Design WSEL (ft, NAVD 88)	Design Freeboard (feet)	Existing Top of Levee Elevation[1] Left Bank (ft, NAVD 88)	Existing Top of Levee Elevation[1] Right Bank (ft, NAVD 88)	CNP	ACE	WSEL (ft, NAVD 88)		
							Without-Project	With-Project	Change
6	50.28	6	54.63	55.06	0.500	50.0%	42.53	42.53	0.00
					0.100	10.0%	46.52	46.52	0.00
					0.040	4.0%	49.04	49.04	0.00
					0.020	2.0%	50.30	50.31	0.01
					0.010	1.0%	51.85	51.85	0.00
					0.005	0.5%	53.69	53.69	0.00
					0.002	0.2%	55.80	55.8	0.00
7	47.45	6	52.87	52.45	0.500	50.0%	40.66	40.66	0.00
					0.100	10.0%	44.57	44.57	0.00
					0.040	4.0%	47.38	47.38	0.00
					0.020	2.0%	48.41	48.41	0.00
					0.010	1.0%	49.76	49.76	0.00
					0.005	0.5%	51.39	51.39	0.00
					0.002	0.2%	53.62	53.62	0.00
8	50.71	6	55.03	55.21	0.500	50.0%	43.38	43.38	0.00
					0.100	10.0%	46.92	46.92	0.00
					0.040	4.0%	49.29	49.29	0.00
					0.020	2.0%	50.53	50.53	0.00
					0.010	1.0%	52.02	52.03	0.01
					0.005	0.5%	53.83	53.84	0.01
					0.002	0.2%	55.91	55.92	0.01

NOTES:
[1] Levee elevations obtained from USACE's Common Features Model (USACE 2014).

TABLE 4
SUMMARY OF CHANGE IN FLOW DISTRIBUTION AT TISDALE WEIR COMPLEX

Location	River Mile	CNP	ACE	Peak Flow (cfs)		
				Without-Project	With-Project	% Change
Sacramento River Upstream of Tisdale Weir	119.5	0.500	50.0%	29,291	29,255	0.02%
		0.100	10.0%	47,735	47,733	0.00%
		0.040	4.0%	49,402	49,402	0.00%
		0.020	2.0%	52,244	52,244	0.00%
		0.010	1.0%	54,775	54,777	0.00%
		0.005	0.5%	58,795	58,793	0.00%
		0.002	0.2%	65,810	65,826	0.07%

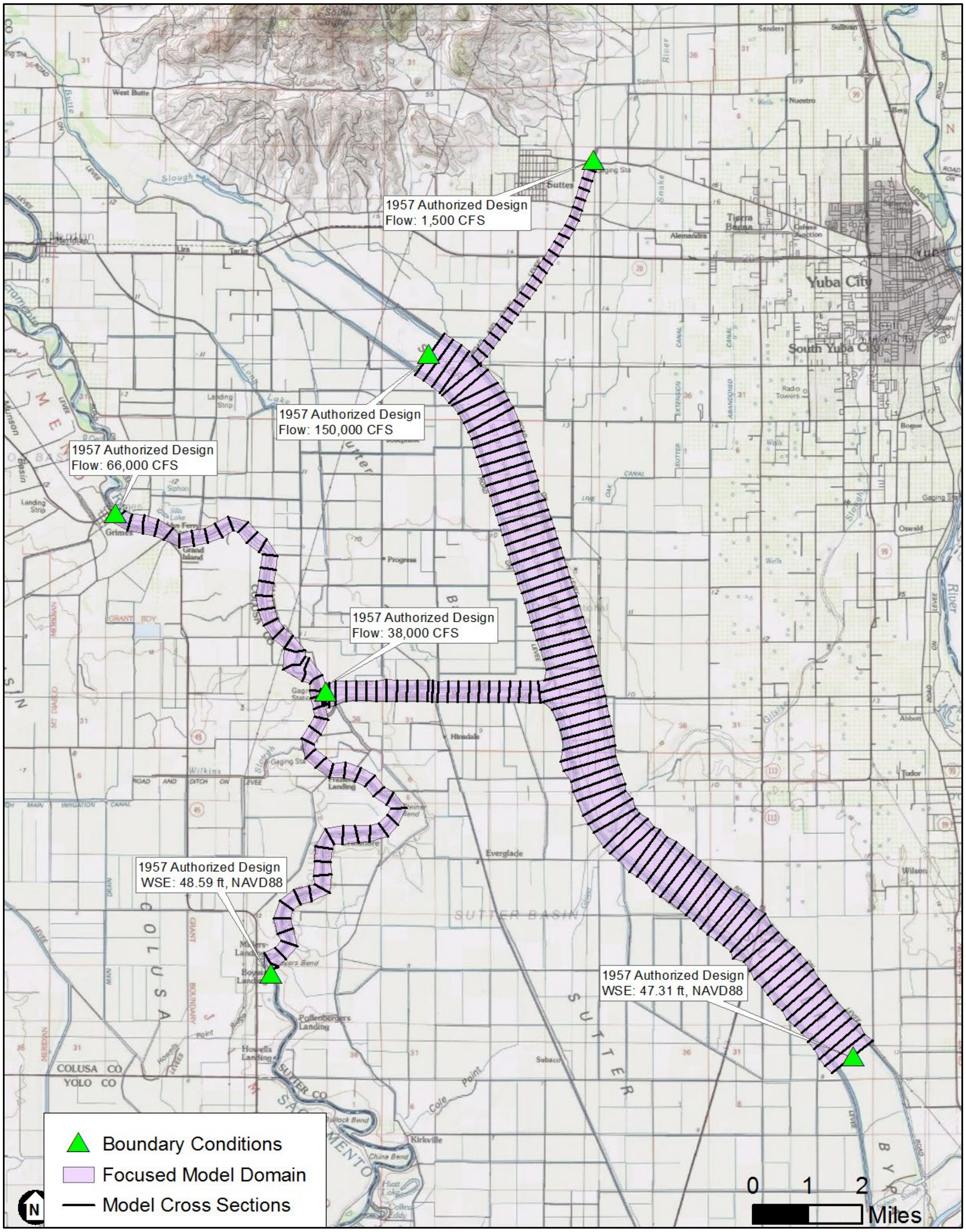
TABLE 4
SUMMARY OF CHANGE IN FLOW DISTRIBUTION AT TISDALE WEIR COMPLEX

Location	River Mile	CNP	ACE	Peak Flow (cfs)		
				Without-Project	With-Project	% Change
Sacramento River Downstream of Tisdale Weir	118.75	0.500	50.0%	28,615	28,620	-0.01%
		0.100	10.0%	26,705	26,700	-0.22%
		0.040	4.0%	28,365	28,356	-0.24%
		0.020	2.0%	30,359	30,360	-0.19%
		0.010	1.0%	33,252	33,245	-0.17%
		0.005	0.5%	38,313	38,307	-0.17%
		0.002	0.2%	45,656	45,658	-0.10%
Tisdale Bypass Downstream of Tisdale Weir	3.76	0.500	50.0%	18,320	18,327	0.06%
		0.100	10.0%	21,078	21,082	0.27%
		0.040	4.0%	21,132	21,139	0.32%
		0.020	2.0%	21,983	21,980	0.25%
		0.010	1.0%	21,619	21,627	0.27%
		0.005	0.5%	20,580	20,583	0.29%
		0.002	0.2%	20,077	20,079	0.49%

3.5.5 Phase 2 – Hydraulic Analysis of 1957 Authorized Design Flow

The Phase 2 analysis was used to assess the performance of the system under the system's authorized design flow. The Common Features model geometry extents were reduced to focus the analysis on the areas surrounding the proposed project (**Figure 9**). The reduced model was then analyzed in steady state using the authorized design flows and water surface elevations documented in the 1957 Levee and Channel Profiles (USACE, 1957). The design flow for each reach was used as upstream boundary conditions for the Phase 2 analysis (**Table 5**). The design water surface elevations for the approximate downstream boundaries for the analysis (**Table 6**) were obtained from Levee and Channel Profiles (USACE, 1957 and Atkins, 2013). All of the authorized design water surface elevations were converted from the U.S. Corps of Engineers Datum (USED) to NAVD 88 heights using the survey datum conversions provided by DWR's Geodetic Branch (L. Grade, personal communication, November 5, 2018 & J. West personal communication, June 27, 2019). The Sacramento River downstream boundary water surface elevation was obtained using the following equation, applicable in the vicinity of the Tisdale Weir (L. Grade, personal communication, November 5, 2018):

Elevation (feet, NAVD 88) = Elevation (feet, USED) - 1.425 feet



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 9
Focused Model Domain for the Phase 2 Hydraulic Analysis and the Associated Boundary Conditions

TABLE 5
UPSTREAM BOUNDARY CONDITIONS FOR AUTHORIZED DESIGN HYDRAULIC ANALYSIS

River Station	1957 Authorized Design Flow (cfs)
Sacramento River 125.5	66,000
Sutter Bypass 84.87	150,000
Tisdale Bypass 4.36	38,000
Wadsworth Canal 4.29	1,500

TABLE 6
DOWNSTREAM BOUNDARY CONDITIONS AND ASSOCIATED DATUM CONVERSIONS FOR AUTHORIZED DESIGN HYDRAULIC ANALYSIS

River Station	1957 Authorized Design WSEL (ft NAVD88) (Atkins, 2013)	1957 Authorized Design WSEL (ft NGVD29)	1957 Authorized Design WSEL (ft USED)	1957 Authorized Design WSEL (ft NAVD88)
Sacramento River 111.25 (index point 4)	NA	NA	50.01	48.59[1]
Sutter Bypass 69.38 (index point 7)	47.45	45.10[2]	48.10[3]	47.31[4]

NOTES:
1 Converted from USED to NAVD88 by subtracting 1.425 ft (DWR, 2018)
2 Converted from NAVD88 to NGVD29 using NOAA's VERTCON Orthometric Height Conversion
3 Converted from NGVD to USED by adding 3 ft (DWR, 2013)
4 Converted from USED to NAVD88 by subtracting 0.79 ft (DWR, 2019)

The downstream boundary water surface elevation for the Sutter Bypass was originally obtained with a NAVD88 reference elevation from CVFED 1955/1957 Profiles and ULOP Levee Elevations (Atkins, 2013). To obtain a more accurate design water surface elevation, the elevation was first converted back to USED and then a more spatially precise conversion obtained from DWR was used to re-convert to NAVD88. The conversion factors and sources are shown in the footnotes of Table 6.

Analysis of the authorized design flow of the system for the without- and with-Project conditions was performed. The water levels for index points 4 and 7 were fixed at the authorized design water surface elevation as the downstream boundary conditions. The model analysis resulted in zero change in water surface elevations for the remaining index points for the 1957 design authorized flow (**Table 7**).

TABLE 7
SUMMARY OF PHASE 2 PEAK WATER SURFACE ELEVATIONS FOR AUTHORIZED DESIGN HYDRAULIC ANALYSIS

Index Point	River Station	Without-Project WSEL (ft, NAVD 88)	With-Project WSEL (ft, NAVD 88)	Change in WSEL
1	125.50	63.27	63.27	0.00
2	119.25	59.30	59.30	0.00
3	118.00	57.70	57.70	0.00
4	111.25	48.59	48.59	0.00
5	84.87	54.28	54.28	0.00
6	77.79	49.75	49.75	0.00
7	69.38	47.31	47.31	0.00
8	2.07	50.54	50.54	0.00

4 Findings and Recommendations

As currently proposed, the fish passage gate at Tisdale Weir will be closed during flood events exceeding a 10% ACE (10-year) design storm. The Phase 1 and Phase 2 analyses were performed to assess impacts resulting from a hypothetical scenario whereby the proposed fish passage gate remained open during flood conditions. The results of the Phase 1 and Phase 2 analyses indicated that even if the gate remains open during flood operations, negligible adverse changes to the hydraulic performance of the flood control system would result. The current analysis is considered sufficient for determining the potential changes to the system performance that would result from implementation of the Project, and demonstrates that any reductions in assurance of the system design capacity would be negligible. Therefore, from a flood safety perspective, the Project will not be injurious to the public or affect the Federal project's ability to meet its authorized purpose.

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