Appendix A

Gate Sizing and Headworks Flow

Appendix A1

Yolo Bypass – Channel Fish Passage East Side

HDR has been running HEC-RAS to evaluate gate opening sizes and channel configurations relative to fish passage and other criteria in the Yolo Bypass of stages prior to overtopping of the Fremont Weir (approximately 32 ft). Up to this point only the east side fish passage channel has been investigated. The criteria we are looking at include:

- Limit discharges into the bypass to 6,000 cfs without operating gates.
- Maximum velocity at gate openings of 6 fps.
- Maximum velocity in channels of 4 fps.
- Flow depth in channel of 5 ft.
- Flow depth in overbank areas of 5 ft.
- No operation of the proposed gate structure at the existing Fremont Weir to control flows.

The conditions at the site make it impossible to meet all of the criteria for the entire range of Sacramento River stages. Much of the land adjacent to the channel is at elevations near 26 ft. This makes it difficult to limit discharges and velocities once the stages in the river rise much higher than this. Decreasing the slope of the energy grade line would help meet discharge and velocity criteria but the downstream energy level is fixed at Tule Pond, removing this option.

Numerous geometry configurations were evaluated varying the bottom widths, inverts, and channel shapes and comparing the results to the established criteria. All of the configurations were unable to meet the established criteria but varied on the range of river stages that maintain compliance. A discussion of the general hydraulic performance of several of the geometric alternatives investigated are included below.

SMALL ALTERNATIVE 14-FT INVERT

This channel alternative is based upon a trapezoidal channel with a 20-ft bottom width, 14 ft invert elevation and 3:1 side slopes. This was the same configuration used in the long term runs conducted to look at wet area through time and last day wet.

- The discharge exceeds the 6,000 cfs criteria at a Sacramento River elevation of around 28.0 ft.
- The stage where the velocity criterion is exceeded varies between cross-sections but is generally first exceeded between about 23 and 24 ft.

MEDIUM ALTERNATIVE 17-FT INVERT 225-FT BOTTOM WIDTH

This channel alternative is based upon a trapezoidal channel with a 225-ft bottom width, 17 ft invert elevation and 3:1 side slopes. This configuration also includes six 30-ft wide gates (3 were 6 ft tall and 3 were 12 ft tall) that were open throughout the simulation. This was the same configuration used in the long term runs conducted to look at wet area through time and last day wet.

- The discharge exceeds the 6,000 cfs criteria at a Sacramento River stages of around 25 ft.
- The stage where the velocity criterion is exceeded varies between cross-sections but is generally first exceeded between about 27 and 28 ft. This is a result of hydraulic control existing at the gate structure at higher stages.
- The velocity at the gates exceeds the allowable velocities at an elevation of about 26 ft.

LARGE ALTERNATIVE 14-FT INVERT 225-FT BOTTOM WIDTH

This channel alternative is based upon a trapezoidal channel with a 225-ft bottom width, 14 ft invert elevation and 3:1 side slopes. This configuration includes six 30-ft wide gates (3 were 7.5 ft tall and 3 were 10 ft tall). This was the same configuration used in the long term runs conducted to look at wet area through time and last day wet.

- The discharge exceeds the 6,000 cfs criteria at a Sacramento River stage of around 24 ft.
- The velocities in the channels exceed 4.0 ft/s at several isolated cross sections at an associated river stage of about 32.0 ft. A number of the channel cross sections never exceed velocity criteria. This is a result of hydraulic control existing at the gate structure at higher stages.
- The velocity at the gates exceeds the allowable velocities at an elevation of about 24 ft.

BENCH MODIFIED 14-FT INVERT WITH BERM

This channel alternative included a gate structure at the existing Fremont Weir cross section with invert elevations of 14 ft. The channel consisted of a 20-ft trapezoidal bottom width with 15 ft wide benches along the channel at the right and left banks. A berm, with crest elevation of 32 ft, was included in cross sections along the right side of the proposed channel to confine flows. Major hydraulic behavior of this alternative included:

- All flows at Sacramento River stages of 14 ft to 32 ft are conveyed through the gates at Fremont Weir and are maintained within the proposed channel section all of the way to Tule Pond.
- Confined flows in the channel increased the minimum Sacramento River stage that exceeded 6,000 cfs in the channel when compared to unconfined alternatives. This discharge control was facilitated through hydraulic control created by the channel itself.
- Velocities in the channel and overbank areas exceed compliance at lower stages in the Sacramento River, when compared to unconfined alternatives. This behavior is due to confinement of flows in the channel area.
- Flow depths in the channel and overbank areas are below compliance levels at higher stages in the Sacramento River, when compared to unconfined alternatives, due to reduced flows in the channel and higher velocities from confinement.

BENCH MODIFIED 17-FT INVERT WITH BERM

This channel alternative was identical to the Bench Modified 14 ft Invert with Berm with the exception of the proposed channel invert being raised by 3 ft. Raised channel invert elevations were completed between the upstream end of the HEC-RAS model and the upstream end of

Tule Pond. All other channel geometry was left the same. Major hydraulic behavior of this alternative included:

- All flows at Sacramento River stages of 17 ft to 32 ft are conveyed through the gates at Fremont Weir and are maintained within the proposed channel section all of the way to Tule Pond.
- Confined flows in the channel increased the minimum Sacramento River stage that exceeded 6,000 cfs in the channel when compared to unconfined alternatives. This discharge control was facilitated through hydraulic control created by the channel itself.
- Higher invert elevation increased the minimum Sacramento River stage that exceeded 6,000 cfs in the channel above the Bench Modified 14 ft Invert with Berm alternative.
- Velocities in the channel and overbank areas exceed compliance at lower stages in the Sacramento River, when compared to unconfined alternatives. This behavior is due to confinement of flows in the channel area.
- Velocities in the channel and overbank areas exceeded compliance at lower stages in areas immediately upstream of Tule Pond due to lower tail water conditions than those observed for the Bench Modified 14 ft Invert with Berm alternative. Lower tail water conditions were a result of lower discharges. Additionally, the increased invert elevation created a larger invert elevation drop at the Tule Pond connection than those observed for the Bench Modified 14 ft Invert with Berm alternative.
- Flow depths in the channel and overbank areas are below compliance levels at higher stages in the Sacramento River, when compared to unconfined alternatives, due to reduced flows in the channel and higher velocities from confinement.
- Flow depths in the channel and overbank areas were below compliance levels at higher stages in the Sacramento River than those observed for the Bench Modified 14 ft Invert with Berm Alternative. This was a result of reduces flows through the channel caused by the higher invert elevation.

BENCH MODIFIED 19-FT INVERT WITH BERM

This channel alternative was identical to the Bench Modified 14 ft Invert with Berm with the exception of the proposed channel invert being raised by 5 ft. Raised channel invert elevations were completed between the upstream end of the HEC-RAS model and the upstream end of Tule Pond. All other channel geometry was left the same. Major hydraulic behavior of this alternative included:

- All flows at Sacramento River stages of 19 ft to 32 ft are conveyed through the gates at Fremont Weir and are maintained within the proposed channel section all of the way to Tule Pond.
- Confined flows in the channel increased the minimum Sacramento River stage that exceeded 6,000 cfs in the channel when compared to unconfined alternatives. This discharge control was facilitated through hydraulic control created by the channel itself.
- Higher invert elevation increased the minimum Sacramento River stage that exceeded 6,000 cfs in the channel above the Bench Modified 17 ft Invert with Berm alternative.

- Velocities in the channel and overbank areas exceed compliance at lower stages in the Sacramento River, when compared to unconfined alternatives. This behavior is due to confinement of flows in the channel area.
- Velocities in the channel and overbank areas exceeded compliance at lower stages in areas immediately upstream of Tule Pond due to lower tail water conditions than those observed for the Bench Modified 17 ft Invert with Berm alternative. Lower tail water conditions were a result of lower discharges. Additionally, the increased invert elevation created a larger invert elevation drop at the Tule Pond connection than those observed for the Bench Modified 17 ft Invert with Berm alternative.
- Flow depths in the channel and overbank areas are below compliance levels at higher stages in the Sacramento River, when compared to unconfined alternatives, due to reduced flows in the channel and higher velocities from confinement.
- Flow depths in the channel and overbank areas were below compliance levels at higher stages in the Sacramento River than those observed for the Bench Modified 17 ft Invert with Berm Alternative. This was a result of reduces flows through the channel caused by the higher invert elevation.

Several iterations looking at modified bench elevations, adjustments to slope, different roughness values, and other tweaks were conducted. These kinds of changes sometimes increased the range of stages that meet the required criteria but these effects were small and varied cross-section to cross-section. Often changes changed the controlling criteria to a different criteria or a different location with little change to the overall range of stages meeting criteria.

TRAPEZOIDAL CHANNEL 123-FT BOTTOM WIDTH

This alternative was based on a trapezoidal channel with 3:1 side slopes with a bottom width that was sized based on a normal depth discharge of 6,000 cfs contained within banks up to an elevation of approximately 26 ft.

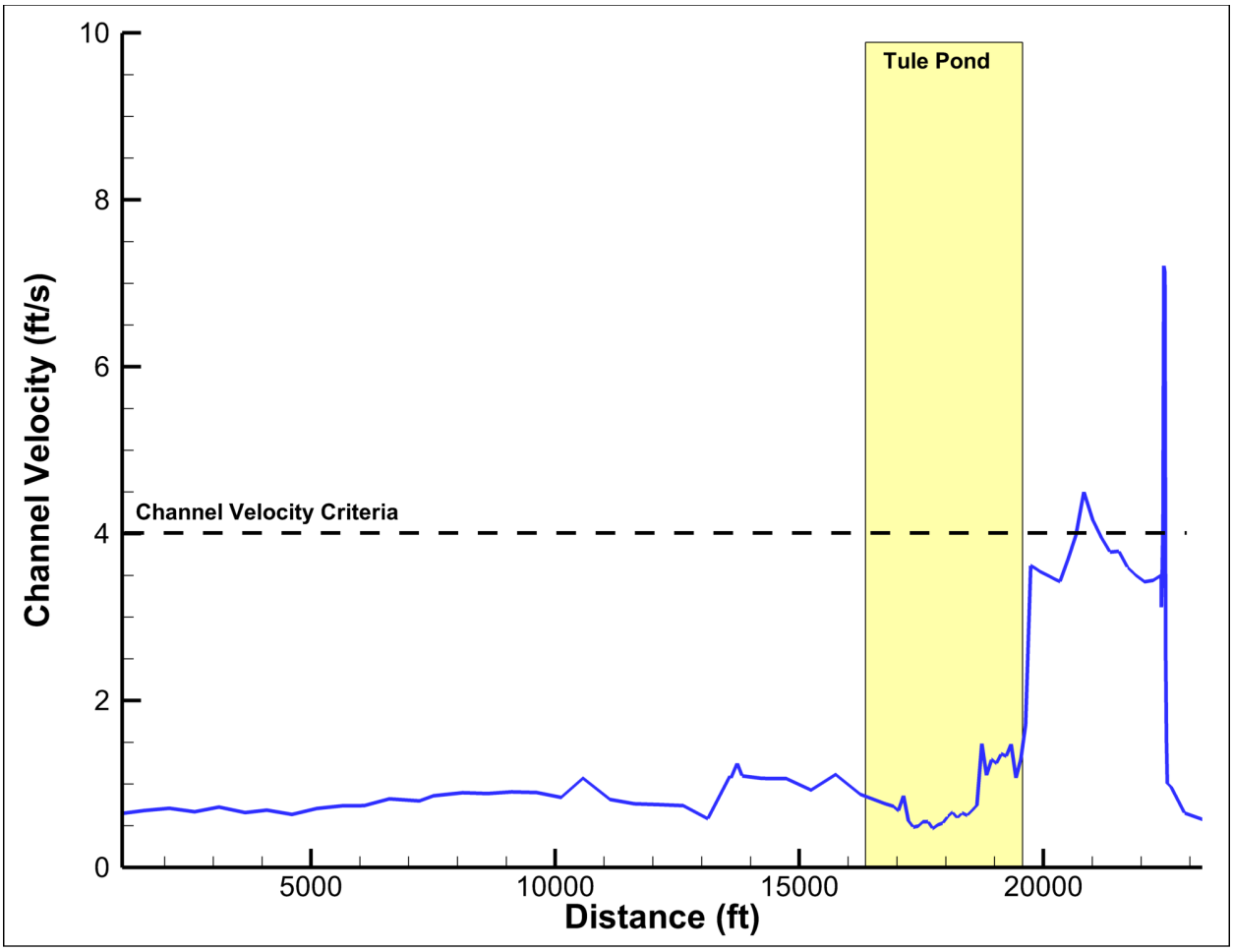
- Channel velocities were within operational condition compliance up to Sacramento River stages of around 26 ft. This was in line with expectations from normal depth computations.
- Discharge was in operational condition compliance up to Sacramento River stages of around 25.5 ft.
- Sacramento River stages greater than around 25.5 ft increased discharge to a maximum of around 18,000 cfs at a stage of 32 ft.

Some general observations can be made based upon the simulation results:

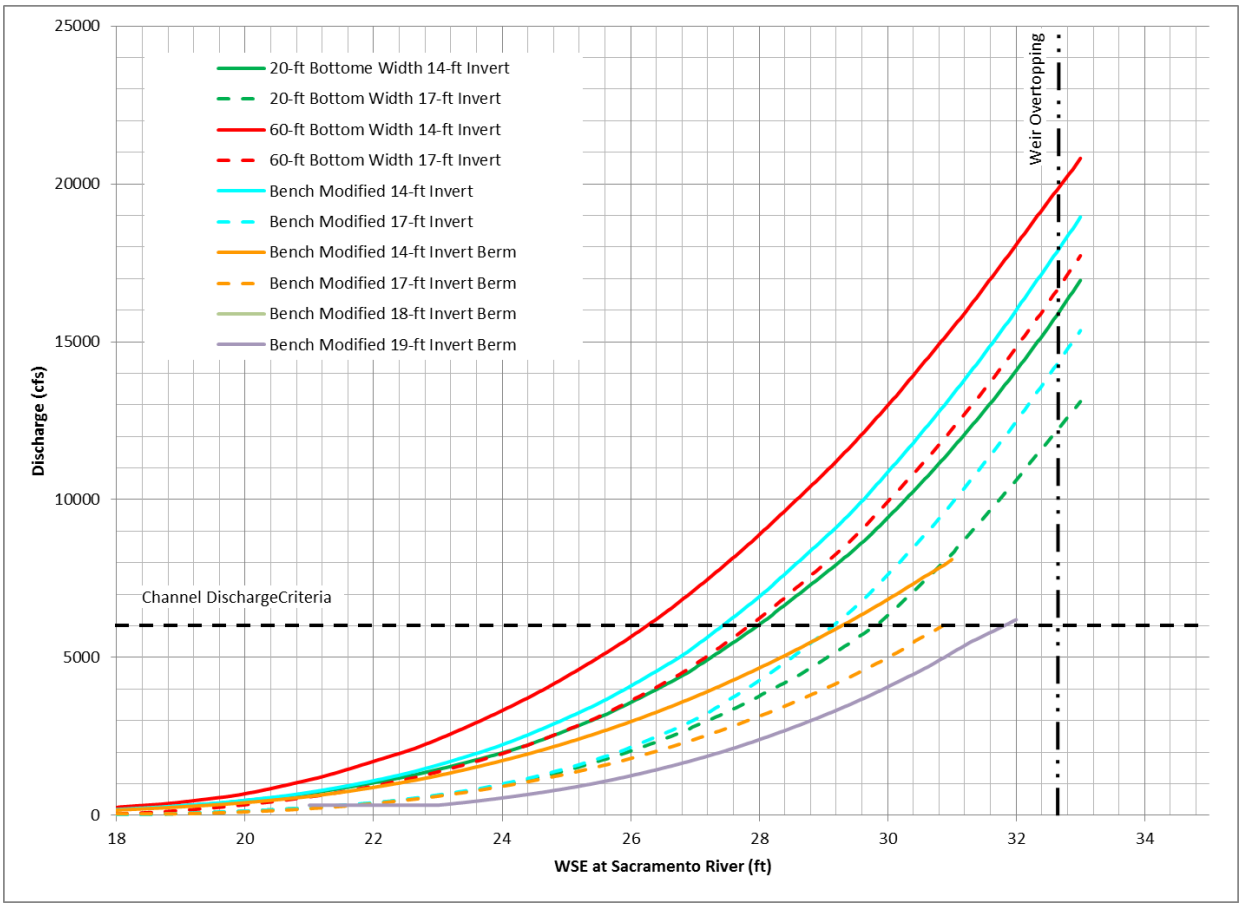
- Widening the channel may lower velocities at the expense of increasing discharges and/or decreasing the stage where gate velocities are exceeded.
- While adjustments to the channel and gate configurations may increase the range of allowable river stages for fish passage, it is unlikely that a simple trapezoidal channel configuration could achieve the proposed criteria for river elevations above 26-27 ft. This is due to discharges exceeding 6,000 cfs. At higher stages, alternatives would also

exceed velocity criteria at the gate or at several isolated cross sections throughout the proposed reaches.

- Velocities in benches are lower than the main channel but may not extend range of allowable river stages significantly because velocities often approach or exceed the criterion by the time the minimum depth of 5 ft is reached.
- Creating a berm and filling areas adjacent to the channel improves the effectiveness of channel modifications by creating a more consistent channel. While this may not be acceptable due to flood impacts and permitting, it does suggest that an alternate alignment with higher neighboring ground elevations or where berms would be acceptable may more easily be designed to achieve effective fish passage.
- Scour protection will be required in the main channels where velocities often exceed 10 ft/s unless the discharge is controlled by gates.
- Higher invert elevations at the gate openings decrease the discharge for a given river stage but have minor and often mixed results on velocities. For higher gate elevations, the slope of the channel must be increased or the channel will be at a higher elevation at the upper end of the Tule Canal which can negatively impact the depths and velocities in this area.
- Adding roughness to the bench areas improves their effectiveness but this may not be feasible due to maintenance considerations.
- When using benches at different heights keeping the benches on the same side may make it easier for fish to find suitable areas based upon velocities and depths because they aren't separated by a channel with high velocities.
- Maintaining operational condition compliance throughout the proposed channel reach is often difficult. Minor changes in geometry affect hydraulic performance upstream and downstream. However, often operational conditions are exceeded for only a minimum distance. A plot is shown below of the channel velocity profile for the Bench Modified 14 ft Invert with Berm alternative at a Sacramento River Stage of 24 ft. This plot indicates velocity compliance is exceeded through a small reach and is representative of the types of operational condition compliance failures observed for other alternatives.



- All channel configurations were assumed to have no operation at the proposed gate structure. Based on this assumption typically the channel functioned as hydraulic control for the system (with the exception of the Medium Alternative and Large Alternative). This created a situation where 6,000 cfs was quickly exceeded at Sacramento River stages above around 26 ft due to rapid expansion into the floodplain areas surrounding the proposed channel (bank elevations of approximately 26 ft). The figure below provides a stage discharge relationship for a wide range of additional alternatives with no gate control. This plot illustrates the impact on discharge from bottom width changes, invert elevation increases, and berm confinement.

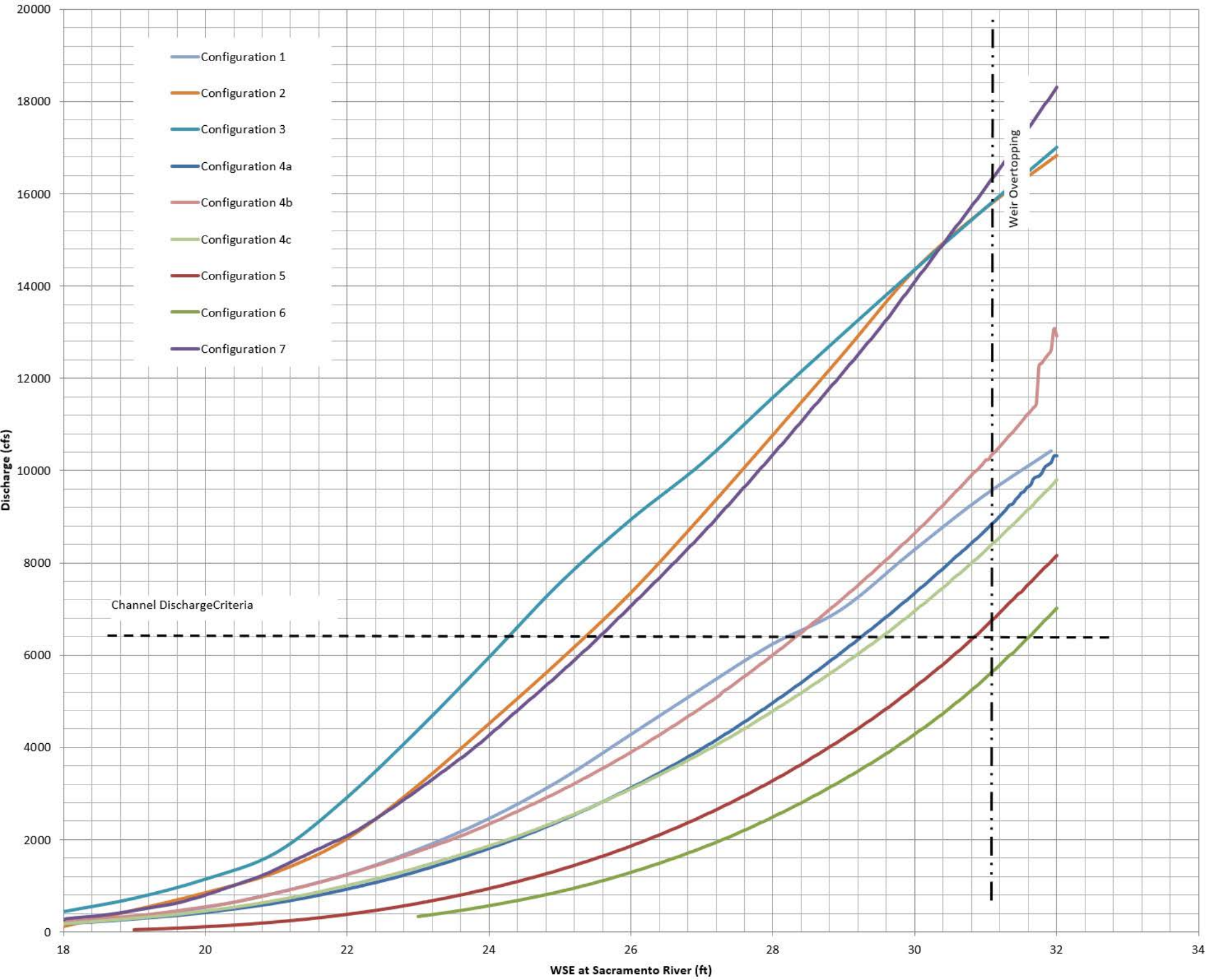


- Due to unknown importance of the various operational conditions and the high variability of the hydraulic performance strengths of the different alternatives there is no clear optimum channel configuration.

Appendix A

Gate Sizing and Headworks Flow

Appendix A2


Configuration 1
Configuration 2
Configuration 3
Configuration 4a
Configuration 4b
Configuration 4c
Configuration 5
Configuration 6
Configuration 7
Channel DischargeCriteria
Weir Overtopping
Discharge (cfs)
WSE at Sacramento River (ft)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
18
20
22
24
26
28
30
32
34

Appendix A

Gate Sizing and Headworks Flow

Appendix A3

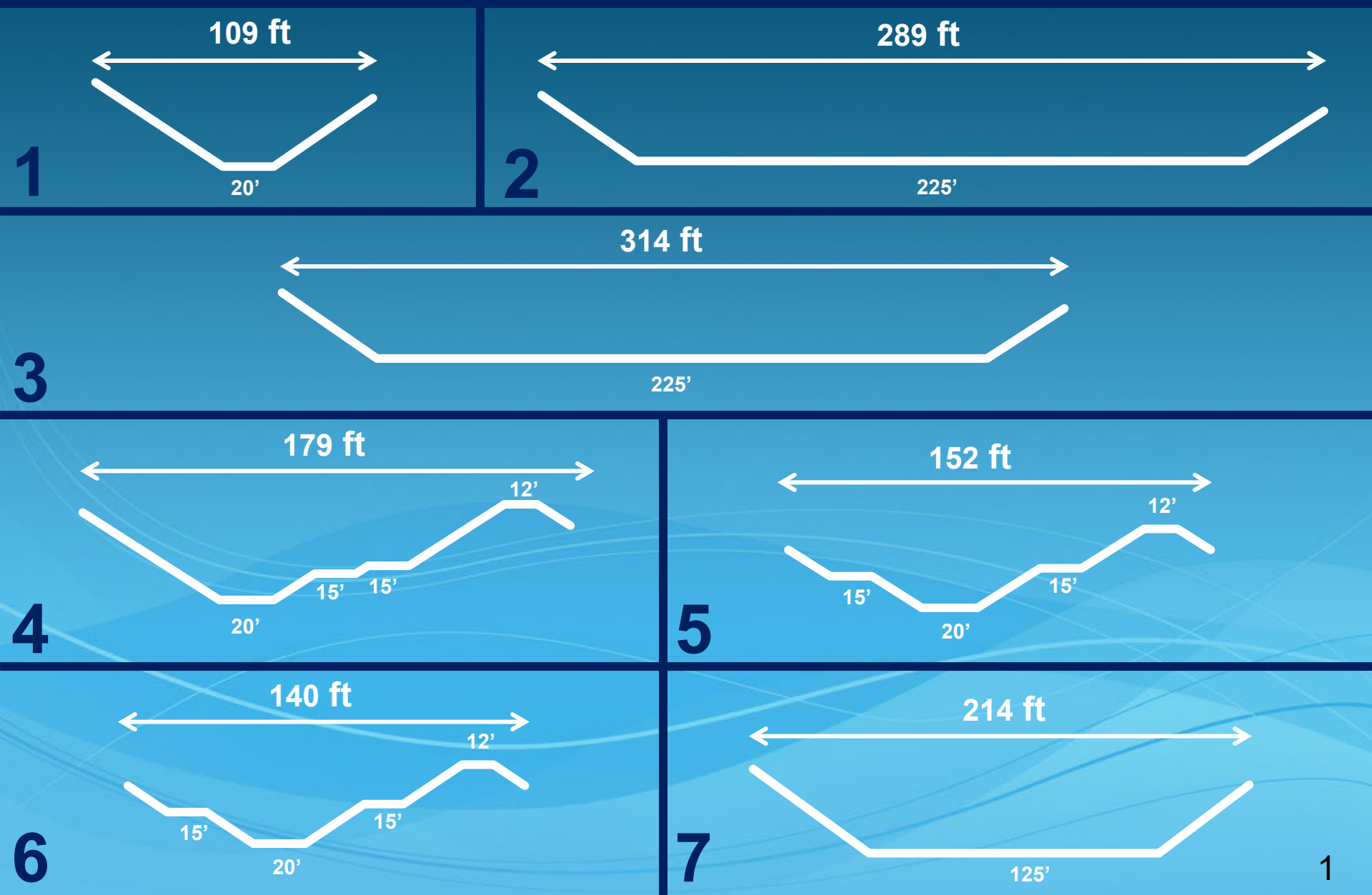
Configuration	Intake Structure		Channel		Lower Bench		Upper Bench		6,000 cfs Discharge Criteria Exceeded at Stages (ft) Greater than:	Operational Range (ft)		
	3-ft Depth Criteria Not Met at Stages (ft) Less than:	6-fps Velocity Criteria Exceeded at Stages (ft) Greater than:	5-ft Depth Criteria Not Met at Stages (ft) Less than:	4-fps Velocity Criteria Exceeded at Stages (ft) Greater than:	5-ft Depth Criteria Not Met at Stages (ft) Less than:	4-fps Velocity Criteria Exceeded at Stages (ft) Greater than:	5-ft Depth Criteria Not Met at Stages (ft) Less than:	4-fps Velocity Criteria Exceeded at Stages (ft) Greater than:		Minimum	Maximum	Delta
1. Small Alternative, 14' invert, 6,000 cfs	17	27.5	19	22.5					27.8	19	22.5	3.5
2. Medium Alternative, 17.5' invert, 225-ft bottom width, 6,000 cfs	21	28.4	22.3	27					25.1	22.3	25.1	2.8
3. Large Alternative, 14' invert, 225-ft bottom width, 6,000 cfs	17	26.7	19	31					24	19	24	5
4a. Original Small Alternative-a, 14' invert, 6,000 cfs (benched crossing section and bermed) *	17	24.9	19	25.3	26.1	27.8	28	30	29.3	19	24.9	5.9
4b. Small Alternative-a, 14' invert, 6,000 cfs (benched crossing section and bermed)**	17	29	19	23.8	23.2	25.8	25.6	28	28	19	28	9
4c Same setup as 4B but extended to make 5000 ft of length to approximate effect of other alignments or sinuosity**	17	31	19	25.6	23.7	27.8	26.1	29	29.2	19	29	10
5. Small Alternative-b, 17' invert, 6,000 cfs (benched crossing section and bermed) *	20	27.7	22	25.5	25.8	27.7	27.7	29.5	30.8	22	25.5	3.5
										25.8	27.7	1.9
6. Small Alternative-c, 19' invert, 6,000 cfs (benched crossing section and bermed) *	22	28.8	24	25.8	25.8	28.1	27.7	29	31.8	24	28.8	4.8
7. Large Alternative-a, 14' invert, 125-ft bottom width, 6,000 cfs	17	25	19	26					25.3	19	25	6

*Note: Configuration 4a, 5, and 6 hydraulic models show lack of operational compliance for a majority of flows immediately upstream of Tule Pond, however, this spreadsheet assumes that some channel improvements could be completed to improve that situation. Reported results ignore these downstream compliance issues based on assumed potential improvements to these area channel geometries. However, significant iterations of Configuration 4b channel geometry, immediately upstream of Tule Pond, indicated that simple solutions to operational criteria were difficult to obtain. Results provided in this table should be viewed as preliminary and subject to further investigations

**Note: Configuration 4b and 4c include the assumption of "burst speed" passage criteria at the HEC-RAS section immediately upstream of Tule Pond. This passage criteria was defined as 6 ft/s and 3 ft flow depth. All other channel cross sections met the standard passage criteria.

Intake
Channel
Left Bench
Right Bench
Operational Range
Discharge Limit
Elevation
35
30
25
20
15
1
2
3
4a
4b
4c
5
6
7
Configuration

Typ. Inundation Channel Configurations



1

2

3

4a

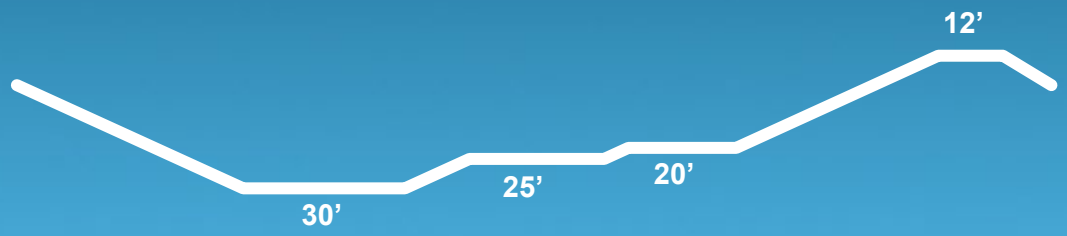
4b

4c

5

6

7



Project: **Yolo Bypass**		Prepared: BS	Date:	3/27/2015
Subject: **Passive Operation Inlet Analysis**		Checked:	Date:	
Task: **HEC-RAS Processing**				
Job#:		No:		

	Station 19838.66 Sacramento River Stage (ft)		Station 21543.86 Sacramento River Stage (ft)		Station 22249.84 Sacramento River Stage (ft)		
Alternative	Velocity Criteria Exceeded	Discharge Criteria Exceeded	Velocity Criteria Exceeded	Discharge Criteria Exceeded	Velocity Criteria Exceeded	Discharge Criteria Exceeded	Minimum Controlling Stage* (ft)
20-ft 14-ft Invert	N/A	N/A	23.3	28.0	23.9	28.0	23.3
20-ft 17-ft Invert	N/A	N/A	25.7	29.8	24.0	29.8	24.0
60-ft 14-ft Invert	N/A	N/A	24.1	26.2	24.5	26.2	24.1
60-ft 17-ft Invert	N/A	N/A	24.3	27.8	24.9	27.8	24.3
Bench Modified 14-ft Invert	N/A	N/A	23.0	27.4	23.5	27.4	27.4
Bench Modified 17-ft Invert	N/A	N/A	24.0	29.1	25.0	29.1	29.1
Bench Modified 14-ft Invert Levee	22.4	28.5	24.3	28.5	23.9	28.5	28.5
Bench Modified 17-ft Invert Levee	20.6	30.9	25.8	30.9	26.4	30.9	30.9
Bench Modified 18-ft Invert Levee	21.6	31.6	26.5	31.6	27.0	31.6	31.6
Bench Modified 19-ft Invert Levee	23.0	32.2	27.3	32.2	27.7	32.1	32.1

*Note: Minimum Controlling Stage for bench modified alternatives only includes discharge criteria. Velocity critiera is assumed to be limited by the bench velocities presented in an additional table

Upstream Invert Elevation

Alternative	14 ft	17 ft	18 ft	19 ft
Trapezoidal 20	X	X		
Trapezoidal 60	X	X		
Trapezoidal Be	X	X		
Trapezoidal Be	X	X	X	X

Bench Modified Bench Velocities

	Station 19838.66 Sacramento River Stage (ft)		Station 21543.86 Sacramento River Stage (ft)		Station 22249.84 Sacramento River Stage (ft)				
Alternative	Left Bench	Right Bench	Left Bench	Right Bench	Left Bench	Right Bench	Minimum Controlling Stage (ft)	Minimum Controlling Left Bench Stage (ft)	Minimum Controlling Right Bench Stage (ft)
Bench Modified 14-ft Invert	N/A	N/A	26.4	27.9	26.4	27.4	27.4	26.4	27.4
Bench Modified 17-ft Invert	N/A	N/A	28.1	30.3	28.1	29.5	29.5	28.1	29.5
Bench Modified 14-ft Invert Levee	29.8	29.8	29.1	28.9	29.6	28.9	29.1	29.1	28.9
Bench Modified 17-ft Invert Levee	29.3	31.8	29.6	31.1	29.6	30.6	30.6	29.3	30.6
Bench Modified 18-ft Invert Levee	30.7	N/A	30.8	31.9	30.2	31.2	30.7	30.2	31.2
Bench Modified 19-ft Invert Levee	32.2	N/A	32.1	32.8	30.8	31.7	31.7	30.8	31.7

Bench Modified Flow Depths (ft)

	Station 19838.66 Sacramento River Stage (ft)			Station 21543.86 Sacramento River Stage (ft)			Station 22249.84 Sacramento River Stage (ft)					
Alternative	Left Bench	Channel	Right Bench	Left Bench	Channel	Right Bench	Left Bench	Channel	Right Bench	Minimum Controlling Left Bench Stage (ft)	Minimum Controlling Channel Stage (ft)	Minimum Controlling Right Bench Stage (ft)
Bench Modified 14-ft Invert Levee	26.8	19.4	30.2	23.4	19.0	25.2	23.1	18.9	24.7	26.8	19.4	30.2
Bench Modified 17-ft Invert Levee	32.9	26.3	Not Inundated	26.7	22.3	28.5	26.2	22.0	27.8	32.9	26.3	N/A
Bench Modified 19-ft Invert Levee	Not Inundated	29.3	Not Inundated	28.9	24.4	30.6	28.3	24.0	30.0	N/A	29.3	N/A

Fish Passage Criteria Met With 19838.66

Alternative	Minimum Controlling Stage for Discharge (ft)	Minimum Controlling Stage for Channel Depth (ft)	Minimum Controlling Stage for Channel Velocity (ft)	Minimum Controlling Stage for Left Bench Depth (ft)	Minimum Controlling Stage for Left Bench Velocity (ft)	Minimum Controlling Stage for Right Bench Depth (ft)	Minimum Controlling Stage for Right Bench Velocity (ft)	Operational Range (ft)
Bench Modified 14-ft Invert Levee	28.5	19.4	22.4	26.8	29.1	30.2	28.9	19.4-22.4
Bench Modified 17-ft Invert Levee	30.9	26.3	20.6	32.9	29.3	N/A	N/A	None
Bench Modified 19-ft Invert Levee	32.1	29.3	23.0	N/A	N/A	N/A	N/A	None

Fish Passage Criteria Met Without 19838.66

Alternative	Minimum Controlling Stage for Discharge (ft)	Minimum Controlling Stage for Channel Depth (ft)	Minimum Controlling Stage for Channel Velocity (ft)	Minimum Controlling Stage for Left Bench Depth (ft)	Minimum Controlling Stage for Left Bench Velocity (ft)	Minimum Controlling Stage for Right Bench Depth (ft)	Minimum Controlling Stage for Right Bench Velocity (ft)	Operational Range (ft)
Bench Modified 14-ft Invert Levee	28.5	19.0	23.9	23.4	29.1	25.2	28.9	19.0-28.5
Bench Modified 17-ft Invert Levee	30.9	22.3	25.8	26.7	29.6	28.5	30.6	22.3-25.8 and 26.7-30.6
Bench Modified 19-ft Invert Levee	32.1	24.4	27.3	28.9	30.8	30.6	31.7	24.4-27.3 and 28.9-31.7

Appendix A

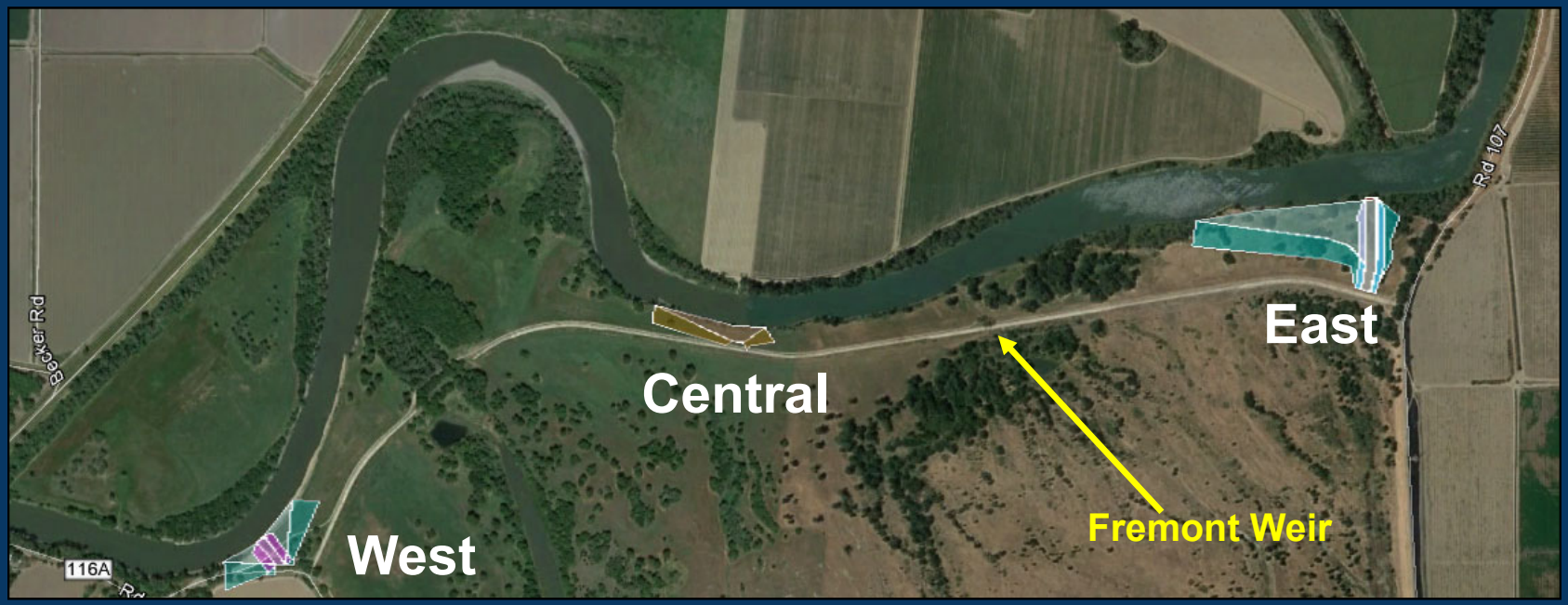
Gate Sizing and Headworks

Flow Appendix A4

Updated on 3/1/16 (DRAFT)

Current EIR/EIS Alternatives at Fremont Weir

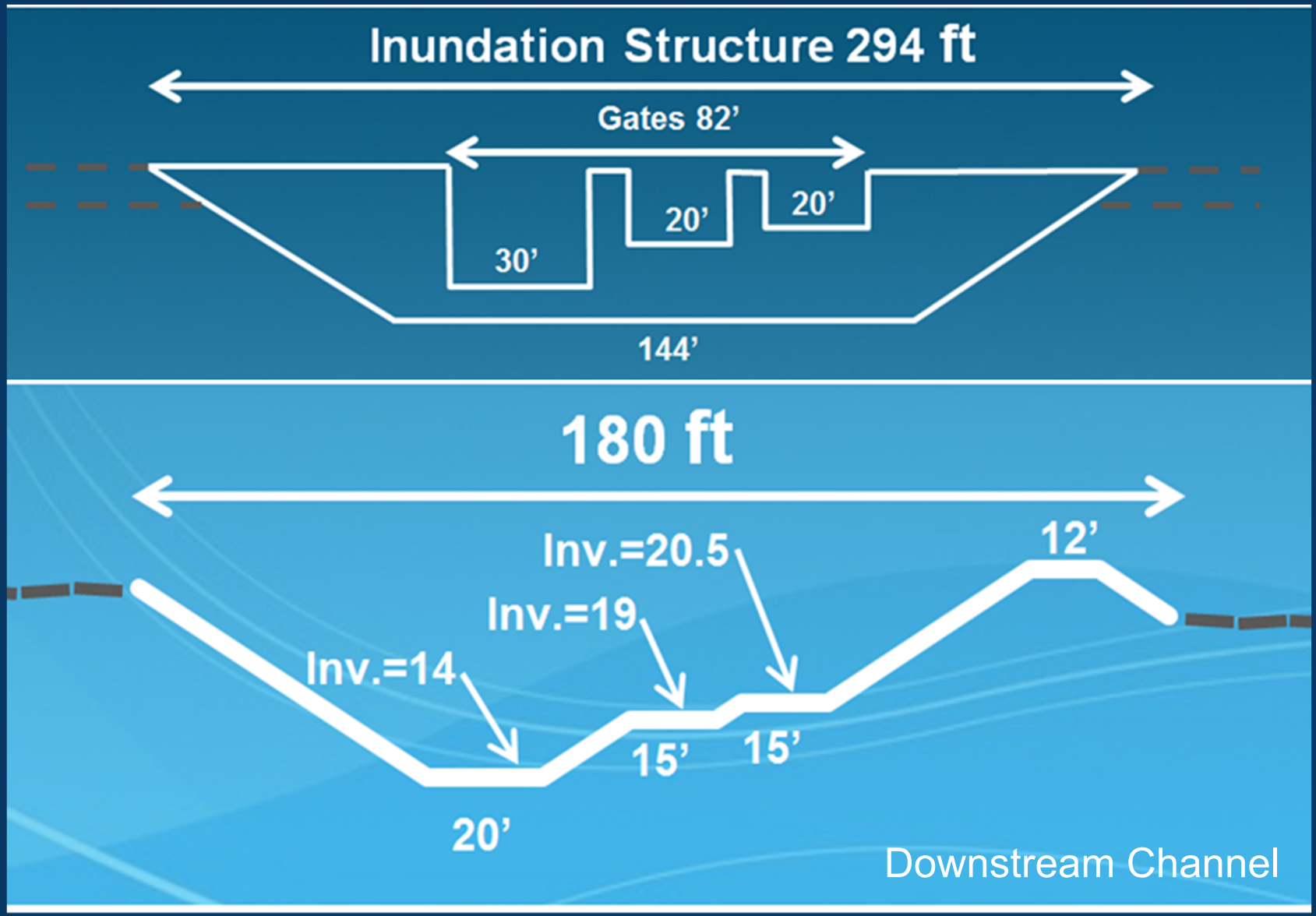
Does not include the jointly developed alternative that is still in development with stakeholders



Configuration		Downstream channel design			Operational Range (ft)
		Bottom Width (ft)	Side Slope	Max Discharge (cfs)	
4b	Small* 14' Invert - Benched	20	3:1	6,000	TBD**

**The operational range has not been set. Preliminary HEC-RAS modeling has indicated that an operational range of 19 to 28 feet would be within adult sturgeon passage criteria and would not exceed a discharge of ~6,000 cfs through the notch. However, there could be situations where the notch could be operated at stages below 19 feet (e.g., sturgeon not present). This will be based on recommendations from an operations management team.

Configuration 4b Design



Based on preliminary analyses, the inundation structure and downstream channel designs are favorable for meeting fish passage criteria. DWR and USBR are currently working on refining these designs to be constructible and maintainable. Modifications to these concepts are expected.

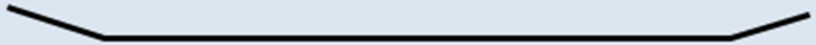
Configuration 4b: Notch Flow Rating Curve

	Configuration 4b
Stage (ft)	Discharge (ft^3/sec)
18.00	205
19.00	344
20.00	543
21.00	842
22.00	1,241
23.00	1,745
24.00	2,334
25.00	3,053
26.00	3,895
27.00	4,868
28.00	6,003

- Rating curve developed in HEC-RAS by HDR
- HDR started HEC-RAS inflowing hydrograph at 18 ft, as this was below the minimum for fish passage for configuration 4b
- Flows capped at 28 feet due to exceeding ~6,000 cfs
- Discharges below 18 feet can be interpolated by USGS if needed

Other Configurations

Notch Flow Rating Curves for Other Configurations Are Available Upon Request

Configuration		Downstream channel design			
		Bottom width (ft)	Side slope	Maximum discharge (cfs)	Cross-section
1.	Small 14' Invert	20	3:1	6000	
2.	Medium 17.5' Invert	225	3:1	6000	
3.	Large 14' Invert	225	3:1	6000	
4a.	Small-a 14' Invert, Benched	20	3:1	6000	
4b.	Small-a* 14' Invert, Benched	20	3:1	6000	
4c.	Small-a** 14' Invert, Benched	30	3:1	6000	
5.	Small-b 17' Invert, Benched	20	3:1	6000	
6.	Small-c 19' Invert, Benched	20	3:1	6000	
7.	Large 14' Invert	125	3:1	6000	

*= benched crossing section and bermed

**= benched crossing section and bermed, but extended to make 5,000 ft of length to approximate effect of other alignments or sinuosity

Appendix A
Gate Sizing and Headworks
Flow Appendix A5

Alternatives Set-Up for TUFLOW Model

Introduction

A new round of modeling is being conducted to look at refinements to the designs modeled in the first phase of the project (FreLg, FreMed, FreSm). The new alternatives that will be modeled are Alternatives #1, #4, and #6.

Common Features

Ag Crossing #1

The proposed design improves conveyance through Ag crossing #1 using a rail car bridge with flow allowed over the top as shown in Figure 1. The TUFLOW model will be modified to match this design with a bridge at the proposed location that allows weir flow over the top. The dimensions will match the figure including an invert elevation of 12.4 feet, bottom of the bridge deck will be 20.0 feet, and the top of the bridge deck will be 22.0 feet. The channel is skewed at ag crossing #1 reducing the effective width of the span to 48.0 feet which will be the width used in the model.

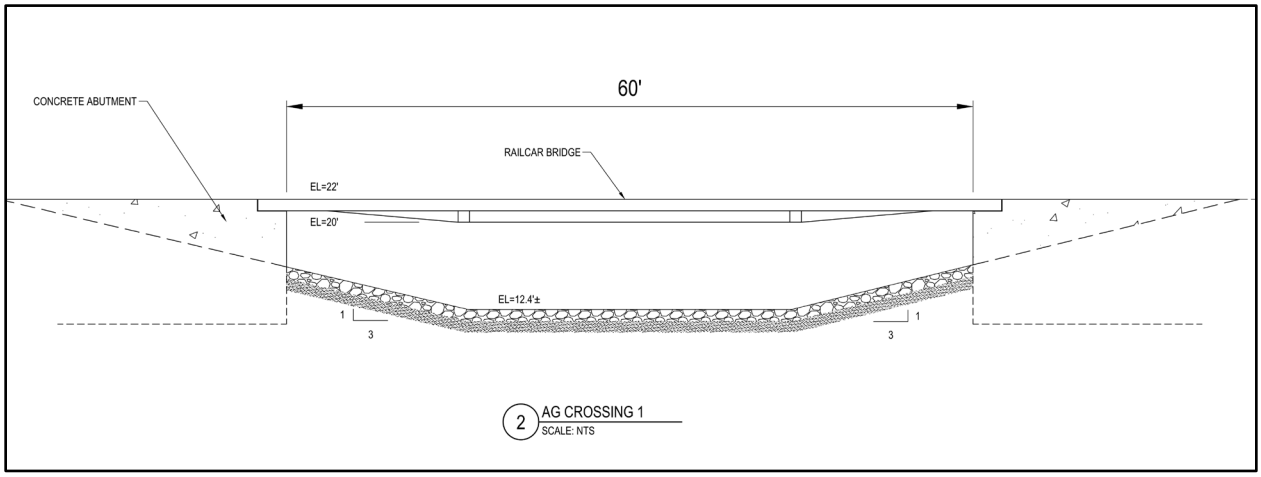


Figure 1 Ag crossing #1 design concept

Ag Crossing #2

Ag crossing #2 will have 6 box culverts and represent flow over the top as a weir. Snippets of the plans that contain the important details are included as Figure 2 and Figure 3.

- Culverts
  - Number 6
  - Width 24 ft; height 7.2 ft; US invert 12.0 ft; DS invert 12.0
  - Manning N 0.015 (concrete) for top
  - Manning N 0.035 (ESM) for bottom
  - Length 18 ft

Alternatives Set-Up for TUFLOW Model

- Weir
    - Elevations at 21.5 at the crossing and rising to over 40 feet on top of the levee

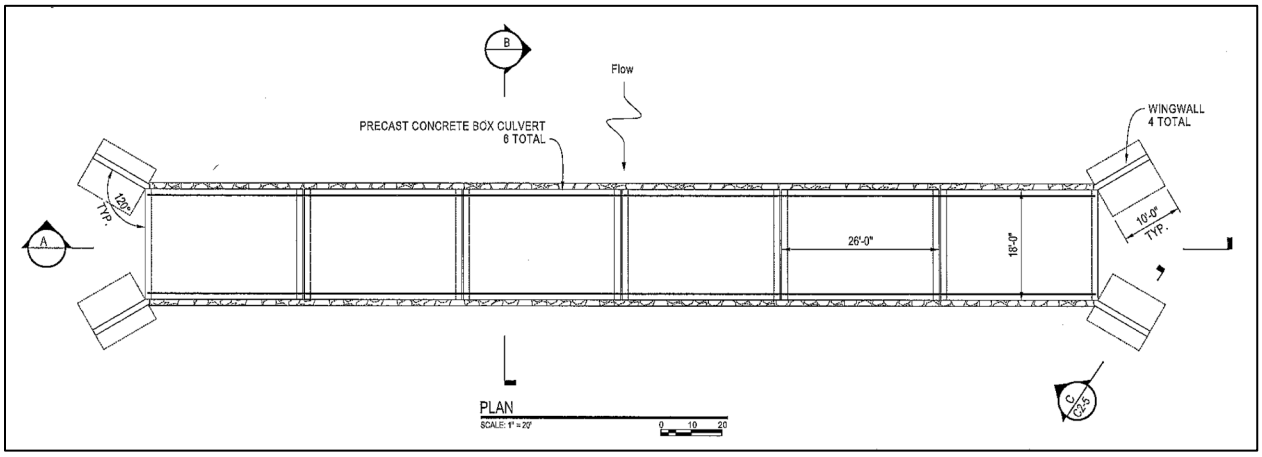


Figure 2 Agricultural crossing #2 plan

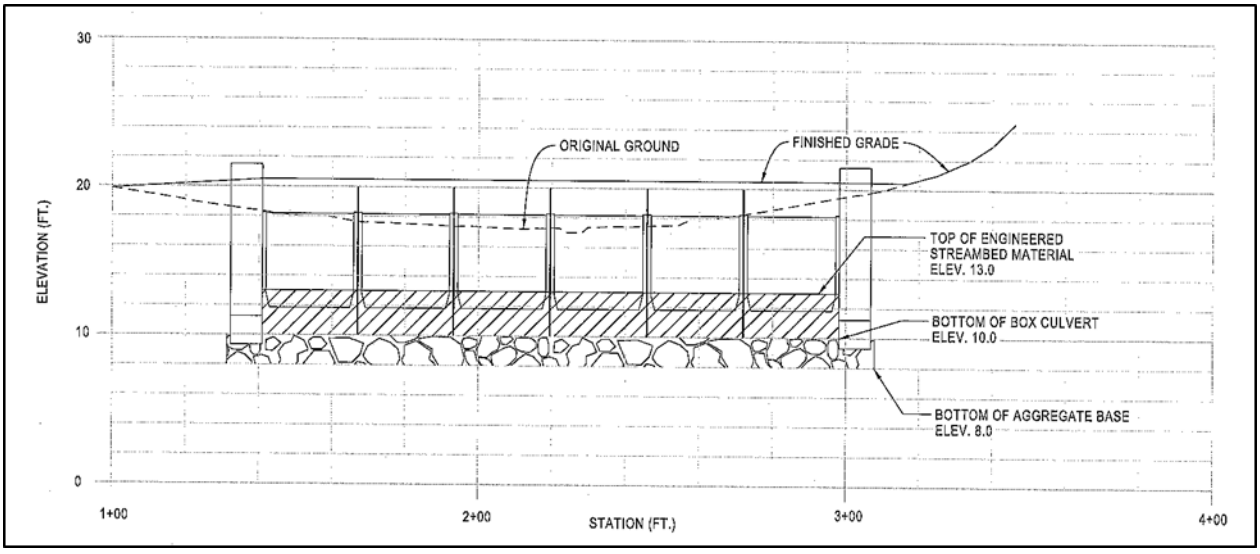


Figure 3 Agricultural crossing #2 elevations (old version showing top of engineered streambed at elevation 13.0 but will be modeled as 12.0 feet)

Ag Crossing #3

Ag crossing #3 is removed and represented as open channel (uses cross-sections upstream and downstream from existing conditions model).

Alternatives Set-Up for TUFLOW Model

Ag Crossing #4
Ag crossing #4 will have 7 culverts and represent flow over the top as a weir.

- Culverts
  - Number 7
  - Width 12 ft; height 10 ft; US invert 3.0 ft; DS invert 3.0
  - Manning N 0.015
  - Length 60 ft
- Weir
  - Weir elevation at 14.0 feet (cross-section does not extend up the levee like ag crossings #1 and #2)
- Operations
  - xxxx

Alt 1 (6k cfs on the east side)

Configuration

- Gate 1 – invert at 14.0; width 34.0 ft; height 18 ft
- Gate 2 & 3 – invert at 18.0; width 27.0 ft; height 14 ft
- The bottom elevation of the bridge deck is at an elevation of 29.0 ft and is not modeled separately so the gate heights will be modified to top out at this elevation. Therefore, the modeled height of gate 1 will be 15.5 ft and height of gates 2 and 3 will be 11.5 ft.
- All gates bottom hinged and will not prevent overtopping at bridge deck at elevation of approximately 32.0 feet.

Operations

- Gates will operate from Nov 1 - March 15
- The gates will open once there is 1.0 feet head above the invert elevation for gate 1 (15.0 feet). This WSE should have no or very little reverse flow based on past modeling.
- After the gates have been opened, gates 2 and 3 will be closed if the discharge through the notch reaches 6,000 cfs (gate 3 first than gate 2).
- Gate 1 will remain open throughout the event but the discharge shouldn't exceed 6,000 cfs before overtopping.
- The gate closure rates aren't significant and 10 minutes per gate will be used which is reasonable and ran stably in the previous models.
- Once Fremont Weir stops overtopping and the river recedes, gates 2 and 3 shall open to let more flow through the notch but the discharge is not to exceed 6,000 cfs into the Bypass. Test runs will be conducted to find a discharge on the receding limb to open gates #2 and #3 that will not immediately cause the discharge to 6,000 cfs to avoid repeatedly opening and closing of gates.

Alternatives Set-Up for TUFLOW Model

- All of the gates shall close when the upstream WSE reaches the invert elevation of gate 1 (14.0 feet).
- All gates shall close on March 15

Alt 4 (3k cfs at western location) (The design for this alternative has not been provided)

Configuration

- xxxx

Operations

- The gates will start operations on November first but will be setup for two different project end dates March 7th and March 15th. The March 15th end date will be run first and only the water years where the gates are open between March 7th and 15th will be run for the earlier closure.
-

Alt 5 (3k cfs at central location)

Configuration

- xxxx

Operations

- xxxx

Alt 6 (12k cfs on the west side)

Configuration

- 5 Identical gates
  - Invert 16.1 feet;
  - Height 13.11 feet (to the bottom of the bridge deck)
  - Width 40.0 feet
- The bottom elevation of the bridge deck is at an elevation of 29.21 ft.
- All gates bottom hinged and will not prevent overtopping at bridge deck at elevation of approximately 32.2 feet.

Operations

- Gates will operate from Nov 1 - March 15
- Open once there is 1.0 feet head above the invert elevation.

Alternatives Set-Up for TUFLOW Model

- Once 12,000 cfs through the notch is achieved, bays will start to close one-by-one until Fremont Weir begins to overtop. The last gate configuration prior to overtopping shall be held during overtopping.
- The gate closure rates are pretty insignificant so let's model them as instantaneously in TUFLOW.
- Once Fremont Weir stops overtopping and the river recedes, gates shall open to allow no greater than 12,000 cfs into the bypass.
- All gates shall close when the upstream water surface elevation drops below the elevation the deepest gate on the receding limb.
- All gates shall close on March 15

Results

Life Cycle Model (Cramer)

- Same as previous

Economics Model (ERA Economics)

- LDW graphics-Same as previous

Waterfowl Analysis (TBD)

- Depths

Mercury Modeling (DWR)

- Discharge, Bathymetry for mercury cells, variety of time varying data (csv format)-Same as previous

Wet area through time (DWR)

- Daily time step for 16 WYs for wetted acres

Entrainment Analysis (DWR)

- Daily time step for 16 WYs for discharge

Minimum Depth Evaluation

Modified Alternative 4b (20ft Bottom Width, 30ft Bench, No Levee)

System (Channel and Control Structure) Operational Range Sacramento River Stage Meeting Criterion* 19.25 ft to 28.1 ft

River Station	Flow to Achieve Depth Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Depth in Channel (ft)	Water Surface Elevation in Sacramento River (ft)	Channel Depth Criterion Met
	Headworks								
22631.29	364.84	13.9	NA	19.09	NA	0.41	5.19	19.09	Yes
22539.45	364.8	13.99	NA	19.09	NA	0.43	5.1	19.09	Yes
22526.59BR U									
22526.59	Structure								
22526.59BR D									
	Channel Improvements								
22371.59	364.8	13.94	17.94	18.99	0.62	1.52	5.05	19.09	Yes
22259.05	364.77	13.89	17.89	18.96	0.62	1.51	5.07	19.09	Yes
22132.74	364.74	13.8	17.8	18.93	0.62	1.48	5.13	19.09	Yes
21987.31	364.69	13.69	17.69	18.9	0.63	1.45	5.21	19.09	Yes
21738.52	364.62	13.5	17.5	18.84	0.63	1.39	5.34	19.09	Yes
21539.51	364.57	13.35	17.35	18.8	0.63	1.34	5.45	19.09	Yes
21332.41	364.52	13.19	17.19	18.77	0.63	1.29	5.58	19.09	Yes
21128.76	364.47	13.04	17.04	18.73	0.63	1.25	5.69	19.09	Yes
20977.12	364.43	12.93	16.93	18.71	0.63	1.22	5.78	19.09	Yes
20825.18	364.39	12.82	16.82	18.69	0.63	1.19	5.87	19.09	Yes
20594.58	364.33	12.65	16.65	18.66	0.62	1.14	6.01	19.09	Yes
20425.89	364.29	12.52	16.52	18.64	0.61	1.11	6.12	19.09	Yes
20236.83	364.24	12.38	16.38	18.62	0.6	1.07	6.24	19.09	Yes
20035.35	364.18	12.23	16.23	18.61	0.59	1.04	6.38	19.09	Yes
19837.62	364.13	12.08	16.08	18.59	0.59	1	6.51	19.09	Yes
19736.81	364.1	12	16	18.58	0.59	0.99	6.58	19.09	Yes
	Tule Pond								
19636.72	364.07	11.4	NA	18.58	NA	0.73	7.18	19.09	Yes
19536.65	363.99	11.4	NA	18.57	NA	0.49	7.17	19.09	Yes
19436.8	363.9	10.3	NA	18.57	NA	0.37	8.27	19.09	Yes
19338.03	363.82	12.1	NA	18.56	NA	0.68	6.46	19.09	Yes
19236.48	363.77	12.1	NA	18.55	NA	0.52	6.45	19.09	Yes
19136.77	363.73	12.2	NA	18.55	NA	0.54	6.35	19.09	Yes
19036.84	363.69	12.1	NA	18.55	NA	0.47	6.45	19.09	Yes
18937.86	363.64	12.2	NA	18.54	NA	0.51	6.34	19.09	Yes
18836.91	363.6	12	NA	18.54	NA	0.39	6.54	19.09	Yes
18737.68	363.55	11	NA	18.54	NA	0.65	7.54	19.09	Yes
18637.81	363.49	11.6	NA	18.54	NA	0.26	6.94	19.09	Yes
18536.29	363.4	11.4	NA	18.54	NA	0.22	7.14	19.09	Yes
18436.81	363.32	10.6	NA	18.54	NA	0.2	7.94	19.09	Yes
18337.51	363.23	10.2	NA	18.54	NA	0.22	8.34	19.09	Yes
18235.95	363.13	11.5	NA	18.54	NA	0.18	7.04	19.09	Yes

18137.15	363.04	11.1	NA	18.54	NA	0.22	7.44	19.09	Yes
18038.68	362.93	10.9	NA	18.54	NA	0.19	7.64	19.09	Yes
17937.95	362.81	7.6	NA	18.54	NA	0.17	10.94	19.09	Yes
17836.38	362.72	7.7	NA	18.54	NA	0.17	10.84	19.09	Yes
17735.46	362.63	2.5	NA	18.54	NA	0.15	16.04	19.09	Yes
17635.3	362.53	7.9	NA	18.54	NA	0.19	10.64	19.09	Yes
17532.95	362.44	9.6	NA	18.54	NA	0.19	8.94	19.09	Yes
17435.02	362.34	10.1	NA	18.54	NA	0.16	8.44	19.09	Yes
17335.67	362.22	8.6	NA	18.54	NA	0.16	9.94	19.09	Yes
17235.93	362.12	8.5	NA	18.54	NA	0.19	10.04	19.09	Yes
17133.86	362.04	8.6	NA	18.53	NA	0.37	9.93	19.09	Yes
17028.39	361.97	7.5	NA	18.53	NA	0.24	11.03	19.09	Yes
16925.24	361.89	9.7	NA	18.53	NA	0.29	8.83	19.09	Yes
16747.88	361.74	7.5	NA	18.53	NA	0.34	11.03	19.09	Yes
16250.1	361.38	12.2	NA	18.52	NA	0.43	6.32	19.09	Yes
15742.99	361.08	12.73	NA	18.42	NA	1.04	5.69	19.09	Yes
15240.24	360.79	12.65	NA	18.34	NA	0.6	5.69	19.09	Yes
14735.95	360.46	12.57	NA	18.16	NA	1.19	5.59	19.09	Yes

Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be

Channel Criterion Evaluation

Modified Alternative 4b (20ft Bottom Width, 30ft Bench, No Levee)

System (Channel and Control Structure) Operational Range Sacramento River Stage Meeting Criterion* 19.25 ft to 28.1 ft

River Sta	Flow to Achieve Channel Velocity Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Mean Velocity (ft/s)	Depth in Channel (ft)	Water Surface Elevation in Sacramento River (ft)		Channel Criterion Met
Headworks											
22631.29	2891.82	13.9	NA	24.54	NA	1.45	1.17	10.64	24.54	TRUE	Yes
22539.45	2891.82	13.99	NA	24.53	NA	1.51	1.23	10.54	24.54	TRUE	Yes
22526.59BR U											
22526.59	Structure										
22526.59BR D											
Channel Improvements											
22371.59	2891.82	13.94	17.94	23.95	3	4	4.06	10.01	24.54	TRUE	Yes
22259.05	2891.82	13.89	17.89	23.86	3.02	4.03	3.66	9.97	24.54	FALSE	No
22132.74	2891.82	13.8	17.8	23.75	3.01	4.04	3.66	9.95	24.54	FALSE	No
21987.31	2891.82	13.69	17.69	23.71	2.65	3.78	2.98	10.02	24.54	TRUE	Yes
21738.52	2891.82	13.5	17.5	23.5	2.71	3.88	3.43	10	24.54	TRUE	Yes
21539.51	2891.82	13.35	17.35	23.35	2.62	3.88	3.47	10	24.54	TRUE	Yes
21332.41	2891.82	13.19	17.19	23.19	2.61	3.9	3.5	10	24.54	TRUE	Yes
21128.76	2891.82	13.04	17.04	23.07	2.43	3.75	3.2	10.03	24.54	TRUE	Yes
20977.12	2891.82	12.93	16.93	22.9	3.01	4.02	3.59	9.97	24.54	FALSE	No
20825.18	2891.82	12.82	16.82	22.79	2.59	4.01	3.49	9.97	24.54	FALSE	No
20594.58	2891.82	12.65	16.65	22.7	1.97	3.49	2.7	10.05	24.54	TRUE	Yes
20425.89	2891.82	12.52	16.52	22.59	2	3.52	2.74	10.07	24.54	TRUE	Yes
20236.83	2891.82	12.38	16.38	22.5	1.9	3.3	2.47	10.12	24.54	TRUE	Yes
20035.35	2891.82	12.23	16.23	22.42	1.77	3.15	2.21	10.19	24.54	TRUE	Yes
19837.62	2891.82	12.08	16.08	22.31	1.78	3.38	2.38	10.23	24.54	TRUE	Yes
19736.81	2891.82	12	16	22.26	1.77	3.4	2.36	10.26	24.54	TRUE	Yes
	Tule Pond										
19636.72	2891.82	11.4	NA	22.26	NA	2.12	1.83	10.86	24.54	TRUE	Yes
19536.65	2891.82	11.4	NA	22.21	NA	1.7	1.43	10.81	24.54	TRUE	Yes
19436.8	2891.82	10.3	NA	22.18	NA	1.44	1.19	11.88	24.54	TRUE	Yes
19338.03	2891.82	12.1	NA	22.11	NA	1.9	1.61	10.01	24.54	TRUE	Yes
19236.48	2891.82	12.1	NA	22.08	NA	1.76	1.47	9.98	24.54	TRUE	Yes
19136.77	2891.82	12.2	NA	22.05	NA	1.76		9.85	24.54	TRUE	Yes
19036.84	2891.82	12.1	NA	22.03	NA	1.63		9.93	24.54	TRUE	Yes
18937.86	2891.82	12.2	NA	22	NA	1.68		9.8	24.54	TRUE	Yes
18836.91	2891.82	12	NA	22	NA	1.48		10	24.54	TRUE	Yes
18737.68	2891.82	11	NA	21.95	NA	1.96		10.95	24.54	TRUE	Yes
18637.81	2891.82	11.6	NA	21.97	NA	1.02		10.37	24.54	TRUE	Yes
18536.29	2891.82	11.4	NA	21.97	NA	0.95		10.57	24.54	TRUE	Yes
18436.81	2891.82	10.6	NA	21.97	NA	0.88		11.37	24.54	TRUE	Yes
18337.51	2891.82	10.2	NA	21.96	NA	0.92		11.76	24.54	TRUE	Yes
18235.95	2891.82	11.5	NA	21.96	NA	0.85		10.46	24.54	TRUE	Yes

18137.15	2891.82	11.1	NA	21.95	NA	0.93		10.85	24.54	TRUE	Yes
18038.68	2891.82	10.9	NA	21.95	NA	0.86		11.05	24.54	TRUE	Yes
17937.95	2891.82	7.6	NA	21.95	NA	0.73		14.35	24.54	TRUE	Yes
17836.38	2891.82	7.7	NA	21.95	NA	0.71		14.25	24.54	TRUE	Yes
17735.46	2891.82	2.5	NA	21.95	NA	0.66		19.45	24.54	TRUE	Yes
17635.3	2891.82	7.9	NA	21.94	NA	0.76		14.04	24.54	TRUE	Yes
17532.95	2891.82	9.6	NA	21.94	NA	0.75		12.34	24.54	TRUE	Yes
17435.02	2891.82	10.1	NA	21.94	NA	0.69	1.48	11.84	24.54	TRUE	Yes
17335.67	2891.82	8.6	NA	21.94	NA	0.68	1.36	13.34	24.54	TRUE	Yes
17235.93	2891.82	8.5	NA	21.93	NA	0.77		13.43	24.54	TRUE	Yes
17133.86	2891.82	8.6	NA	21.92	NA	1.1		13.32	24.54	TRUE	Yes
17028.39	2891.82	7.5	NA	21.91	NA	0.92		14.41	24.54	TRUE	Yes
16925.24	2891.82	9.7	NA	21.91	NA	0.98		12.21	24.54	TRUE	Yes
16747.88	2891.82	7.5	NA	21.89	NA	1.02		14.39	24.54	TRUE	Yes
16250.1	2891.82	12.2	NA	21.84	NA	1.12		9.64	24.54	TRUE	Yes
15742.99	2891.82	12.73	NA	21.76	NA	1.26		9.03	24.54	TRUE	Yes
15240.24	2891.82	12.65	NA	21.69	NA	1.1		9.04	24.54	TRUE	Yes
14735.95	2891.82	12.57	NA	21.62	NA	1.2		9.05	24.54	TRUE	Yes
	2891.82										

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a

Bench Criterion Evaluation

Modified Alternative 4b (20ft Bottom Width, 30ft Bench, No Levee)

System (Channel and Control Structure) Operational Range Sacramento River Stage Meeting Criterion* 19.25 ft to 28.1 ft

River Sta	Flow to Achieve Bench Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Mean Velocity (ft/s)	Water Depth at Bench When Channel Velocity is Less than 4ft/sec (ft)	Representative Reach Length (ft)	Water Surface Elevation in Sacramento River (ft)	Bench Criterion Met
Headworks											
22631.29	4457.80	13.90	NA	26.33	NA	1.85	1.85	NA	48.54	26.33	Yes
22539.45	4457.80	13.99	NA	26.32	NA	1.93	1.93	NA	131.27	26.33	Yes
22526.59BR U											
22526.59	Structure										
22526.59BR D											
Channel Improvements											
22371.59	4457.80	13.94	17.94	25.39	3.90	4.99	4.64	6.01	127.45	26.33	Yes
22259.05	4457.80	13.89	17.89	25.27	3.93	5.04	4.69	5.97	98.23	26.33	Yes
22132.74	4457.80	13.80	17.80	25.16	3.79	5.07	4.42	5.95	126.32	26.33	Yes
21987.31	4457.80	13.69	17.69	25.12	3.26	4.59	3.57	6.02	194.31	26.33	Yes
21738.52	4457.80	13.50	17.50	24.84	3.37	4.79	4.24	6.00	219.23	26.33	Yes
21539.51	4457.80	13.35	17.35	24.66	3.13	4.74	4.01	6.00	202.41	26.33	Yes
21332.41	4457.80	13.19	17.19	24.46	2.97	4.80	4.01	6.00	206.56	26.33	Yes
21128.76	4457.80	13.04	17.04	24.34	2.77	4.40	3.26	6.03	177.93	26.33	Yes
20977.12	4457.80	12.93	16.93	24.07	3.67	5.18	4.55	5.97	151.41	26.33	Yes
20825.18	4457.80	12.82	16.82	23.92	2.93	5.17	4.21	5.97	191.31	26.33	Yes
20594.58	4457.80	12.65	16.65	23.81	2.52	4.30	3.37	6.05	200.49	26.33	Yes
20425.89	4457.80	12.52	16.52	23.66	2.53	4.42	3.43	6.07	178.86	26.33	Yes
20236.83	4457.80	12.38	16.38	23.53	2.47	4.19	3.25	6.12	194.68	26.33	Yes
20035.35	4457.80	12.23	16.23	23.42	2.34	4.04	3.02	6.19	199.33	26.33	Yes
19837.62	4457.80	12.08	16.08	23.27	2.32	4.31	3.08	6.23	149.11	26.33	Yes
19736.81	4457.80	12.00	16.00	23.20	2.29	4.33	3.02	6.26	100.66	26.33	Yes
Tule Pond											
19636.72	4457.80	11.4	NA	23.2	NA	2.65	2.65	NA	150.45	26.33	Yes
19536.65	4457.80	11.4	NA	23.13	NA	2.2	2.2	NA	200.085	26.33	Yes
19436.8	4457.80	10.3	NA	23.09	NA	1.91	1.91	NA	200.095	26.33	Yes
19338.03	4457.80	12.1	NA	22.98	NA	2.42	2.42	NA	150.705	26.33	Yes
19236.48	4457.80	12.1	NA	22.94	NA	2.28	2.28	NA	100.63	26.33	Yes
19136.77	4457.80	12.2	NA	22.9	NA	2.26	2.26	NA	99.82	26.33	Yes
19036.84	4457.80	12.1	NA	22.87	NA	2.12	2.12	NA	49.965	26.33	Yes
18937.86	4457.80	12.2	NA	22.83	NA	2.17	2.17	NA			
18836.91	4457.80	12	NA	22.82	NA	1.96	1.96	NA			
18737.68	4457.80	11	NA	22.78	NA	2.54	2.54	NA			
18637.81	4457.80	11.6	NA	22.8	NA	1.37	1.37	NA			
18536.29	4457.80	11.4	NA	22.79	NA	1.3	1.3	NA			
18436.81	4457.80	10.6	NA	22.79	NA	1.21	1.21	NA			
18337.51	4457.80	10.2	NA	22.78	NA	1.26	1.26	NA			
18235.95	4457.80	11.5	NA	22.78	NA	1.18	1.18	NA			
18137.15	4457.80	11.1	NA	22.77	NA	1.28	1.28	NA			
18038.68	4457.80	10.9	NA	22.77	NA	1.19	1.16	NA			
17937.95	4457.80	7.6	NA	22.77	NA	0.99	0.99	NA			

17836.38	4457.80	7.7	NA	22.77	NA	0.96	0.96	NA			
17735.46	4457.80	2.5	NA	22.77	NA	0.9	0.9	NA			
17635.3	4457.80	7.9	NA	22.76	NA	1.02	1.02	NA			
17532.95	4457.80	9.6	NA	22.75	NA	1.02	1.02	NA			
17435.02	4457.80	10.1	NA	22.75	NA	0.94	0.94	NA			
17335.67	4457.80	8.6	NA	22.75	NA	0.92	0.92	NA			
17235.93	4457.80	8.5	NA	22.74	NA	1.04	1.04	NA			
17133.86	4457.80	8.6	NA	22.72	NA	1.41	1.41	NA			
17028.39	4457.80	7.5	NA	22.71	NA	1.22	1.2	NA			
16925.24	4457.80	9.7	NA	22.7	NA	1.28	1.25	NA			
16747.88	4457.80	7.5	NA	22.68	NA	1.33	1.27	NA			
16250.1	4457.80	12.2	NA	22.62	NA	1.42	1.27	NA			
15742.99	4457.80	12.73	NA	22.53	NA	1.49	1.29	NA			
15240.24	4457.80	12.65	NA	22.44	NA	1.37	1.06	NA			
14735.95	4457.80	12.57	NA	22.37	NA	1.42	1.06	NA			

* Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 200 ft)

** Maximum Velocity of 4 ft/sec exceeded for 225 ft

*** Maximum Velocity of 4 ft/sec exceeded for 219 ft

System Capacity Evalualtion(6,000 cfs)

Modified Alternative 4b (20ft Bottom Width, 30ft Bench, No Levee)

System (Channel and Control Structure) Operational Range Sacramento River Stage Meeting Criterion* 19.25 ft to 28.1 ft

River Sta	System Capacith Flow (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Mean Velocity (ft/s)	Water Depth at Bench When Channel Velocity is Less than 4ft/sec (ft)	Representative Reach Length (ft)	Water Surface Elevation in Sacramento River (ft)	Channel Criterion Met	Bench Criterion Met
Headworks												
22631.29	6010.55	13.9	NA	28.1	NA	2.13	2.08	NA	48.535	28.1	Yes	Yes
22539.45	6010.55	13.99	NA	28.08	NA	2.22	2.22	NA	131.265	28.1	Yes	Yes
22526.59	Structure											
22371.59	6010.55	13.94	19.94	26.26	3.89	7.74	6.67	6.01	127.45	28.1	No	Yes
Channel Improvements												
22259.05	6010.55	13.89	17.89	26.22	5.57	6.74	6.31	5.97	98.23	28.1	No	No**
22132.74	6010.55	13.8	17.8	26.15	5.19	6.65	5.54	5.95	126.32	28.1	No	No**
21987.31	6010.55	13.69	17.69	26.15	4.37	5.96	4.39	6.02	194.31	28.1	No	No***
21738.52	6010.55	13.5	17.5	25.77	4.37	6.26	5.38	6	219.23	28.1	No	No**
21539.51	6010.55	13.35	17.35	25.6	3.95	6.1	4.77	6	202.405	28.1	No	Yes
21332.41	6010.55	13.19	17.19	25.39	3.63	6.15	4.43	6	206.555	28.1	No	Yes
21128.76	6010.55	13.04	17.04	25.28	3.39	5.49	3.75	6.03	177.93	28.1	No	Yes
20977.12	6010.55	12.93	16.93	24.88	4.47	6.87	5.53	5.97	151.405	28.1	No	Yes
20825.18	6010.55	12.82	16.82	24.73	3.63	6.82	4.82	5.97	191.31	28.1	No	Yes
20594.58	6010.55	12.65	16.65	24.6	3.2	5.69	4.14	6.05	200.485	28.1	No	Yes
20425.89	6010.55	12.52	16.52	24.41	3.24	5.88	4.23	6.07	178.855	28.1	No	Yes
20236.83	6010.55	12.38	16.38	24.26	3.14	5.7	3.94	6.12	194.675	28.1	No	Yes
20035.35	6010.55	12.23	16.23	24.1	3	5.51	3.78	6.19	199.33	28.1	No	Yes
19837.62	6010.55	12.08	16.08	23.91	3.05	5.8	3.82	6.23	149.105	28.1	No	Yes
19736.81	6010.55	12	16	23.82	3	5.8	3.73	6.26	100.655	28.1	No	Yes
Tule Pond												
19636.72	6010.55	11.4	NA	23.87		3.13	3.13	NA	150.45	28.1	Yes	Yes
19536.65	6010.55	11.4	NA	23.82	0.2	2.65	2.65	NA	200.085	28.1	Yes	Yes
19436.8	6010.55	10.3	NA	23.78	0.02	2.32	2.32	NA	200.095	28.1	Yes	Yes
19338.03	6010.55	12.1	NA	23.67		2.85	2.85	NA	150.705	28.1	Yes	Yes
19236.48	6010.55	12.1	NA	23.64	0.13	2.71	2.71	NA	100.63	28.1	Yes	Yes
19136.77	6010.55	12.2	NA	23.6	0.16	2.67	2.67	NA	99.82	28.1	Yes	Yes
19036.84	6010.56	12.1	NA	23.58		2.51	2.51	NA	49.965	28.1	Yes	Yes

* Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 200 ft)

** Maximum Velocity of 4 ft/sec exceeded for 638 ft

*** Maximum Velocity of 4 ft/sec exceeded for 638 ft, Right bank has a Bench that will meet bench criterion

Large Gate width	34 ft	Large Gate invert	14 ft
Small Gate width	27 ft	Small Gate invert	18 ft

	US Stage	At Headwork Structure			Effective head		Flow Area			Velocity
Date		Stage HW	Stage TW	Flow	Small Gates	Large Gate	Small Gates	Large Gate	Total	through the
	(ft. NAVD88)	(ft. NAVD88)	(ft. NAVD88)	cfs	(ft.)	(ft.)	(Sq. ft.)	(Sq. ft.)	(Sq. ft.)	(fps)
31Dec1999 2400	17	19.94	19.35	1008.96	1.35	5.35	72.9	181.9	254.8	4.0
01Jan2000 0100	17.04	17.04	17.05	-58.46	0	3.05	0	103.7	103.7	-0.6
01Jan2000 0200	17.08	17.08	17.04	120.45	0	3.04	0	103.4	103.4	1.2
01Jan2000 0300	17.13	17.12	17.07	138.56	0	3.07	0	104.4	104.4	1.3
01Jan2000 0400	17.17	17.17	17.1	147.2	0	3.1	0	105.4	105.4	1.4
01Jan2000 0500	17.21	17.21	17.14	153.11	0	3.14	0	106.8	106.8	1.4
01Jan2000 0600	17.25	17.25	17.18	158.16	0	3.18	0	108.1	108.1	1.5
01Jan2000 0700	17.29	17.29	17.22	162.83	0	3.22	0	109.5	109.5	1.5
01Jan2000 0800	17.33	17.33	17.26	167.43	0	3.26	0	110.8	110.8	1.5
01Jan2000 0900	17.38	17.37	17.3	172.07	0	3.3	0	112.2	112.2	1.5
01Jan2000 1000	17.42	17.42	17.34	176.59	0	3.34	0	113.6	113.6	1.6
01Jan2000 1100	17.46	17.46	17.38	180.69	0	3.38	0	114.9	114.9	1.6
01Jan2000 1200	17.5	17.5	17.42	184.57	0	3.42	0	116.3	116.3	1.6
01Jan2000 1300	17.54	17.54	17.46	188.4	0	3.46	0	117.6	117.6	1.6
01Jan2000 1400	17.58	17.58	17.5	192.18	0	3.5	0	119.0	119.0	1.6
01Jan2000 1500	17.63	17.62	17.54	195.82	0	3.54	0	120.4	120.4	1.6
01Jan2000 1600	17.67	17.67	17.58	199.44	0	3.58	0	121.7	121.7	1.6
01Jan2000 1700	17.71	17.71	17.62	203.12	0	3.62	0	123.1	123.1	1.7
01Jan2000 1800	17.75	17.75	17.67	206.62	0	3.67	0	124.8	124.8	1.7
01Jan2000 1900	17.79	17.79	17.71	210.07	0	3.71	0	126.1	126.1	1.7
01Jan2000 2000	17.83	17.83	17.75	213.41	0	3.75	0	127.5	127.5	1.7
01Jan2000 2100	17.88	17.87	17.79	216.72	0	3.79	0	128.9	128.9	1.7
01Jan2000 2200	17.92	17.92	17.83	219.96	0	3.83	0	130.2	130.2	1.7
01Jan2000 2300	17.96	17.96	17.87	223.54	0	3.87	0	131.6	131.6	1.7
01Jan2000 2400	18	18	17.91	227.62	0	3.91	0	132.9	132.9	1.7
02Jan2000 0100	18.04	18.04	17.96	232.25	0	3.96	0	134.6	134.6	1.7
02Jan2000 0200	18.09	18.09	18	237	0	4	0	136.0	136.0	1.7
02Jan2000 0300	18.13	18.13	18.04	241.75	0.04	4.04	2.16	137.4	139.5	1.7
02Jan2000 0400	18.17	18.17	18.08	246.76	0.08	4.08	4.32	138.7	143.0	1.7
02Jan2000 0500	18.22	18.22	18.12	251.89	0.12	4.12	6.48	140.1	146.6	1.7
02Jan2000 0600	18.26	18.26	18.17	257.12	0.17	4.17	9.18	141.8	151.0	1.7
02Jan2000 0700	18.3	18.3	18.21	262.47	0.21	4.21	11.34	143.1	154.5	1.7
02Jan2000 0800	18.35	18.35	18.25	267.77	0.25	4.25	13.5	144.5	158.0	1.7
02Jan2000 0900	18.39	18.39	18.29	273.18	0.29	4.29	15.66	145.9	161.5	1.7
02Jan2000 1000	18.43	18.43	18.34	278.57	0.34	4.34	18.36	147.6	165.9	1.7
02Jan2000 1100	18.48	18.47	18.38	284.03	0.38	4.38	20.52	148.9	169.4	1.7
02Jan2000 1200	18.52	18.52	18.42	289.68	0.42	4.42	22.68	150.3	173.0	1.7
02Jan2000 1300	18.56	18.56	18.47	295.47	0.47	4.47	25.38	152.0	177.4	1.7
02Jan2000 1400	18.61	18.6	18.51	301.36	0.51	4.51	27.54	153.3	180.9	1.7
02Jan2000 1500	18.65	18.65	18.55	307.18	0.55	4.55	29.7	154.7	184.4	1.7
02Jan2000 1600	18.69	18.69	18.59	312.96	0.59	4.59	31.86	156.1	187.9	1.7
02Jan2000 1700	18.74	18.73	18.64	318.84	0.64	4.64	34.56	157.8	192.3	1.7
02Jan2000 1800	18.78	18.78	18.68	324.75	0.68	4.68	36.72	159.1	195.8	1.7
02Jan2000 1900	18.82	18.82	18.72	330.63	0.72	4.72	38.88	160.5	199.4	1.7
02Jan2000 2000	18.87	18.86	18.77	336.69	0.77	4.77	41.58	162.2	203.8	1.7
02Jan2000 2100	18.91	18.91	18.81	342.94	0.81	4.81	43.74	163.5	207.3	1.7
02Jan2000 2200	18.95	18.95	18.85	349.49	0.85	4.85	45.9	164.9	210.8	1.7
02Jan2000 2300	19	18.99	18.9	356.27	0.9	4.9	48.6	166.6	215.2	1.7
02Jan2000 2400	19.04	19.04	18.94	363.52	0.94	4.94	50.76	168.0	218.7	1.7
03Jan2000 0100	19.04	19.04	18.94	356.92	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0200	19.04	19.04	18.94	354.82	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0300	19.04	19.04	18.94	354.15	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0400	19.04	19.04	18.94	353.94	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0500	19.04	19.04	18.94	353.88	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0600	19.04	19.04	18.94	353.86	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0700	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0800	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 0900	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1000	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1100	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1200	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1300	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1400	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1500	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6

03Jan2000 1600	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1700	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1800	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 1900	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 2000	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 2100	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 2200	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 2300	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
03Jan2000 2400	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0100	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0200	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0300	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0400	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0500	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0600	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0700	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0800	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 0900	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1000	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1100	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1200	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1300	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1400	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1500	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1600	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1700	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1800	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 1900	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 2000	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 2100	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 2200	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 2300	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
04Jan2000 2400	19.04	19.04	18.94	353.85	0.94	4.94	50.76	168.0	218.7	1.6
05Jan2000 0100	19.08	19.08	18.98	367.29	0.98	4.98	52.92	169.3	222.2	1.7
05Jan2000 0200	19.12	19.12	19.02	376.78	1.02	5.02	55.08	170.7	225.8	1.7
05Jan2000 0300	19.16	19.16	19.05	385.17	1.05	5.05	56.7	171.7	228.4	1.7
05Jan2000 0400	19.2	19.2	19.09	393.26	1.09	5.09	58.86	173.1	231.9	1.7
05Jan2000 0500	19.24	19.24	19.13	401.37	1.13	5.13	61.02	174.4	235.4	1.7
05Jan2000 0600	19.28	19.28	19.17	409.44	1.17	5.17	63.18	175.8	239.0	1.7
05Jan2000 0700	19.32	19.32	19.21	417.59	1.21	5.21	65.34	177.1	242.5	1.7
05Jan2000 0800	19.36	19.36	19.25	425.58	1.25	5.25	67.5	178.5	246.0	1.7
05Jan2000 0900	19.4	19.4	19.29	433.6	1.29	5.29	69.66	179.9	249.5	1.7
05Jan2000 1000	19.44	19.44	19.33	441.66	1.33	5.33	71.82	181.2	253.0	1.7
05Jan2000 1100	19.48	19.48	19.36	449.86	1.36	5.36	73.44	182.2	255.7	1.8
05Jan2000 1200	19.52	19.52	19.4	458.3	1.4	5.4	75.6	183.6	259.2	1.8
05Jan2000 1300	19.56	19.56	19.44	467.17	1.44	5.44	77.76	185.0	262.7	1.8
05Jan2000 1400	19.6	19.6	19.48	476.29	1.48	5.48	79.92	186.3	266.2	1.8
05Jan2000 1500	19.64	19.64	19.52	485.55	1.52	5.52	82.08	187.7	269.8	1.8
05Jan2000 1600	19.68	19.68	19.56	494.85	1.56	5.56	84.24	189.0	273.3	1.8
05Jan2000 1700	19.72	19.72	19.6	503.92	1.6	5.6	86.4	190.4	276.8	1.8
05Jan2000 1800	19.76	19.76	19.63	513.09	1.63	5.63	88.02	191.4	279.4	1.8
05Jan2000 1900	19.8	19.8	19.67	522.34	1.67	5.67	90.18	192.8	283.0	1.8
05Jan2000 2000	19.84	19.84	19.71	531.7	1.71	5.71	92.34	194.1	286.5	1.9
05Jan2000 2100	19.88	19.88	19.75	541.2	1.75	5.75	94.5	195.5	290.0	1.9
05Jan2000 2200	19.92	19.92	19.79	550.92	1.79	5.79	96.66	196.9	293.5	1.9
05Jan2000 2300	19.96	19.96	19.83	560.68	1.83	5.83	98.82	198.2	297.0	1.9
05Jan2000 2400	20	20	19.87	570.39	1.87	5.87	100.98	199.6	300.6	1.9
06Jan2000 0100	20.04	20.04	19.91	580.76	1.91	5.91	103.14	200.9	304.1	1.9
06Jan2000 0200	20.08	20.08	19.95	590.8	1.95	5.95	105.3	202.3	307.6	1.9
06Jan2000 0300	20.13	20.12	19.99	601.8	1.99	5.99	107.46	203.7	311.1	1.9
06Jan2000 0400	20.17	20.16	20.03	613.43	2.03	6.03	109.62	205.0	314.6	1.9
06Jan2000 0500	20.21	20.21	20.07	625.46	2.07	6.07	111.78	206.4	318.2	2.0
06Jan2000 0600	20.25	20.25	20.11	637.65	2.11	6.11	113.94	207.7	321.7	2.0
06Jan2000 0700	20.29	20.29	20.15	649.93	2.15	6.15	116.1	209.1	325.2	2.0
06Jan2000 0800	20.33	20.33	20.19	662.35	2.19	6.19	118.26	210.5	328.7	2.0
06Jan2000 0900	20.38	20.37	20.23	674.99	2.23	6.23	120.42	211.8	332.2	2.0
06Jan2000 1000	20.42	20.41	20.26	687.67	2.26	6.26	122.04	212.8	334.9	2.1
06Jan2000 1100	20.46	20.46	20.3	700.97	2.3	6.3	124.2	214.2	338.4	2.1
06Jan2000 1200	20.5	20.5	20.34	714.63	2.34	6.34	126.36	215.6	341.9	2.1
06Jan2000 1300	20.54	20.54	20.38	728.42	2.38	6.38	128.52	216.9	345.4	2.1
06Jan2000 1400	20.58	20.58	20.42	742.3	2.42	6.42	130.68	218.3	349.0	2.1
06Jan2000 1500	20.63	20.62	20.46	756.36	2.46	6.46	132.84	219.6	352.5	2.1

06Jan2000 1600	20.67	20.66	20.5	770.55	2.5	6.5	135	221.0	356.0	2.2
06Jan2000 1700	20.71	20.7	20.54	784.83	2.54	6.54	137.16	222.4	359.5	2.2
06Jan2000 1800	20.75	20.75	20.58	799.36	2.58	6.58	139.32	223.7	363.0	2.2
06Jan2000 1900	20.79	20.79	20.62	813.83	2.62	6.62	141.48	225.1	366.6	2.2
06Jan2000 2000	20.83	20.83	20.65	828.69	2.65	6.65	143.1	226.1	369.2	2.2
06Jan2000 2100	20.88	20.87	20.69	844.2	2.69	6.69	145.26	227.5	372.7	2.3
06Jan2000 2200	20.92	20.91	20.73	860.01	2.73	6.73	147.42	228.8	376.2	2.3
06Jan2000 2300	20.96	20.95	20.77	875.88	2.77	6.77	149.58	230.2	379.8	2.3
06Jan2000 2400	21	21	20.81	891.95	2.81	6.81	151.74	231.5	383.3	2.3
07Jan2000 0100	21.04	21.04	20.85	908.28	2.85	6.85	153.9	232.9	386.8	2.3
07Jan2000 0200	21.08	21.08	20.89	924.85	2.89	6.89	156.06	234.3	390.3	2.4
07Jan2000 0300	21.13	21.12	20.92	941.49	2.92	6.92	157.68	235.3	393.0	2.4
07Jan2000 0400	21.17	21.16	20.96	957.97	2.96	6.96	159.84	236.6	396.5	2.4
07Jan2000 0500	21.21	21.2	21	974.55	3	7	162	238.0	400.0	2.4
07Jan2000 0600	21.25	21.25	21.04	991.29	3.04	7.04	164.16	239.4	403.5	2.5
07Jan2000 0700	21.29	21.29	21.08	1008.2	3.08	7.08	166.32	240.7	407.0	2.5
07Jan2000 0800	21.33	21.33	21.12	1025.19	3.12	7.12	168.48	242.1	410.6	2.5
07Jan2000 0900	21.38	21.37	21.15	1042.4	3.15	7.15	170.1	243.1	413.2	2.5
07Jan2000 1000	21.42	21.41	21.19	1059.96	3.19	7.19	172.26	244.5	416.7	2.5
07Jan2000 1100	21.46	21.45	21.23	1077.68	3.23	7.23	174.42	245.8	420.2	2.6
07Jan2000 1200	21.5	21.5	21.27	1095.35	3.27	7.27	176.58	247.2	423.8	2.6
07Jan2000 1300	21.54	21.54	21.31	1112.95	3.31	7.31	178.74	248.5	427.3	2.6
07Jan2000 1400	21.58	21.58	21.35	1130.69	3.35	7.35	180.9	249.9	430.8	2.6
07Jan2000 1500	21.63	21.62	21.38	1148.51	3.38	7.38	182.52	250.9	433.4	2.6
07Jan2000 1600	21.67	21.66	21.42	1166.87	3.42	7.42	184.68	252.3	437.0	2.7
07Jan2000 1700	21.71	21.7	21.46	1185.98	3.46	7.46	186.84	253.6	440.5	2.7
07Jan2000 1800	21.75	21.74	21.5	1205.37	3.5	7.5	189	255.0	444.0	2.7
07Jan2000 1900	21.79	21.79	21.54	1224.97	3.54	7.54	191.16	256.4	447.5	2.7
07Jan2000 2000	21.83	21.83	21.57	1244.77	3.57	7.57	192.78	257.4	450.2	2.8
07Jan2000 2100	21.88	21.87	21.61	1264.48	3.61	7.61	194.94	258.7	453.7	2.8
07Jan2000 2200	21.92	21.91	21.65	1284.18	3.65	7.65	197.1	260.1	457.2	2.8
07Jan2000 2300	21.96	21.95	21.69	1304.13	3.69	7.69	199.26	261.5	460.7	2.8
07Jan2000 2400	22	21.99	21.73	1324.13	3.73	7.73	201.42	262.8	464.2	2.9
08Jan2000 0100	22.04	22.04	21.76	1344.28	3.76	7.76	203.04	263.8	466.9	2.9
08Jan2000 0200	22.08	22.08	21.8	1364.8	3.8	7.8	205.2	265.2	470.4	2.9
08Jan2000 0300	22.13	22.12	21.84	1385.47	3.84	7.84	207.36	266.6	473.9	2.9
08Jan2000 0400	22.17	22.16	21.88	1406.26	3.88	7.88	209.52	267.9	477.4	2.9
08Jan2000 0500	22.21	22.2	21.91	1427.25	3.91	7.91	211.14	268.9	480.1	3.0
08Jan2000 0600	22.25	22.24	21.95	1448.24	3.95	7.95	213.3	270.3	483.6	3.0
08Jan2000 0700	22.29	22.29	21.99	1469.08	3.99	7.99	215.46	271.7	487.1	3.0
08Jan2000 0800	22.33	22.33	22.03	1490.2	4.03	8.03	217.62	273.0	490.6	3.0
08Jan2000 0900	22.38	22.37	22.06	1511.74	4.06	8.06	219.24	274.0	493.3	3.1
08Jan2000 1000	22.42	22.41	22.1	1533.33	4.1	8.1	221.4	275.4	496.8	3.1
08Jan2000 1100	22.46	22.45	22.14	1555.2	4.14	8.14	223.56	276.8	500.3	3.1
08Jan2000 1200	22.5	22.49	22.18	1577.28	4.18	8.18	225.72	278.1	503.8	3.1
08Jan2000 1300	22.54	22.54	22.21	1599.29	4.21	8.21	227.34	279.1	506.5	3.2
08Jan2000 1400	22.58	22.58	22.25	1621.47	4.25	8.25	229.5	280.5	510.0	3.2
08Jan2000 1500	22.63	22.62	22.29	1643.72	4.29	8.29	231.66	281.9	513.5	3.2
08Jan2000 1600	22.67	22.66	22.33	1665.77	4.33	8.33	233.82	283.2	517.0	3.2
08Jan2000 1700	22.71	22.7	22.36	1688.01	4.36	8.36	235.44	284.2	519.7	3.2
08Jan2000 1800	22.75	22.74	22.4	1710.54	4.4	8.4	237.6	285.6	523.2	3.3
08Jan2000 1900	22.79	22.78	22.44	1733.33	4.44	8.44	239.76	287.0	526.7	3.3
08Jan2000 2000	22.83	22.83	22.48	1756.18	4.48	8.48	241.92	288.3	530.2	3.3
08Jan2000 2100	22.88	22.87	22.51	1779.27	4.51	8.51	243.54	289.3	532.9	3.3
08Jan2000 2200	22.92	22.91	22.55	1802.56	4.55	8.55	245.7	290.7	536.4	3.4
08Jan2000 2300	22.96	22.95	22.59	1825.9	4.59	8.59	247.86	292.1	539.9	3.4
08Jan2000 2400	23	22.99	22.63	1849.3	4.63	8.63	250.02	293.4	543.4	3.4
09Jan2000 0100	23.06	23.05	22.68	1885.89	4.68	8.68	252.72	295.1	547.8	3.4
09Jan2000 0200	23.12	23.11	22.73	1921.04	4.73	8.73	255.42	296.8	552.2	3.5
09Jan2000 0300	23.18	23.17	22.79	1956.26	4.79	8.79	258.66	298.9	557.5	3.5
09Jan2000 0400	23.24	23.24	22.84	1991.75	4.84	8.84	261.36	300.6	561.9	3.5
09Jan2000 0500	23.3	23.3	22.9	2029.03	4.9	8.9	264.6	302.6	567.2	3.6
09Jan2000 0600	23.37	23.36	22.95	2067.9	4.95	8.95	267.3	304.3	571.6	3.6
09Jan2000 0700	23.43	23.42	23	2106.94	5	9	270	306.0	576.0	3.7
09Jan2000 0800	23.49	23.48	23.05	2146.44	5.05	9.05	272.7	307.7	580.4	3.7
09Jan2000 0900	23.55	23.54	23.11	2186.13	5.11	9.11	275.94	309.7	585.7	3.7
09Jan2000 1000	23.61	23.6	23.16	2226.2	5.16	9.16	278.64	311.4	590.1	3.8
09Jan2000 1100	23.67	23.66	23.21	2266.84	5.21	9.21	281.34	313.1	594.5	3.8
09Jan2000 1200	23.73	23.72	23.26	2308	5.26	9.26	284.04	314.8	598.9	3.9
09Jan2000 1300	23.79	23.78	23.32	2349.07	5.32	9.32	287.28	316.9	604.2	3.9
09Jan2000 1400	23.85	23.84	23.37	2390.13	5.37	9.37	289.98	318.6	608.6	3.9
09Jan2000 1500	23.91	23.9	23.42	2431.88	5.42	9.42	292.68	320.3	613.0	4.0

09Jan2000 1600	23.97	23.96	23.47	2474.1	5.47	9.47	295.38	322.0	617.4	4.0
09Jan2000 1700	24.03	24.02	23.53	2516.61	5.53	9.53	298.62	324.0	622.6	4.0
09Jan2000 1800	24.1	24.09	23.58	2559.41	5.58	9.58	301.32	325.7	627.0	4.1
09Jan2000 1900	24.16	24.15	23.63	2602.77	5.63	9.63	304.02	327.4	631.4	4.1
09Jan2000 2000	24.22	24.21	23.68	2646.13	5.68	9.68	306.72	329.1	635.8	4.2
09Jan2000 2100	24.28	24.27	23.73	2689.75	5.73	9.73	309.42	330.8	640.2	4.2
09Jan2000 2200	24.34	24.33	23.79	2733.98	5.79	9.79	312.66	332.9	645.5	4.2
09Jan2000 2300	24.4	24.39	23.84	2779.38	5.84	9.84	315.36	334.6	649.9	4.3
09Jan2000 2400	24.46	24.45	23.89	2825.71	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0100	24.46	24.45	23.89	2821.09	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0200	24.46	24.45	23.89	2820.57	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0300	24.46	24.45	23.89	2820.49	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0400	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0500	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0600	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0700	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0800	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 0900	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1000	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1100	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1200	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1300	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1400	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1500	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1600	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1700	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1800	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 1900	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 2000	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 2100	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 2200	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 2300	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
10Jan2000 2400	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0100	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0200	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0300	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0400	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0500	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0600	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0700	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0800	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 0900	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1000	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1100	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1200	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1300	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1400	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1500	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1600	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1700	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1800	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 1900	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 2000	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 2100	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 2200	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 2300	24.46	24.45	23.89	2820.48	5.89	9.89	318.06	336.3	654.3	4.3
11Jan2000 2400	24.46	24.45	23.89	2820.47	5.89	9.89	318.06	336.3	654.3	4.3
12Jan2000 0100	24.48	24.47	23.91	2839.49	5.91	9.91	319.14	336.9	656.1	4.3
12Jan2000 0200	24.51	24.49	23.93	2857.07	5.93	9.93	320.22	337.6	657.8	4.3
12Jan2000 0300	24.53	24.52	23.95	2874.37	5.95	9.95	321.3	338.3	659.6	4.4
12Jan2000 0400	24.55	24.54	23.97	2891.68	5.97	9.97	322.38	339.0	661.4	4.4
12Jan2000 0500	24.57	24.56	23.98	2908.87	5.98	9.98	322.92	339.3	662.2	4.4
12Jan2000 0600	24.6	24.58	24	2926	6	10	324	340.0	664.0	4.4
12Jan2000 0700	24.62	24.61	24.02	2943.23	6.02	10.02	325.08	340.7	665.8	4.4
12Jan2000 0800	24.64	24.63	24.04	2960.53	6.04	10.04	326.16	341.4	667.5	4.4
12Jan2000 0900	24.66	24.65	24.06	2977.92	6.06	10.06	327.24	342.0	669.3	4.4
12Jan2000 1000	24.69	24.67	24.08	2995.43	6.08	10.08	328.32	342.7	671.0	4.5
12Jan2000 1100	24.71	24.7	24.1	3013.13	6.1	10.1	329.4	343.4	672.8	4.5
12Jan2000 1200	24.73	24.72	24.12	3030.87	6.12	10.12	330.48	344.1	674.6	4.5
12Jan2000 1300	24.75	24.74	24.13	3048.56	6.13	10.13	331.02	344.4	675.4	4.5
12Jan2000 1400	24.78	24.76	24.15	3066.36	6.15	10.15	332.1	345.1	677.2	4.5
12Jan2000 1500	24.8	24.79	24.17	3084.12	6.17	10.17	333.18	345.8	679.0	4.5

12Jan2000 1600	24.82	24.81	24.19	3101.95	6.19	10.19	334.26	346.5	680.7	4.6
12Jan2000 1700	24.84	24.83	24.21	3119.85	6.21	10.21	335.34	347.1	682.5	4.6
12Jan2000 1800	24.87	24.85	24.23	3137.81	6.23	10.23	336.42	347.8	684.2	4.6
12Jan2000 1900	24.89	24.88	24.25	3155.85	6.25	10.25	337.5	348.5	686.0	4.6
12Jan2000 2000	24.91	24.9	24.27	3173.98	6.27	10.27	338.58	349.2	687.8	4.6
12Jan2000 2100	24.93	24.92	24.28	3192.19	6.28	10.28	339.12	349.5	688.6	4.6
12Jan2000 2200	24.96	24.94	24.3	3210.49	6.3	10.3	340.2	350.2	690.4	4.7
12Jan2000 2300	24.98	24.97	24.32	3228.82	6.32	10.32	341.28	350.9	692.2	4.7
12Jan2000 2400	25	24.99	24.34	3247.11	6.34	10.34	342.36	351.6	693.9	4.7
13Jan2000 0100	25.06	25.05	24.39	3296.25	6.39	10.39	345.06	353.3	698.3	4.7
13Jan2000 0200	25.12	25.1	24.43	3343.45	6.43	10.43	347.22	354.6	701.8	4.8
13Jan2000 0300	25.17	25.16	24.48	3390.96	6.48	10.48	349.92	356.3	706.2	4.8
13Jan2000 0400	25.23	25.22	24.53	3439.01	6.53	10.53	352.62	358.0	710.6	4.8
13Jan2000 0500	25.29	25.27	24.58	3487.48	6.58	10.58	355.32	359.7	715.0	4.9
13Jan2000 0600	25.35	25.33	24.62	3536.12	6.62	10.62	357.48	361.1	718.6	4.9
13Jan2000 0700	25.4	25.39	24.67	3584.94	6.67	10.67	360.18	362.8	723.0	5.0
13Jan2000 0800	25.46	25.45	24.72	3633.8	6.72	10.72	362.88	364.5	727.4	5.0
13Jan2000 0900	25.52	25.5	24.76	3683.23	6.76	10.76	365.04	365.8	730.9	5.0
13Jan2000 1000	25.58	25.56	24.81	3733.26	6.81	10.81	367.74	367.5	735.3	5.1
13Jan2000 1100	25.63	25.62	24.86	3783.73	6.86	10.86	370.44	369.2	739.7	5.1
13Jan2000 1200	25.69	25.68	24.9	3834.86	6.9	10.9	372.6	370.6	743.2	5.2
13Jan2000 1300	25.75	25.73	24.95	3886.63	6.95	10.95	375.3	372.3	747.6	5.2
13Jan2000 1400	25.81	25.79	25	3938.8	7	11	378	374.0	752.0	5.2
13Jan2000 1500	25.86	25.85	25.04	3990.58	7.04	11.04	380.16	375.4	755.5	5.3
13Jan2000 1600	25.92	25.91	25.09	4043.05	7.09	11.09	382.86	377.1	759.9	5.3
13Jan2000 1700	25.98	25.96	25.13	4096.13	7.13	11.13	385.02	378.4	763.4	5.4
13Jan2000 1800	26.04	26.02	25.18	4149.34	7.18	11.18	387.72	380.1	767.8	5.4
13Jan2000 1900	26.09	26.08	25.22	4203.25	7.22	11.22	389.88	381.5	771.4	5.4
13Jan2000 2000	26.15	26.14	25.27	4257.93	7.27	11.27	392.58	383.2	775.8	5.5
13Jan2000 2100	26.21	26.19	25.31	4312.98	7.31	11.31	394.74	384.5	779.3	5.5
13Jan2000 2200	26.27	26.25	25.36	4367.94	7.36	11.36	397.44	386.2	783.7	5.6
13Jan2000 2300	26.32	26.31	25.4	4422.65	7.4	11.4	399.6	387.6	787.2	5.6
13Jan2000 2400	26.38	26.36	25.45	4478	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0100	26.38	26.36	25.45	4473.98	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0200	26.38	26.36	25.45	4473.63	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0300	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0400	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0500	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0600	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0700	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0800	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 0900	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1000	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1100	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1200	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1300	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1400	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1500	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1600	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1700	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1800	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 1900	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 2000	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 2100	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 2200	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 2300	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
14Jan2000 2400	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0100	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0200	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0300	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0400	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0500	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0600	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0700	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0800	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 0900	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1000	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1100	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1200	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1300	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1400	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1500	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7

15Jan2000 1600	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1700	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1800	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 1900	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 2000	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 2100	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 2200	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 2300	26.38	26.36	25.45	4473.58	7.45	11.45	402.3	389.3	791.6	5.7
15Jan2000 2400	26.38	26.36	25.45	4473.57	7.45	11.45	402.3	389.3	791.6	5.7
16Jan2000 0100	26.41	26.39	25.47	4500.55	7.47	11.47	403.38	390.0	793.4	5.7
16Jan2000 0200	26.43	26.42	25.49	4526	7.49	11.49	404.46	390.7	795.1	5.7
16Jan2000 0300	26.46	26.44	25.51	4551.26	7.51	11.51	405.54	391.3	796.9	5.7
16Jan2000 0400	26.48	26.47	25.53	4576.57	7.53	11.53	406.62	392.0	798.6	5.7
16Jan2000 0500	26.51	26.49	25.55	4602.03	7.55	11.55	407.7	392.7	800.4	5.7
16Jan2000 0600	26.54	26.52	25.57	4627.65	7.57	11.57	408.78	393.4	802.2	5.8
16Jan2000 0700	26.56	26.54	25.59	4653.44	7.59	11.59	409.86	394.1	803.9	5.8
16Jan2000 0800	26.59	26.57	25.61	4679.21	7.61	11.61	410.94	394.7	805.7	5.8
16Jan2000 0900	26.61	26.6	25.63	4704.95	7.63	11.63	412.02	395.4	807.4	5.8
16Jan2000 1000	26.64	26.62	25.65	4730.84	7.65	11.65	413.1	396.1	809.2	5.8
16Jan2000 1100	26.66	26.65	25.67	4756.97	7.67	11.67	414.18	396.8	811.0	5.9
16Jan2000 1200	26.69	26.67	25.69	4783.12	7.69	11.69	415.26	397.5	812.7	5.9
16Jan2000 1300	26.72	26.7	25.71	4809.34	7.71	11.71	416.34	398.1	814.5	5.9
16Jan2000 1400	26.74	26.73	25.73	4835.51	7.73	11.73	417.42	398.8	816.2	5.9
16Jan2000 1500	26.77	26.75	25.75	4861.75	7.75	11.75	418.5	399.5	818.0	5.9
16Jan2000 1600	26.79	26.78	25.77	4888.12	7.77	11.77	419.58	400.2	819.8	6.0
16Jan2000 1700	26.82	26.8	25.79	4914.62	7.79	11.79	420.66	400.9	821.5	6.0
16Jan2000 1800	26.85	26.83	25.81	4941.26	7.81	11.81	421.74	401.5	823.3	6.0
16Jan2000 1900	26.87	26.85	25.83	4967.92	7.83	11.83	422.82	402.2	825.0	6.0
16Jan2000 2000	26.9	26.88	25.85	4994.61	7.85	11.85	423.9	402.9	826.8	6.0
16Jan2000 2100	26.92	26.91	25.87	5021.42	7.87	11.87	424.98	403.6	828.6	6.1
16Jan2000 2200	26.95	26.93	25.89	5048.32	7.89	11.89	426.06	404.3	830.3	6.1
16Jan2000 2300	26.97	26.96	25.9	5075.35	7.9	11.9	426.6	404.6	831.2	6.1
16Jan2000 2400	27	26.98	25.92	5102.55	7.92	11.92	427.68	405.3	833.0	6.1
17Jan2000 0100	27.03	27.02	25.95	5138.86	7.95	11.95	429.3	406.3	835.6	6.1
17Jan2000 0200	27.07	27.05	25.98	5174.67	7.98	11.98	430.92	407.3	838.2	6.2
17Jan2000 0300	27.1	27.09	26	5210.81	8	12	432	408.0	840.0	6.2
17Jan2000 0400	27.14	27.12	26.03	5246.81	8.03	12.03	433.62	409.0	842.6	6.2
17Jan2000 0500	27.17	27.15	26.05	5282.75	8.05	12.05	434.7	409.7	844.4	6.3
17Jan2000 0600	27.21	27.19	26.08	5318.68	8.08	12.08	436.32	410.7	847.0	6.3
17Jan2000 0700	27.24	27.22	26.1	5354.81	8.1	12.1	437.4	411.4	848.8	6.3
17Jan2000 0800	27.27	27.26	26.13	5391.14	8.13	12.13	439.02	412.4	851.4	6.3
17Jan2000 0900	27.31	27.29	26.15	5427.72	8.15	12.15	440.1	413.1	853.2	6.4
17Jan2000 1000	27.34	27.32	26.18	5464.14	8.18	12.18	441.72	414.1	855.8	6.4
17Jan2000 1100	27.38	27.36	26.2	5500.58	8.2	12.2	442.8	414.8	857.6	6.4
17Jan2000 1200	27.41	27.39	26.23	5537.38	8.23	12.23	444.42	415.8	860.2	6.4
17Jan2000 1300	27.44	27.43	26.26	5574.44	8.26	12.26	446.04	416.8	862.9	6.5
17Jan2000 1400	27.48	27.46	26.28	5611.74	8.28	12.28	447.12	417.5	864.6	6.5
17Jan2000 1500	27.51	27.49	26.31	5649.25	8.31	12.31	448.74	418.5	867.3	6.5
17Jan2000 1600	27.55	27.53	26.33	5687.07	8.33	12.33	449.82	419.2	869.0	6.5
17Jan2000 1700	27.58	27.56	26.36	5725.06	8.36	12.36	451.44	420.2	871.7	6.6
17Jan2000 1800	27.62	27.6	26.38	5762.72	8.38	12.38	452.52	420.9	873.4	6.6
17Jan2000 1900	27.65	27.63	26.41	5799.7	8.41	12.41	454.14	421.9	876.1	6.6
17Jan2000 2000	27.68	27.66	26.43	5836.95	8.43	12.43	455.22	422.6	877.8	6.6
17Jan2000 2100	27.72	27.7	26.46	5874.56	8.46	12.46	456.84	423.6	880.5	6.7
17Jan2000 2200	27.75	27.73	26.48	5912.45	8.48	12.48	457.92	424.3	882.2	6.7
17Jan2000 2300	27.79	27.77	26.5	5950.47	8.5	12.5	459	425.0	884.0	6.7
17Jan2000 2400	27.82	27.8	26.53	5988.75	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0100	27.82	27.8	26.53	5986.52	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0200	27.82	27.8	26.53	5986.32	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0300	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0400	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0500	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0600	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0700	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0800	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 0900	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1000	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1100	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1200	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1300	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1400	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1500	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8

18Jan2000 1600	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1700	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1800	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 1900	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 2000	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 2100	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 2200	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 2300	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
18Jan2000 2400	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0100	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0200	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0300	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0400	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0500	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0600	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0700	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0800	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 0900	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1000	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1100	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1200	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1300	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1400	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1500	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1600	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1700	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1800	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 1900	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 2000	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 2100	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 2200	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 2300	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
19Jan2000 2400	27.82	27.8	26.53	5986.3	8.53	12.53	460.62	426.0	886.6	6.8
20Jan2000 0100	27.85	27.83	26.55	6020.16	8.55	12.55	461.7	426.7	888.4	6.8
20Jan2000 0200	27.88	27.86	26.57	6052.61	8.57	12.57	462.78	427.4	890.2	6.8
20Jan2000 0300	27.91	27.88	26.59	6085.16	8.59	12.59	463.86	428.1	891.9	6.8
20Jan2000 0400	27.93	27.91	26.61	6117.48	8.61	12.61	464.94	428.7	893.7	6.8
20Jan2000 0500	27.96	27.94	26.63	6149.6	8.63	12.63	466.02	429.4	895.4	6.9
20Jan2000 0600	27.99	27.97	26.65	6181.85	8.65	12.65	467.1	430.1	897.2	6.9
20Jan2000 0700	28.02	28	26.67	6214.27	8.67	12.67	468.18	430.8	899.0	6.9
20Jan2000 0800	28.05	28.03	26.69	6243.54	8.69	12.69	469.26	431.5	900.7	6.9
20Jan2000 0900	28.08	28.05	26.7	6253.23	8.7	12.7	469.8	431.8	901.6	6.9
20Jan2000 1000	28.1	28.08	26.7	6262.9	8.7	12.7	469.8	431.8	901.6	6.9
20Jan2000 1100	28.13	28.11	26.71	6271.96	8.71	12.71	470.34	432.1	902.5	6.9
20Jan2000 1200	28.16	28.14	26.72	6280.45	8.72	12.72	470.88	432.5	903.4	7.0
20Jan2000 1300	28.19	28.17	26.72	6288.46	8.72	12.72	470.88	432.5	903.4	7.0
20Jan2000 1400	28.22	28.2	26.72	6296.05	8.72	12.72	470.88	432.5	903.4	7.0
20Jan2000 1500	28.25	28.22	26.73	6303.29	8.73	12.73	471.42	432.8	904.2	7.0
20Jan2000 1600	28.27	28.25	26.73	6310.22	8.73	12.73	471.42	432.8	904.2	7.0
20Jan2000 1700	28.3	28.28	26.74	6318.63	8.74	12.74	471.96	433.2	905.1	7.0
20Jan2000 1800	28.33	28.31	26.74	6327.01	8.74	12.74	471.96	433.2	905.1	7.0
20Jan2000 1900	28.36	28.34	26.75	6335.34	8.75	12.75	472.5	433.5	906.0	7.0
20Jan2000 2000	28.39	28.37	26.75	6343.63	8.75	12.75	472.5	433.5	906.0	7.0
20Jan2000 2100	28.42	28.39	26.76	6351.9	8.76	12.76	473.04	433.8	906.9	7.0
20Jan2000 2200	28.44	28.42	26.76	6360.14	8.76	12.76	473.04	433.8	906.9	7.0
20Jan2000 2300	28.47	28.45	26.77	6368.35	8.77	12.77	473.58	434.2	907.8	7.0
20Jan2000 2400	28.5	28.48	26.77	6376.55	8.77	12.77	473.58	434.2	907.8	7.0
21Jan2000 0100	28.54	28.52	26.78	6388.94	8.78	12.78	474.12	434.5	908.6	7.0
21Jan2000 0200	28.58	28.56	26.79	6400.93	8.79	12.79	474.66	434.9	909.5	7.0
21Jan2000 0300	28.63	28.61	26.8	6412.82	8.8	12.8	475.2	435.2	910.4	7.0
21Jan2000 0400	28.67	28.65	26.8	6424.64	8.8	12.8	475.2	435.2	910.4	7.1
21Jan2000 0500	28.71	28.69	26.81	6436.4	8.81	12.81	475.74	435.5	911.3	7.1
21Jan2000 0600	28.75	28.73	26.82	6448.7	8.82	12.82	476.28	435.9	912.2	7.1
21Jan2000 0700	28.79	28.77	26.83	6461.02	8.83	12.83	476.82	436.2	913.0	7.1
21Jan2000 0800	28.83	28.81	26.83	6473.34	8.83	12.83	476.82	436.2	913.0	7.1
21Jan2000 0900	28.88	28.86	26.84	6485.65	8.84	12.84	477.36	436.6	913.9	7.1
21Jan2000 1000	28.92	28.9	26.85	6497.96	8.85	12.85	477.9	436.9	914.8	7.1
21Jan2000 1100	28.96	28.94	26.85	6510.29	8.85	12.85	477.9	436.9	914.8	7.1
21Jan2000 1200	29	28.98	26.86	6522.63	8.86	12.86	478.44	437.2	915.7	7.1
21Jan2000 1300	29.04	29.02	26.87	6534.97	8.87	12.87	478.98	437.6	916.6	7.1
21Jan2000 1400	29.08	29.06	26.88	6547.31	8.88	12.88	479.52	437.9	917.4	7.1
21Jan2000 1500	29.13	29.11	26.88	6559.67	8.88	12.88	479.52	437.9	917.4	7.1

21Jan2000 1600	29.17	29.15	26.89	6572.07	8.89	12.89	480.06	438.3	918.3	7.2
21Jan2000 1700	29.21	29.19	26.9	6584.46	8.9	12.9	480.6	438.6	919.2	7.2
21Jan2000 1800	29.25	29.23	26.91	6596.87	8.91	12.91	481.14	438.9	920.1	7.2
21Jan2000 1900	29.29	29.27	26.91	6609.27	8.91	12.91	481.14	438.9	920.1	7.2
21Jan2000 2000	29.33	29.31	26.92	6621.68	8.92	12.92	481.68	439.3	921.0	7.2
21Jan2000 2100	29.38	29.36	26.93	6634.18	8.93	12.93	482.22	439.6	921.8	7.2
21Jan2000 2200	29.42	29.4	26.94	6647.2	8.94	12.94	482.76	440.0	922.7	7.2
21Jan2000 2300	29.46	29.44	26.94	6660.22	8.94	12.94	482.76	440.0	922.7	7.2
21Jan2000 2400	29.5	29.48	26.95	6673.27	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0100	29.5	29.48	26.95	6671.89	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0200	29.5	29.48	26.95	6671.79	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0300	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0400	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0500	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0600	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0700	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0800	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 0900	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1000	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1100	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1200	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1300	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1400	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1500	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1600	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1700	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1800	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 1900	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 2000	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 2100	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 2200	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 2300	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
22Jan2000 2400	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0100	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0200	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0300	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0400	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0500	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0600	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0700	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0800	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 0900	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1000	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1100	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1200	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1300	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1400	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1500	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1600	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1700	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1800	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 1900	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 2000	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 2100	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 2200	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 2300	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2
23Jan2000 2400	29.5	29.48	26.95	6671.78	8.95	12.95	483.3	440.3	923.6	7.2

Appendix A
Gate Sizing and Headworks Flow
Appendix A6

A Simulation Method for Combining Hydrodynamic Data and Acoustic Tag Tracks to Predict the Entrainment of Juvenile Salmonids Onto the Yolo Bypass Under Future Engineering Scenarios

Authors: Aaron Blake, Paul Stumpner, and Jon Burau

U.S. Geological Survey, West Sacramento, CA

July 21, 2017

Table of Contents

Executive Summary 5

Introduction 6

Methods 8

Overview of entrainment simulation process 8

Along-channel cross-channel coordinate system 8

Simulation Period 8

Simulation Time Step 9

Pseudocode summary of entrainment simulation 9

Estimating covariate values at every time step 10

Estimating Sacramento River Stage and Sacramento River Discharge 10

Estimating abundance at each time step 11

Drawing the bootstrap sample 12

Determining entrainment of bootstrap sample tracks 13

Fundamentals of the critical streakline method 13

General approach to estimating the location of the critical streakline 14

Estimating entrainment within the simulation: estimating cross stream distribution of discharge at each location given Sacramento River Stage. 14

Estimating cross stream distribution of discharge at measured transect locations and stages 14

Estimating the cross stream distribution of discharge at unmeasured locations and stages 15

Estimating entrainment within the simulation: estimating the discharge through each notch 15

Estimating entrainment within the simulation: estimating the cross-channel location of the critical streakline 15

Estimating entrainment within the simulation: estimating entrainment for each track a bootstrap sample 15

Estimating entrainment within the simulation: estimating entrainment over the Fremont Weir during overtopping events 16

Simulated scenarios 16

Table 1- Notch rating curves for simulated scenarios 18

Results 19

Simulation entrainment as a function of notch location 19

Effects of notch rating curves and run abundance timing on entrainment 21

Table 2 - percent of simulation abundance for each run that passed through the study area during the notch operation period. 23

Entrainment rate and entrainment efficiency for each scenario as a function of stage. 23

Entrainment as a function of water year 26

Table 3 - Water year type classifications based on number of hours that the weir overtopped during each season in the simulation 28
Table 4 - Number of hours that the fremont weir overtopped during each season in the simulation 29

Discussion 31
Primary sources of uncertainty in the entrainment simulation 31
Implications for design of weir modifications 32

References 34

Figures 35
Figure 1- Aerial photograph showing the approximate boundary of the USGS study area36
Figure 2 - Aerial photograph showing the bathymetry and hydrophone locations in study area 37
Figure 3 - Plot showing the range of estimated stage-discharge values for the Sacramento River in the vicinity of the western end of the Fremont Weir from 1996 to 2011 38
Figure 4 - Aerial photo of the vicinity of the western end of the Fremont Weir overlaid with scenario evaluation locations. 39
Figure 5 - Plot showing Sacramento River discharge and Sacramento River stage during the time period that 2016 acoustic tag tracks were collected 40
Figure 6 - Plot showing cumulative distribution functions for the daily percentage of yearly catch per unit effort over the 15 year simulation period 41
Figure 7 - Plot showing the hourly derivative for Sacramento River stage during the simulation period when Knights Landing catch was greater than zero during the operational window 42
Figure 8 - Plot showing how the daily percent yearly CPUE data was converted into discrete sample sizes for each time step 43
Figure 9 - Plot showing cumulative distribution functions on time step discrete sample size for each run 44
Figure 10 - Plot showing the range of stage and discharge conditions associated with each of the 2016 acoustic tag tracks 45
Figure 11 - Plots illustrating the bivariate weighting and the resulting bootstrap sampling for a stage of 27 ft and a discharge of 21,000cfs 46
Figure 12 - Plots illustrating the bivariate weighting and the resulting bootstrap sampling for a stage of 20ft and a discharge of 13,000cfs 47
Figure 13 - Number of hours per year that the weir overtopped during the notch operation period 48
Figure 14 - Total entrainment as a function of notch location for each scenario 49
Figure 15 - Total entrainment rate as a function of notch location for each scenario 50
Figure 16 - Figure showing the location of maximum and minimum entrainment for fall run for all scenarios overlaid on the study area bathymetry model used for the entrainment simulation 51
Figure 17 - Plan view of study area showing the location of minimum and maximum entrainment along with example fish tracks. 52

Figure 18 - Plan view of study area showing the location of minimum and maximum entrainment along with example fish tracks 53
Figure 19 - Plan view of the study area bathymetry colored by fish density 54
Figure 20 - Stage-discharge curves for each scenario and run abundance cdfs on stage 55
Figure 21 - Entrainment rate and discharge ratio for each scenario as a function of Sacramento River stage. 56
Figure 22 - Entrainment efficiency and discharge ratio for each scenario as a function of Sacramento River stage, with small sample sizes removed 57
Figure 23 - Figure showing the location of maximum and minimum entrainment for fall run for all scenarios overlaid on fish density distribution 58
Figure 24 - Figure from cross-channel velocity transect data collected during 2016. 59
Figure 25 - Spatial distribution of 2016 study fish tracks for periods when Sacramento River was greater than bankfull and below the weir crest 60
Figure 27- Scenario 1 water year type total entrainment curves 62
Figure 28- Scenario 2 water year type total entrainment curves 63
Figure 29- Scenario 3 water year type total entrainment curves 64
Figure 30- Scenario 4 water year type total entrainment curves 65
Figure 31- Scenario 5 water year type total entrainment curves 66
Figure 32- Scenario 6 water year type total entrainment curves 67

Appendix A - Table giving the conversion between along stream coordinates and UTM for the River Right bank of the Sacramento River. 68

Appendix B - Detailed rating curves and drawings for Scenario 5 and Scenario 6 73
Table B1 - Stage - discharge relationships for scenario 5 and scenario 6 73
Table B2 - Gate spacing for scenario 5 and scenario 6 76
Figure B1 - Conceptual drawing of alternative 5 showing the gate spacing used for scenario 5 and scenario 6 77

Executive Summary

The USGS analyzed acoustic tag track data and detailed hydrodynamic data collected in the Sacramento River during the winter/spring of water year 2016 in the vicinity of the western end of the Fremont Weir to asses the potential for enhancing the entrainment of Sacramento River Chinook salmon onto the Yolo Bypass under six different Fremont Weir modification scenarios. The primary goal of the USGS entrainment analysis was to investigate how the location of the notch or notches in each scenario could influence the entrainment of Chinook salmon under each modification scenario.

The USGS's analysis of hydraulic data collected during the 2016 study period showed that backwater effects in the Sacramento River could create variability in the relationship between Sacramento River stage and the proportion of the Sacramento River diverted into the Yolo Bypass under the modification scenarios. Because of this variability, the USGS felt that accurately evaluating the entrainment potential of possible locations for each scenario would require combining historic abundance data for Sacramento River Chinook salmon with historic hydraulic data for the Sacramento River in the vicinity of the Fremont Weir, so that the entrainment estimates would reflect the covariance between Sacramento River stage, Sacramento River discharge, and run abundance within the historic record. As a result, the USGS used a simulation approach to asses the entrainment potential of possible locations for each modification scenario.

The entrainment evaluation simulation conducted by the USGS evaluated the entrainment potential of four single notch modification scenarios, and two multiple notch modification scenarios. This simulation used the high resolution hydrodynamic data and acoustic tag track data collected in 2016, along with historic abundance, stage, and discharge data from a period spanning water years 1996-2010 to assess the entrainment potential of these scenarios under historic conditions at 63 possible locations for each scenario in the vicinity of the western end of the Fremont Weir.

This results of this entrainment simulation show that the location of each modification scenario had a major impact on the entrainment potential of the scenario; the predicted entrainment potential of some scenarios varied by as much as 400% based on where the scenario was located in the study area. Overall, all of the single notch scenarios performed best when they were located within a 100 meter long section of the Sacramento River bank beginning at utm coordinates 615762m E, 4290896m N (NAD 83) and progressing downstream, and the multiple notch scenarios performed best when their upstream gates were near utm coordinates 615636m E, 4290860m N (NAD 83). The entrainment simulation results indicated that these locations resulted in near-maximum entrainment for the scenarios under all water year types simulated, and for all run abundance histories simulated, indicating that these locations are likely to be near-optimal under a range of conditions for fish that behave similarly to the hatchery surrogates used in the study. Comparisons between the maximum entrainment potential for each scenario suggested that total entrainment of winter run, spring run, and fall run can be increased by lowering the stage-discharge curves of modification scenarios to focus on

entraining fish when the Sacramento River is between 19' stage and 22' stage (NAVD88). The relationship between Sacramento River stage and entrainment for each scenario suggests that entrainment efficiency for each scenario declines significantly once Sacramento River stage exceeds bankfull (approximately 28.5 feet NAVD88). Finally, the results of the simulation suggest that bathymetry features upstream of weir modifications can have a major impact on the entrainment potential of weir modifications. All of these results are sensitive to differences in behavior between the hatchery surrogates used for the 2016 study and wild and run of the river fish.

Introduction

During the winter and spring of water year 2016 the U.S.G.S. California Water Science Center (USGS) collaborated with the California Department of Water Resources (CADWR) to conduct a joint hydrodynamic and fisheries study to acquire data that could be used to evaluate the effects of proposed modifications to the Fremont Weir on outmigrating Chinook salmon. During this study the USGS and CADWR deployed and operated an array of hydrophones in a bend in the Sacramento River (figure 1, figure 2) that allowed researchers to track acoustically tagged juvenile Chinook salmon in the horizontal plane as they emigrated through the hydrophone array. During the winter and spring of water year 2016 researchers surgically implanted juvenile late fall run Chinook salmon from the Coleman National Fish Hatchery with acoustic tags and released the fish in small batches upstream of the study area, with the goal of obtaining fish tracks over the range of Sacramento River stage values that were likely to be relevant to the design of weir modifications (ref fish tagging and condition report). During this time period the USGS and CADWR collected high resolution water velocity measurements throughout the study area over a range of Sacramento River stage values. Additionally, the USGS deployed, rated, and operated a temporary index velocity gauge in the vicinity of the study area to estimate the discharge in the Sacramento River entering the study area.

The USGS analysis of the data from the 2016 study is focused on three primary areas: summarizing the information obtained from the acoustic tag tracking array and estimating the spatial distribution of the acoustically tagged study fish, analyzing the hydrodynamic data to improve our understanding of the physical processes in the Sacramento River that may influence the design of weir modifications, and combining the hydrodynamic analysis with the acoustic tag data to estimate the entrainment potential of notch modification scenarios. The USGS's hydrodynamic analysis is presented in the Stumpner et al., In Review, while this report focuses on combining the fish tracking data with the high resolution hydrodynamic data to evaluate the entrainment potential of weir modification scenarios.

In the past, the USGS has found that the spatial distribution of acoustically tagged fish can be combined with hydrodynamic data to understand, and in some cases predict, the entrainment rate of juvenile Chinook salmon in tidally forced riverine junctions on the Sacramento River (California Department of Water Resources, 2012, 2015, 2016). This research at the Georgiana Slough junction has shown that the proportion of water diverted into a junction branch is a key variable affecting the entrainment of acoustically tagged juvenile Chinook salmon transiting a

junction (California Department of Water Resources, 2012, 2015, 2016). Upon analyzing the data from the temporary index velocity gauge we found that backwater effects in the Sacramento River caused by the Sutter Bypass and the Feather River created substantial variance in the relationship between Sacramento River stage, and the proportion of Sacramento River discharge that was expected to be diverted into the Yolo Bypass under each modification scenario, (The ratio of sacramento river discharge to notch discharge is called the scenario Discharge Ratio, see Stumpner et al., In Review, for a more detailed discussion) (Figure 3). As a result, we can expect that entrainment under each scenario will vary as a function of backwater condition.

Because of the variance in scenario discharge ratios caused by backwater effects, assessing the entrainment potential of each scenario requires an approach that accounts for the structure of the joint probability distribution that describes the probability of a fish belonging to a specific run of Sacramento River Chinook salmon transiting the study area under any possible backwater condition. We addressed this challenge by using a simulation approach for evaluating the entrainment potential of modification scenarios using historical time series of Sacramento River stage, Sacramento River discharge, and the abundance of fall run, winter run, spring run, and late fall run Chinook salmon. The result of this simulation approach is a time series of estimated entrainment for each run under each modification scenario; when these time series are summed they produce an estimate of total entrainment for a run that is a function of the hydraulic conditions (discharge, stage, backwater condition) during the simulation period weighted by the relative abundance of the run over the range of hydraulic conditions measured during the simulation period. Thus, this approach implicitly accounts for the joint probability of run abundance and backwater condition within the simulation period.

The basic structure of the entrainment simulation is a monte carlo bootstrap simulation; at each timestep within the simulation a bootstrap sample of acoustic tag tracks for each run is drawn from the pool of all acoustic tag tracks collected during the 2016 study, and then hydrodynamic data collected during the 2016 study period is used to determine which of the tracks in each bootstrap sample are entrained under each modification scenario. The key to the entrainment simulation is that at every timestep the bootstrap sample size for each run is determined by the historic abundance data for each run, and the sampling weights used for the bootstrapping are a function of the hydraulic conditions when each acoustic tag track passed through the study area relative to the hydraulic conditions for the simulation timestep.

The primary goal of the entrainment simulation is to explore the relationship between notch location and entrainment for each modification scenario in order to provide insights that can be used to aid in site selection for each of the proposed alternatives. Because the cross-stream distribution of discharge at any location within the study area is a function of Sacramento River stage and discharge (see Stumpner et al., In Review for more details), we expect that differences in entrainment between possible scenario locations will also be a function of Sacramento River stage and discharge. As a result, we performed the monte carlo bootstrap simulation process for each run of Sacramento River Chinook under each modification scenario at 63 alternative scenario locations within the study area (Figure 4, Appendix A). This approach

allows us to explore the effects of notch location on entrainment over a range of hydraulic conditions given the historic abundance timing for fall run, winter run, spring run, and late fall run Chinook salmon.

The entrainment stimulation results in an extremely rich dataset that consists of covariate values and the resulting entrainment estimates for each run, at each location, under each scenario for every timestep. Our analysis of these results is focused on answering the following questions: (1) Which location or locations result in maximum entrainment for each run under each scenario? (2) How robust are these locations to changes in run abundance and water year? (3) What can we learn from the relationship between stage and entrainment for each scenario that may be useful for optimizing weir modifications?

Methods

The basic structure of the entrainment simulation is a monte carlo bootstrap simulation that performs three fundamental functions at each time step: (1) Estimating covariate values and run abundance for each time step, (2) Selecting a bootstrap sample of acoustic tag tracks based on time step covariate values for each run of Chinook salmon, and (3) determining whether each track is entrained under each scenario. In this section we will provide an overview of the simulation with pseudocode summarizing the simulation process, followed by a detailed description of the methods used to perform each of the core simulation functions. The final section of the methods contains a detailed description of the weir modification scenarios included in the entrainment simulation.

Overview of entrainment simulation process

Along-channel cross-channel coordinate system

We created an along-channel, cross-channel curvilinear coordinate system for the study domain that was used to place the scenario evaluation location cross-sections at uniform increments in the along-channel direction. The along-channel axis is roughly parallel to the river right bank of the Sacramento River in the study area at a stage of 28', and the cross-channel axis is defined as always instantaneously normal to the along-channel axis. The resulting cross-channel evaluation sections for a Sacramento River stage of 28.5' is shown in figure 4.

Simulation Period

For consistency with other analyses we use the cleaned Knights Landing catch data provided by the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project team to estimate abundance for each run of Chinook salmon within the entrainment simulation (see California Department of Water Resources, 2017). The abundance times series limits the simulation

period to water years 1997-2011. Within these water years the simulation only estimates entrainment during the prescribed structural operational window of November 1 through March 15, outside of this period entrainment is set to zero within the simulation. Within this document we refer to the structural operational window as the “notch operation season” or “season”. Within this document notch operation seasons are named by the year in which operations began for the season, so the notch operation seasons from October 1, 1996 - March 15, 1997 is referred to herein as the 1996 season.

Simulation Time Step

Sacramento River stage in the vicinity of the Fremont Weir can increase rapidly during the winter and spring freshettes associated with juvenile salmon outmigration on the Sacramento River. For example, during the 2016 study period Sacramento River stage increased 13.45 feet over a two day period (Figure 5). Additionally, the Knights Landing rotary screw trap data Catch Per Unit Effort (CPUE) is highly episodic in nature (Figure 6), with about half of the total percent of yearly CPUE in the 15 year record observed on days when more than 5% of the total yearly CPUE was caught. The combined effect of these two factors is that there are days within the simulation period when there is significant CPUE for a run of Sacramento River Chinook salmon and Sacramento River stage changes rapidly (Figure 7). As a result, we chose a time step of 4 hours for the simulation, because this time step would limit the maximum change in stage between time steps to about 1foot during days when the yearly fraction of CPUE was much greater than 1%.

Pseudocode summary of entrainment simulation

The core functionality of the entrainment simulation is summarized in pseudocode below:

For every time step

1. Estimate Sacramento River Discharge, Sacramento River Stage and Abundance of each run of Chinook salmon

   For every location in the study area

   1. Estimate the cross stream distribution of discharge at this location, given Sacramento River Stage; F(Sacramento River stage, notch location)

      For every scenario

      (There is another loop nested here for multi notch scenarios that is not shown)

      1. Estimate the discharge through the notch(s) given Sacramento River Stage; F(Sacramento River stage)
      2. Estimate the location of the critical streakline given Sacramento River discharge, notch discharge, and the cross stream distribution of Sacramento River discharge; F(Sacramento River stage, Sacramento River discharge, notch discharge)

         For every run

1. Estimate a discrete abundance for this run using the Knights Landing catch data
2. Draw a weighted random sample of tracks from the pool of observed 2016 tracks with weights determined by the time steps Sacramento River Stage, and Sacramento River discharge. The size of this sample is determined by the discrete abundance estimated above.

   For every track

   1. Determine if the track is entrained in the notch; if the track is to the notch side (river right) of the critical streakline at the cross section being evaluated, it is entrained, otherwise it is not entrained.
   2. Increment all entrainment logs
   3. Store all covariates for this location, run, scenario, and time step.

End All

Estimating covariate values at every time step

Estimating Sacramento River Stage and Sacramento River Discharge

The process of developing time series for the physical covariates used in the entrainment simulation is described in detail in Stumpner et al., In Review. Sacramento River stage in the study area was estimated by applying a correction of -0.5ft to hourly historical data collected at the Fremont Weir gauge by CADWR, after this historical data had been corrected to the 2016 CADWR NAVD88 datum. The reasons for this correction are discussed in depth in Stumpner et al., In Review, in brief, this correction produced good agreement between the CDEC data and the USGS temporary index velocity gauge measurements (figure 5, lower panel), and this correction improved the agreement between CDEC data and USGS surveys of the water surface elevation (Appendix C). **Within this report and its figures we refer to the USGS estimate of Sacramento River stage at the western end of the Fremont Weir as "NAVD88, USGS",** to avoid confusion between the USGS estimate and the CDEC data.

Sacramento River discharge in the study area was estimated using a regression model using historic data from other stage and discharge gauges in the region (see Stumpner et al., In Review for details). This regression model produced hourly discharge estimates that are in good agreement with our 2016 index velocity data (Figure 5, upper panel), however, there were a limited number of time steps (2.3% of simulation time steps during notch operational periods) when the historic data needed for this regression was not available. For these time steps Sacramento River discharge was estimated by means of a weighted random draw on Sacramento River stage using the full range of historic stage and discharge estimates available (Water years 1990-2016). The weights for each draw were calculated using a normal

distribution with the distribution mean equal to the time step's stage, and a std of 0.167. We used this approach to make sure the missing discharge estimates were filled in using data that reflected the historical variance between Sacramento River stage and Sacramento River discharge at the study site caused by backwater effects.

Estimating abundance at each time step

At each time step the bootstrap sample size for each of four runs of Sacramento River Chinook salmon (fall run, spring run, winter run, and late fall run) was determined using historic estimates of abundance of these runs. We used the daily percent of yearly CPUE time series in from the cleaned Knights Landing catch data provided by the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project team to estimate abundance for each run. The daily percent of yearly CPUE time series for each run normalizes each run's daily CPUE by the total CPUE for that run over the trap operational season for each year, so that each water year's CPUE is weighted equally within the simulation; the total abundance for the 15 year simulation period sums to 1500% (see California Department of Water Resources, 2017 for more information on this normalization). Using the normalized daily CPUE data assures that the results of the entrainment simulation will not be weighted towards years of extremely high CPUE because each water year's daily percent of yearly CPUE sums to 100%. Per conversations with the FETT team we filled in missing values in the Knights Landing daily percent of yearly CPUE data with zeros.

In order to use the Knights Landing data to calculate a bootstrap sample size for each time step the daily Knights Landing data had to be apportioned between 4 hr time steps. We chose to apportion the daily catch data uniformly between the six time steps that occurred within each day (based on a 4 hour time step), with a new day's catch beginning at the time step that occurred at 00:00 hours on each day, so that the catch for time step 1-6 on any day summed to the Knights Landing catch for the day (Figure 8). Within the context of the entrainment simulation this approach is analogous to assuming a uniform probability distribution for abundance as a function of hour for each hour within a day; this approach allows us to run the simulation at a fine enough time scale to capture rapid changes in stage and discharge while maintaining the temporal resolution of Knights Landing catch data.

The final step in converting the Knights Landing daily percent of yearly CPUE data into a discrete bootstrap sample size for each run was to convert time step proportion of daily percent of yearly CPUE to a discrete sample size. Because daily percent of yearly CPUE could be quite low, we multiplied the timestep fraction of daily percent of yearly CPUE by 1000 and rounded the result to the nearest integer to obtain a discrete sample size for each time step (Figure 8). We chose the multiplier of 1000 so that the majority of time steps with low abundance would have a non zero sample size. This approach resulted in bootstrap sample sizes of one or two tracks for periods of extremely low abundance, sample size of 100-1000 for many of the time steps, and extremely high sample sizes for the time steps when abundance was large (Figure 9). Within this report we refer to the time series of discrete sample sizes for each run at each timestep as the "discrete abundance" for each run. These time series sum to slightly less than

1500% for the entire simulation period due to the conversion from continuous catch data to discrete sample sizes. For the purpose of our analyses we use the discrete abundance time series for all entrainment normalizations.

Drawing the bootstrap sample

At each time step, we drew a discrete sample of acoustic tag tracks to represent the fish available for entrainment for each run based on the discrete abundance time series. For each bootstrap sample tracks were drawn from the pool of all 2016 tracks using weighted random sampling with replacement. Bivariate weights for each of the 2016 tracks were calculated at each time step based on the stage and discharge at the time that each 2016 track entered the study area, given the stage and discharge for each simulation time step. The bivariate weights were calculated using a bivariate normal distribution with mean discharge and stage values equal to the time step discharge and stage values, and the covariance matrix computed from a subset of the USGS estimates of historic Sacramento River stage and discharge for water years 1990-2016. The subset of data used to compute the covariance matrix at each time step was defined as all historic data having a stage value within +/- 0.623 ft of the time step stage, and having a discharge value within +/- 638 cfs of the time step discharge. The stage and discharge radii criteria for selecting the covariance data for each timestep are 1/10th the standard deviation of the stage and discharge values for the entire pool of 2016 fish tracks. The radii criteria was chosen as a balance between obtaining diversity in the bootstrap pool against the need to select a bootstrap pool that reflected the covariate values for each timestep. Figure 11 and figure 12 illustrate the bivariate weighting function and resulting sampling for two combinations of Sacramento River stage and discharge.

We chose to use a bivariate weighting function because of the variance in the relationship between stage and discharge within simulation period and within the period when the 2016 acoustic tag tracks were collected (figure 10). Because of this variance the relative “suitability” of a track for estimating entrainment should be a function of both the stage and discharge when the track was collected (figure 11, figure 12. By computing the covariance matrix for the weighting function at every timestep we allow the historic covariance between stage and discharge to determine the relative importance of stage and discharge to the weighting function at any point in the stage-discharge space. Finally, the bivariate weighting improved sample selection over univariate approaches (not shown) at locations in the stage-discharge space where the pool of acoustic tag tracks was sparse by allowing the sampling to select tracks based on both stage and discharge (figure 12). The same bootstrap sample drawn for each run at a given timestep is used to evaluate entrainment under each scenario at each of the 63 evaluation locations.

Determining entrainment of bootstrap sample tracks

For every time step, each track in a run's bootstrap sample was classified as either entrained or not entrained under each scenario based on the cross-stream location of each fish track relative to the cross-stream location of the critical streakline, at each of the notch evaluation locations (figure 4). The techniques used to estimate the location of the critical streakline are discussed in detail in Stumpner et al., In Review, and the theory behind using the location of the critical streakline to predict the routing of juvenile Chinook salmon in river junctions is covered in detail in California Department of Water Resources (CADWR), 2016. We present a summary of the critical streakline method below, followed the application of this approach to the methods used in the entrainment simulation. Within these sections we describe the approach to estimating entrainment at a single possible notch location; these steps are repeated for each of the 63 possible notch locations at every time step.

Fundamentals of the critical streakline method

For this project, the critical streakline is the cross-stream dividing line upstream of the notch that separates water that will go in the notch from water that will continue to go down the Sacramento River. The cross-stream location of the critical streakline upstream of the notch can be estimated from the cross-stream distribution of bathymetry and discharge immediately upstream of the notch which can then be overlain on fish spatial distributions to estimate entrainment rates into the notch; the fraction of the cross-stream fish distribution on each side of the critical streakline is apportioned to either the notch or Sacramento River depending on where the water goes on either side of the streakline.

The USGS hydrodynamics group has worked on refining and testing various techniques for estimating the location of the critical streakline since 2009, working with members of the Columbia River Research Lab to test whether the location of the critical streakline can be used to predict the fate of fish moving through tidally forced river junctions based on the analysis of data collected during the DWR Georgiana Slough studies (CADWR, 2012, 2015, 2016). Over the course of the 2011, 2012, and 2014 studies we have found that the cross-stream location of the critical streakline relative the cross stream location of a fish immediately upstream of a junction is a good predictor of an individual fish's fate within the junction, and a very good predictor of aggregate entrainment rates when these predictions are summed over a group of fish (ibid). Based on this body of work, the USGS hydrodynamics group has developed the critical streakline approach to estimating entrainment in tidally forced riverine junctions, which can be simply summarized as follows:

1. Use hydrodynamic data to estimate the location of the critical streakline immediately upstream of a junction (or notch), and
2. Use the cross stream location of the critical streakline to apportion fish mass into the downstream branches of the junction, either in an aggregate sense (using fish density distributions), or on an individual basis (one track at a time).

Although the critical streakline concept is extremely simple, our substantial body of telemetry work (to date we have analyzed more than 11,000 track segments moving through tidal junctions) suggests that it can be a very good predictor of entrainment in junctions (ibid).

General approach to estimating the location of the critical streakline

Over the course of the Georgiana Slough studies the USGS hydrodynamics group has explored various techniques for estimating the location of the critical streakline (ibid). In all cases we begin with the bulk, or total discharge in each branch in a junction, and, thus, we know, apriori, the **discharge ratio** (DR): the ratio of discharge in each junction branch. The most accurate approach (CADWR 2016), and the approach used here, takes into account the influence of the cross stream variation in depth in the integration as well as the shape of the sidewall boundary layer. The first step is to estimate a cross-stream velocity field upstream of the junction. We estimate the cross-stream velocity field by combining a cross stream velocity profile obtained from downward-looking ADCP transects (see Stumpner et al., In Review) along with the assumption of the ⅙ power law for the shape of the vertical velocity profile in the unmeasured portions of the cross section at each point along the cross section (see Stumpner et al., In Review) The mean location of the critical streakline is then determined by integrating this synthetic velocity field from the river bed to the water surface across the channel starting from the bank with the side channel (or notch) to the point in the cross section where the discharge from this integration matches the discharge in the side channel (or notch). This location is the estimated mean location of the critical streakline; we refer to this location as the “mean location” because in real flows turbulent perturbations to the mean velocity field will result in variance in the instantaneous location of the critical streakline.

Estimating entrainment within the simulation: estimating cross stream distribution of discharge at each location given Sacramento River Stage.

Estimating cross stream distribution of discharge at measured transect locations and stages

During 2015, 2016, and the spring of 2017 the USGS and DWR collected downward looking adcp transects at 9 transect locations throughout the western end of the study area at multiple Sacramento River stage values (Stumpner et al., In Review). The USGS then processed this data to develop an estimate of the cross-stream distribution of Sacramento River discharge at each cross section, for each stage value sampled, see Stumpner et al., In Review for more details.

Estimating the cross stream distribution of discharge at unmeasured locations and stages

We used gridded, multidimensional linear interpolation to estimate the cross-stream distribution of discharge for combinations of along-stream location and stage that we did not measure. The cross-stream discharge distributions were normalized to give the cross-stream distribution of discharge as a function of normalized cross-channel location, and then integrated to create cdfs. We then used these observations to create a multidimensional gridded interpolant to estimate cumulative fraction of cross stream discharge as a function of: stage, along-channel coordinate, and fraction of cross-channel width.

We used this interpolant to estimate a cdf of cross-channel distribution of discharge as a function of fraction of channel width for unmeasured combinations of along-channel location and stage.

Estimating entrainment within the simulation: estimating the discharge through each notch

We used linear interpolation to estimate discharge through each notch as a function of the estimated stage for each time step based on the stage-discharge relationships for each scenario. The stage discharge relationships for each scenario are discussed in detail below, and are summarized in Table 1.

Estimating entrainment within the simulation: estimating the cross-channel location of the critical streakline

At each timestep we divide the notch discharge by the estimated Sacramento River discharge to calculate the notch discharge ratio. The estimated cross-channel discharge CDF obtained from the gridded interpolant is then used to find the cross-channel location where the fraction of Sacramento River discharge equals the Discharge Ratio. This is the estimated location of the mean critical streakline. We then add a random perturbation to this location to account uncertainty in the location of the critical streakline due to the effects of Sacramento River backwater condition on the cross-channel distribution of water velocity. (See Stumpner et al., In Review). The random perturbation drawn from a normal distribution with a mean of zero, and a standard deviation of 1.97 meters; see Stumpner et al., In Review for details on the parameter selection for this distribution.

Estimating entrainment within the simulation: estimating entrainment for each track a bootstrap sample

For each track in each of the bootstrap samples drawn for each run the cross-channel location of the track is computed at the point where the track crosses a line instantaneously normal to

the along stream axis at each of the notch evaluation locations. If the track's location is to the right of the location of the critical streakline, then the track is marked as entrained, if the track is to the left of the critical streakline, the track is not entrained. There are a few additional details for multi-gate scenarios (scenario 5 and scenario 6)

- Only fish from the bootstrap pool that are not entrained in upstream gates are available for entrainment in subsequent downstream gates, thus, number of fish tracks available for entrainment in each gate decreases for downstream gates to prevent "double entrainment" for a single fish track
- Entrainment for all gates that make up a scenario has to be estimated for each of the 63 evaluation locations In the case of multigate scenarios, we assume that the center of the upstream most gate is at the evaluation location being used, and then compute entrainment for each downstream gates as occurring at a point located in the center of each downstream gate. The location of each downstream gate is based on the spacing of the gates in the engineering drawings provided for Alternative 5, see Appendix B. As the simulation iterates through along stream evaluation locations, the whole multigate simulation is shifted downstream.

Estimating entrainment within the simulation: estimating entrainment over the Fremont Weir during overtopping events

The purpose of the entrainment simulation is to explore the effects of scenario location and scenario design on the entrainment of juvenile Chinook salmon as a result of each scenario. As a result, the entrainment simulation does not estimate entrainment over the fremont weir. During periods when the weir is overtopping entrainment for each scenario is based only on the computations described above, and thus, represents an estimate of the entrainment during overtopping events that is due to modifications made to the Fremont Weir made under each scenario.

Simulated scenarios

The entrainment analysis simulation evaluated entrainment for six scenarios:

1. Scenario 1 consists of a single notch in the weir with the notch rating curve for Alternative 3. Under scenario 1 flow through the notch begins at 19 ft, and notch discharge reaches a maximum flow of 6,105 cfs at 31ft, and notch flow is maintained at 6,105 cfs for all Sacramento River stages above 31 ft.
2. Scenario 2 consists of a single notch in the weir with the notch rating curve for Alternative 4. Under scenario 2 flow through the notch begins at 19 ft, and notch discharge reaches a maximum flow of 3,166 cfs at 27 ft, and notch flow is maintained at 3,166 cfs for all Sacramento River stages above 27 ft.
3. Scenario 3 consists of a single notch in the weir with the notch rating curve for Alternative 6. Under scenario 3 flow through the notch begins at 20 ft, and notch discharge reaches a maximum flow of 12,253 cfs at 30 ft, and notch flow is maintained at 12,253cfs for all Sacramento River stages above 30 ft.

4. Scenario 4 consists of a single notch in the weir with a notch rating curve similar to Alternative 4, but with flow through the notch beginning at 15 ft instead of 19 ft. Under scenario 4 flow through the notch begins at 15 ft, and notch discharge reaches a maximum flow of 3,166 cfs at 23 ft, and notch flow is maintained at 3,166 cfs for all Sacramento River stages above 23 ft. The purpose of scenario 4 is to evaluate how the entrainment of winter run Chinook might be enhanced by modifying the weir to pass water at lower Sacramento River stages.
5. Scenario 5 consists of four gated notches in the weir. The notch rating curves and gate dimensions and spacing are based on the design for Alternative 5, but the rating curve has been shifted up by 1.3' Under scenario 5 flow through the notch begins at 17', reaches a maximum of 3,424 cfs at 29', then flow through the notch ceases with overtopping at 32.3'. The purpose of scenario 5 is to increase our understanding of the performance of multi-gate scenarios located on the outside of a bend in the Sacramento River.
6. Scenario 6 consists of four gated notches in the weir. The notch rating curves and gate dimensions and spacing are based on the design for Alternative 5. Under scenario 6 flow through the notch begins at 15', reaches a maximum of 3,863 cfs at 31.7', then flow through the notch ceases with overtopping at 32.3'. The purpose of scenario 6 is to increase our understanding of the performance of multi-gate scenarios located on the outside of a bend in the Sacramento River.

Table 1 summarizes the notch rating curves for all scenarios in 1 ft increments from 15' to 35', and gives an estimate of the magnitude of the Sacramento River discharge that is likely to occur at each stage value, based on the USGS 2016 stage-discharge rating. Note that because of backwater effects there can be a wide range of Sacramento River discharge values which occur for any stage, so the discharge given in Table N, Column 1 is only indicative of the order of magnitude of Sacramento River discharge for each stage value. A spreadsheet containing more details on the multi-gate scenarios is contained in Appendix B.

The same simulation procedure and covariate data was used to evaluate entrainment under each scenario, with the exception that extra steps were used to estimate entrainment for the multi-gate scenarios as described above.

Table 1- Notch rating curves for simulated scenarios

Sacramento River Stage, ft, NAVD88, USGS	2016 Stage – Discharge Rating For Sacramento River Discharge, CFS	Scenario 1 Notch Flow, CFS	Scenario 2 Notch Flow, CFS	Scenario 3 Notch Flow, CFS	Scenario 4 Notch Flow, CFS	Scenario 5 Notch Flow, CFS (Total flow through all gates)	Scenario 6 Notch Flow, CFS (Total flow through all gates)
15	8,680	0	0	0	218	0	12
16	9,693	0	0	0	349	0	45
17	10,706	0	0	0	551	35	94
18	11,720	0	0	0	804	79	177
19	12,733	218	218	0	1,142	152	316
20	13,746	349	349	679	1,547	274	498
21	14,759	551	551	1,195	2,013	443	769
22	15,772	804	804	1,831	2,555	678	1,073
23	16,785	1,142	1,142	2,661	3,166	982	1,776
24	17,798	1,547	1,547	3,664	3,166	1,565	2,381
25	18,811	2,013	2,013	4,787	3,166	2,200	3,084
26	19,825	2,555	2,555	6,067	3,166	2,873	3,223
27	20,838	3,166	3,166	7,502	3,166	3,171	3,259

28	21,851	3,845	3,166	9,041	3,166	3,405	3,182
29	22,864	4,624	3,166	10,675	3,166	3,424	3,407
30	23,877	5,365	3,166	12,253	3,166	3,182	3,246
31	24,890	6,105	3,166	12,253	3,166	3,376	3,403
32	25,903	6,105	3,166	12,253	3,166	3,325	3,863
33	26,916	6,105	3,166	12,253	3,166	0	0
34	27,930	6,105	3,166	12,253	3,166	0	0
35	28,943	6,105	3,166	12,253	3,166	0	0

Results

Simulation entrainment as a function of notch location

The primary goal of this analysis is to understand how the performance of each notch scenario is affected by the location of the notch or notches within the study area given historical relationships between Sacramento River stage, Sacramento River discharge, and run abundance. To this end we used an entrainment simulation to estimate time series of entrainment for each run, for each scenario, at 63 locations within the study area spaced 10 meters apart in the along stream direction (figure 4, Appendix A). This approach allows us to use a variety of metrics that allow us to compare entrainment at each of the potential locations for six simulation scenarios and, further, suggest alternative strategies for optimizing entrainment rates in future designs.

The entrainment simulation period (water years 1997 - 2011) includes a mix of dry years when the weir did not overtop during the notch operation period (October 1-March 15), years when the weir overtopped infrequently during the notch operation period, and wet years when the weir

frequently overtopped during the notch operation period (Figure 13). Because the simulation period contains a mix of water year types, estimates of the total entrainment and the total entrainment ***rate*** for each location over the course of the simulation provide a good summary of how notch location affects scenario performance in the long run by incorporating a wide range of conditions. Figure 14 shows the overall entrainment for each run for each scenario at each location in the study area. For this analysis, total entrainment is expressed as the overall fraction of the yearly abundance time series for each run that is entrained in the notch over the 15 year simulation period; because the yearly abundance time series sums to 100% for each season, entrainment for each year is weighted equally. This Normalization allows us to make between year comparisons. Figure 15 is similar to figure 14, but expresses scenario performance as overall entrainment rate for each scenario, which is calculated as the fraction of the simulation fish that passed through the study area during the notch performance period when notch flow was greater than zero which were entrained under each scenario. Figure 14 addresses the question “where should a scenario be located to maximize the overall entrainment of a run”, while figure 15 addresses the question “where should a scenario be located to maximize the entrainment of that proportion of each run that passes through the study area when the notch is operating”.

The good news is that the total entrainment and entrainment rate curves for each run show similar trends in scenario performance as a function of notch location. For single gate scenarios (scenario 1 - scenario 4) notch performance for all run has a peak around 275 meters, a sharp decrease in performance between 300 meters and 375 meters, followed by a broad peak in performance that slowly drops off after 500 meters. For single gate scenarios the maximum entrainment and entrainment rate for all run is located between 400 meters and 500 meters. Figure 16 shows where these along channel coordinates are located in the study area, and Appendix A provides a table that can be used to convert between along-channel coordinates and UTM.

The relationship between notch locations and performance for multigate scenarios (scenario 5 and scenario 6) is similar, but these scenarios had the highest entrainment and entrainment rate for all run between 260 meters and 280 meters. For multigate scenarios the location indicated on the entrainment and entrainment rate plots is the along-channel location of the center of the first gate, so a peak entrainment listed at 270m indicates that peak entrainment occurred for the scenario when the center of the first gate was located 270m, the center of the second gate was located at 282m, the center of the third gate was located at 430m, and the center of the fourth gate was located at 510 meters (See Appendix B for gate spacing for scenario 5 and scenario 6). The spacing of the gates for the multigate scenarios explains why these scenarios reached peak performance when the center of the first gate was located near 270 meters, because this location placed all 4 gates in regions where the single gate scenarios had high entrainment.

It is likely that the dramatic drop in scenario entrainment and scenario entrainment rate shown in figure 14 and figure 15 around 300 meters is caused by interactions between the study fish’s behavior and hydrodynamic effects of the sudden change in bathymetry near the river right bank (figure 16) in this area of the river. Figure 17 show the location of the notch evaluation cross-

section at 365m on a bathymetry map of the study area with some example fish tracks; it appears that fish near the river right bank of the study area upstream of the scour hole on the outside of the bend avoid the area around the scour hole. Additionally, it appears that the geometry of the bend interacts with the outmigration behavior of the study fish in a way that resulted in many fish on the river left side of the sacramento river passing by this portion of the bend (figure 18). The net result of these effects is that there is a drop in the density of fish tracks in the near-bank area in the vicinity of this scour hole (figure 19), while the area of peak water velocity moves closer to the bank in the scour hole. Accordingly, a notch located in the vicinity of the scour hole will likely need to entrain a large amount of water to move the critical streakline into locations in the cross-section with high fish densities. The effects of the scour hole on scenario performance suggest that the bathymetry and hydrodynamics immediately upstream of a notch can have significant impacts on the notches entrainment rate.

Because the entrainment simulation is based on tracks of acoustically tagged hatchery late fall run Chinook, the differences between the simulated entrainment for each run are entirely the result of the difference in abundance timing for each run during the simulation period. Thus, differences in scenario performance between run show the expected effect of each run' outmigration timing on the entrainment of hatchery late fall run Chinook, and are not indicative of any behavioral differences between run. Nevertheless, the differences between scenario performance for each run can inform our understanding of how the covariance between abundance timing, Sacramento River stage, Sacramento River discharge and scenario notch rating curves combine to affect entrainment.

The most significant observation from figures 14-15 is that the entrainment and entrainment rate curves for each run suggest that differences in abundance timing between run determine the maximum entrainment and entrainment rate for each run under each scenario, but, differences in abundance timing do not significantly alter the relationship between along-channel location and scenario performance. In other words, these results suggest that a notch location that maximizes entrainment for fall run abundance timing is likely to have near maximum entrainment for winter and spring run abundance timing as well. Again, we caution that these results are based only on run abundance timing, and do not incorporate behavioral and physiological differences between runs, nor between the size and degree of smoltification of the juvenile salmon that can vary between years and throughout any given outmigration season.

Effects of notch rating curves and run abundance timing on entrainment

While differences in abundance timing between each run did not result in significant differences in the relationship between notch location and notch performance for each run, the differences in abundance timing did have a significant effect on the maximum entrainment rate and maximum total entrainment for each run. With the exception of scenario 4, all scenarios showed the same pattern in the relative entrainment rate between run throughout the study area: fall run had the highest entrainment rate, spring run and winter run had similar entrainment rates that were lower than fall run, and late fall run had the lowest entrainment rates (figure 15).

Scenario 4 is the exception, as all run experienced similar entrainment rates under this scenario (figure 15, panel 4). Patterns in the relative differences between total entrainment for each run are similar to the patterns in the relative difference between entrainment rate for each run, with scenarios 1,2,3,5, and 6 showing the highest total entrainment for fall run, the lowest entrainment for late fall run, and middle values for spring run and winter run. Again, the exception was scenario 4, which showed similar total entrainment for fall run, spring run, and winter run, and the highest overall entrainment for winter run rather than fall run.

The reason that scenario 4 had the most consistent entrainment rates between run is that this scenario had the highest notch flows for stages below 22', when a large proportion of spring run, winter run, and fall run were present in the study area during the simulation period (Figure 20). The cumulative distribution functions (cdfs) for each run' simulation abundance as a function of stage shown in figure 20 show that during the simulation period around half of the spring run, winter run, and late fall run yearly abundance passed through the study area when stage was below 22', while only about 30% of fall run abundance passed through the study area when stage was below 22'. Additionally, the cdf's for spring run, winter run, and late fall run all show a rapid increase in cumulative abundance between 19' and 22' that does not occur in the cdf for fall run. This rapid rise in abundance between 19' and 22' for spring run, winter run, and late fall run suggests that there is some interaction between watershed hydrology and the life history of these run that consistently results in these runs moving through the study area during outflow events that result in Sacramento River stages in the study area between 19' and 22'. As a result, scenario 4, which entrains about 10% of Sacramento River water at 19', and reaches a peak discharge ratio at 23' has the second highest total entrainment for all run. Scenario 3 has higher total entrainment for all run, but, scenario 3 reaches a peak discharge of 12,000 cfs, while scenario 4 has a peak discharge only 3,166 cfs.

Finally, scenario 4 has similar entrainment rates for all run, and similar total entrainment for fall run, spring run, and winter run, but lower total entrainment for late fall run. The lower total entrainment for late fall run under scenario 4 (and all other scenarios) is the result of two factors: first, during the simulation period about 25% of late fall run yearly abundance passed through the study area at stages below 16', while only about 10% of other run yearly abundance passed through the study area below 16' during the simulation (all scenarios entrained little to no water below 16'), and second, during the simulation period, late fall run had lowest proportion of total yearly abundance that occurred during the notch operation period (Table 2). Thus, even though scenario 4 entrained late fall run at the same rate as other run, there was a lower overall proportion of late fall run available for entrainment during periods when the notch was operating.

Table 2 - percent of simulation abundance for each run that passed through the study area during the notch operation period.

run	Percent of simulation total yearly abundance for the simulation period that transited the study area during notch operation periods
Fall Run	79%
Spring Run	81%
Winter Run	98%
Late Fall Run	68%

Entrainment rate and entrainment efficiency for each scenario as a function of stage.

As discussed above, the entrainment simulation is only based on acoustic tag tracks from hatchery late fall run chinook, so the differences in simulated entrainment between run reflects the differences in the frequency of the relative timing of stage, discharge and run abundance during the simulation period. In order to better understand how abundance timing affected entrainment under each scenario we computed stage vs entrainment rate curves for each scenario (Figure 21), and stage vs entrainment efficiency curves for each scenario (Figure 22). Entrainment rate indicates the fraction of the bootstrap sample at each timestep that was marked as entrained under each scenario, and entrainment efficiency is the ratio of the time step entrainment rate for each scenario divided by the time step discharge ratio for each scenario. When entrainment efficiency is greater than one a notch is entraining a greater proportion of fish than water.

The underlying stage vs entrainment relationship for each scenario is the same for each run, so we chose to compute the relationship for winter run because the winter run abundance timing resulted in the largest number of entrainment “trials” within the simulation. Because the spatial distribution of discharge and fish tracks changes throughout the study area and, thus, the stage vs entrainment rate/efficiency curves for each scenario change throughout the study area; it is possible to compute a stage-entrainment rate curve for each of the 63 along-channel notch locations evaluated in the simulation. For the sake of brevity, we chose to present curves for the location in the study area that had the highest total entrainment of winter run for each scenario (These locations are shown in figure 16).

Because of backwater effects in the study area, a range of Sacramento River discharge values occur in the historical record for any Sacramento River stage value (Stumpner et.al., in review). As a result, there is a range of notch discharge ratios for each scenario at any stage, and, because of this variability in discharge ratio and variability in behaviors and other environmental covariates, we expect that run of the river fish will experience a range of entrainment rates at any Sacramento River stage under all future notch scenarios. Within the entrainment simulation the range of entrainment rates predicted for any stage is a function of three processes: firstly, the entrainment simulation is driven by historic stage and discharge data, so the historic variance in discharge ratio for each scenario is captured in the simulation. Secondly, there is stochasticity inherent in the bootstrapping approach used to draw the track pools at each timestamp, so any particular stage-discharge pair will not always draw from the same track pool. Thirdly, we add stochastic error to the computed critical streakline location for each scenario at each time step to account for uncertainty in our ability to predict the critical streakline location given the effects of backwater condition on cross-channel velocity distributions within the study area (Stumpner et.al., in review). As a result of these three factors the stage vs entrainment rate and stage vs entrainment efficiency curves presented in figure 21 and 22 are in the form of a 90% confidence interval and median value for scenario entrainment rate as a function of stage. The range of discharge ratios at each stage is shown for each scenario to illustrate the variability in discharge ratio. For the multigate scenarios the entrainment rate and median discharge ratio are based on total entrainment of water and fish through all gates operating at any stage value.

The scenario stage vs entrainment rate curves shown in figure 21 indicate how efficient each scenario is at entraining fish at any stage: when the scenario entrainment rate is greater than the scenario discharge ratio the scenario is entraining proportionally more fish than water, and when the entrainment rate is lower than the discharge ratio the scenario is entraining proportionally more water than fish. Figure 22 shows the range of entrainment efficiency values for all timesteps at a particular stage. The entrainment efficiency of each scenario at any location is controlled by the balance between the cross-channel distribution of fish and the cross-channel distribution of flow. Figure 23 and figure 24 illustrate the cross-channel distribution of fish and flow in the study area. The interaction between fish distribution, flow distribution, and notch rating curves controls entrainment efficiency. This interaction is complex; however, in general, the effects of discharge ratio on entrainment can be summarized for the locations in the study area that produced maximum scenario entrainment as follows:

1. There is a zone very near the river bank where there are few fish, so extremely low discharge ratios produced low entrainment rates for all scenarios.

2. There is a zone a little further from the bank where fish densities are high and water velocities are not the peak within the cross section: increasing the discharge ratio to the point where the critical streakline enters this zone will result in rapid increase in entrainment and entrainment efficiency for all scenarios (this is a highly non-linear relationship - almost step function process due to the high gradient in the fish densities).

3. There is a zone beginning at about 15-25 meters from the river right bank (figure 24) where water velocities reach a peak. A large proportion of the total discharge in the cross-section is contained in this region. Once a scenario's discharge ratio is high enough that the critical streakline reaches this zone, a large increase in discharge ratio is required to move the critical streakline further out into the river cross section, and entrainment efficiency decreased.

4. The spatial distribution of 2016 study fish tracks for periods when Sacramento River was below bankfull (see figure 23) was dramatically different than the spatial distribution of 2016 fish tracks for periods when the Sacramento River was above bankfull (figure 25, figure 26). In general, fish tracks collected after the Sacramento River stage exceeded bankfull (28.5') were less concentrated on the outside of the bend, so that at higher stage scenarios needed a very high discharge ratio to entrain many fish. This observation is likely related to the influence of the slow velocity water associated with the overbank region pushing the influence of the sidewall boundary layer into the center of the channel (See Stumpner et.al., In Review).

The entrainment rate and entrainment efficiency curves shown in figure 21 and figure 22 reflect these general trends. For all scenarios entrainment efficiency increased rapidly once the discharge ratio exceeded 10%, with most scenarios reaching a peak entrainment efficiency between 25' and 27' and a discharge ratio of about 15%. Because of the covariance between stage and discharge ratio for all of the scenarios tested, we cannot ascertain whether the location of peak entrainment efficiency is a function of discharge ratio, a result of the spatial distribution of fish and flow at 25' - 27' of stage, or some combination of the two. In the future, we recommend simulating scenarios with constant discharge ratios which will allow us to explore the effects of stage and discharge ratio independently.

For all scenarios except scenario 3, entrainment rate and entrainment efficiency dropped off rapidly once stage exceeded bankfull. Scenario 3 maintained high entrainment rates and an entrainment efficiency near 1 for stages greater than bankfull because of the high discharge ratio for this scenario places the critical streakline near the center of the river at high stage values. The multigate scenarios had lower entrainment rates that scenarios 2 and 4 (which have similar overall notch rating curves), because at many stages the discharge for these scenarios was spread between multiple notches, so the lower discharge ratio for each individual notch (not shown) was less likely to push the critical streakline into the region in the cross-section where fish were more concentrated.

Finally, there are several features of the entrainment rate and entrainment efficiency curves that are a result of the mechanics of the simulation process. First, the dip in the entrainment rate for scenario 4 at 20' is a result of the small number of study fish tracks that passed through the study area at 20' of stage (figure 10); because of the limited fish tracks collected at this stage the bootstrap samples for stages around 20' are heavily influenced by a small number of fish tracks that happened to be far away from the bank at the location which we chose to compute the stage vs entrainment curves. When stage vs entrainment curves are computed for locations

where these fish tracks were closer to the bank (not shown) the dip in entrainment is not evident, and the plots showed a smooth entrainment curve for scenario 4 from 15' to the peak in entrainment located around 24.5'. Secondly, the extremely high entrainment efficiency for scenarios 1,2,5, and 6 at low notch flows are due to the extremely low discharge ratios for these scenarios when the notches first begin to take water. Entrainment efficiency is calculated using discrete numbers and cannot change with the same precision as discharge ratio, which is a continuous variable. As a result, when discharge ratios are very low entrainment of a single fish track can cause the entrainment rate to increase out of proportion with the discharge ratio, and entrainment efficiency becomes large. Note that the two scenarios that took more water at low flows do not indicate the very high entrainment efficiencies at the lowest notch flows.

Entrainment as a function of water year

Because of the complex relationship between Sacramento River stage, run abundance, and scenario entrainment rate, we wanted to be sure that the along-stream location vs entrainment curves we computed for the entire simulation were not being disproportionately influenced by water years with extremely high or low Sacramento River stage values. To explore the effects of water year on simulated entrainment, we placed each notch operation season (November 1 - March 15) into one of three water year categories based on the number of hours within the operation season that the weir overtopped (Tables 3 and 4), and then computed total entrainment vs along-stream location curves for each water year category (overtopping was defined as Sacramento River stage > 32.3'). The operation season classifications are shown in Table 3, and the entrainment vs along-stream location curves for each water year class, run, and scenario are shown in figure 27 through figure 32. The most important result of analysis of the water year entrainment vs along-stream location curves is that these curves suggest that water year type has a large influence on the maximum entrainment for each run under each scenario, but, water year type doesn't change the overall trends in scenario performance vs along-stream location. This is a positive result because it suggests that the same location in the cross section will produce maximum entrainment for a variety of abundance timing and water years.

The entrainment vs along-stream location curves shown in figure 27 through figure 32 show many interesting differences in the maximum entrainment for each water year category for each run and scenario. Some of the most important observations are:

1. Most scenarios entrained the most fall run in seasons when the weir did not overtop. This is because fall run are most likely to be present in the study area at high sacramento river stage values when entrainment efficiency for most scenarios is lowest; in dry years fall run most likely pass through the study area at lower stages when entrainment efficiency was higher.

2. During years when the weir did not overtop, scenario 4 had the highest peak entrainment for spring run, winter run, and late fall run. This is despite the fact that

scenario 3 has maximum notch flows that are nearly 4 times higher than the maximum notch flows for scenario 4. This observation suggests that lowering scenario stage-discharge curves to capture fish passing through the study area between 19' and 22' could be an efficient way to increase entrainment of these run in dry years.

3. Late fall run tended to experience the highest overall entrainment during wet or moderately wet years, as opposed to the other runs which experienced the highest overall entrainment during dry or moderately wet years.

Table 3 - Water year type classifications based on number of hours that the weir overtopped during each season in the simulation

Number of hours that the weir overtopped per season (Overtopping is defined as Sacramento River >32.3 ft, NAVD88, USGS)	
0	No overtopping, Category 1
1-200	Few overtopping, Category 2
200 +	Wet, Category 3

Table 4 - Number of hours that the fremont weir overtopped during each season in the simulation

Season	Hours of weir overtopping per season	Season classification
1996	1204	Wet
1997	1268	Wet
1998	744	Wet
1999	712	Wet
2000	0	No Overtopping
2001	112	Few Overtopping
2002	156	Few Overtopping
2003	448	Wet
2004	0	No Overtopping
2005	1120	Wet
2006	0	No Overtopping
2007	0	No Overtopping
2008	0	No Overtopping
2009	12	Few Overtopping
2010	36	Few Overtopping

Discussion

Primary sources of uncertainty in the entrainment simulation

The entrainment simulation uses hydrodynamic data and acoustically tagged fish track data collected under a limited range of field conditions to predict entrainment for future weir modification scenarios over a range of hydraulic conditions and run abundance timing scenarios. As a result, we view the entrainment simulation results primarily as tool for exploring the interaction between factors which we expect to be the primary drivers of scenario efficacy: a scenario's stage-discharge rating, a scenario's location within the study area, the covariance between stage and discharge at the study location, and the timing of salmon run abundance. However, the entrainment simulation is not designed to explore the fifth factor that we expect to control scenario entrainment: the physiology and behavior of wild and run of the river fish. The entrainment simulation is entirely based on a limited sample of tracks from acoustically tagged hatchery late fall run Chinook salmon, and this is the single largest source of uncertainty within the entrainment simulation. At this time we lack the data to evaluate the suitability of using hatchery surrogate late fall run fish to predict the high resolution movement patterns of other runs (or wild and run of the river late fall run), but it is reasonable to expect that the behavior of the hatchery surrogates will not be a good predictor of the behavior of some, or all, of the wild and run of the river fish that are the focus of this project. With that said, there is little that can be done to directly address this uncertainty in the absence of detailed data on the fine scale movement patterns of wild and run of the river fish.

There are additional sources of uncertainty in the entrainment simulation that we view as secondary to the fundamental limitation of using hatchery surrogate fish to predict the movements of wild and run of the river fishes. These other primary sources of uncertainty are:

1. The limited range of Sacramento River backwater conditions and other covariates represented in the 2016 track data set. The bivariate weighting function used in the bootstrap sample selection process helps to mitigate the limited range of backwater conditions within the 2016 track data set, but given the limited data collection window for the 2016 track data there may be covariates which are first order drivers of entrainment that we do not account for within the entrainment simulation.
2. The possibility that weir modifications will alter the hydrodynamics within the study area. We expect that weir modifications will alter the water velocity patterns within the study area in the immediate vicinity of a notch, but, we do not expect that modifications to the weir will significantly change the cross-channel distribution of flow at a notch. As a result, we only expect local changes to water velocity patterns to affect entrainment if these velocity changes cause fish to alter their behavior in the vicinity of a notch, and, if water velocities in the vicinity of the notch are low enough for the altered behavior to affect entrainment.
3. The effects of backwater condition on the cross-channel distribution of flow in the study area. We have directly incorporated this uncertainty into the simulation by adding stochastic error to our estimated location for the mean critical streakline, the uncertainty

in the stage-entrainment rate curves for each scenario are a direct result of this stochastic error.

Implications for design of weir modifications

Based on the USGS's past analyses of entrainment at the Georgiana Slough junction we feel that the location of the critical streakline in a riverine junction is a good predictor of entrainment probabilities for individual acoustically tagged juvenile salmon, and a good predictor of the entrainment rate for aggregated groups of acoustically tagged juvenile salmon (CADWR 2012, 2015, 2016) . For this reason, we feel that the critical streakline approach used in the entrainment simulation is a good method for estimating entrainment under future scenarios based on fundamental hydrodynamic principles and observed acoustic tag tracks. In other words, we view the entrainment simulation as a sophisticated "back of the envelope calculation" that combines physical principals with the observed track data to produce entrainment estimates. We expect that the results of the entrainment simulation are a good order of magnitude predictor for the entrainment and entrainment rate of **fish that are physiologically and behaviorally similar to the 2016 study fish** under each scenario. While we caution that the results of the entrainment simulation may not be applicable to run of the river or wild fish, the reality is that we lack the high resolution tracking data for wild and run of the river fish needed to improve on these estimates. Given these limitations, the results of the entrainment simulation suggest the following:

- The entrainment simulation suggests that locating single notch scenarios between 400m and 500m in the along-channel direction (see Appendix A for UTM locations) will result in near maximum entrainment and entrainment rates for all single notch scenarios, and that performance of scenarios located in this area will be robust to changes in abundance timing and water year type. We have no means of assessing weather this area will produce maximum entrainment for wild or run of the river fish.

- The relationship between scenario performance and scenario location suggests that bathymetry and hydrodynamics upstream of a weir modification could have large impacts on performance. Care should be taken to avoid siting modifications in areas where fish are likely to respond to bathymetric gradient in the along-channel direction. It may be possible to enhance entrainment in a weir modification by altering (reducing) the along channel bathymetric gradients upstream of the modification.

- Shifting notch stage-discharge curves lower (increasing notch flows at lower stage values) will likely increase the entrainment of winter run, spring run, and late fall run, especially during very dry years. Specifically, entrainment of winter run and spring run may be greatly increased by designing a weir modification to enhance entrainment of fish between Sacramento River stage values of 19ft and 22ft. This result is likely to be robust to differences between wild fish and the hatchery surrogates used in the analysis, because it is primarily driven by run abundance timing. If the physical constraints make

it impracticable to lower the notch invert elevation sufficiently to achieve an adequate notch discharge ratio at 19' stage, it may be possible to design a hydraulic control section in the Sacramento River to increase entrainment through notches with higher invert elevations at lower Sacramento River stage values

- It is likely that the entrainment efficiency of the multi-notch scenarios can be improved by optimizing the trade off between the number of notches utilized, and the discharge ratio for each notch. Further analysis could be performed to estimate the most efficient discharge ratio for each notch location as a function of stage, and then the total number of notches could be set based on the desired total scenario discharge as a function of stage.

- The decrease in entrainment efficiency observed for Sacramento River stages above bankfull for all scenarios was likely the result of the hydrodynamic effects of inundation of the floodplain between the Sacramento River and the weir (Stumpner et al., In Review), combined with the study fish's response to these hydrodynamic effects. In another bend on the Sacramento River that lacks a floodplain the USGS has observed increased cross channel velocities towards the outside of the bend (Dinehart and Burau, 2005); in general we would expect increased cross channel velocities to enhance entrainment under most scenarios. For this reason it may be possible to increase entrainment in the study area for most scenarios by extending the Sacramento River levee from the western end of the Fremont Weir to the upstream end of a weir modification to prevent this floodplain area from inundating prior to notch overtopping.

References

California Department of Water Resources.(2017). Evaluating juvenile Chinook Salmon entrainment potential for multiple modified Fremont Weir configurations: Application of *Estimating juvenile winter-run and spring-run Chinook Salmon entrainment onto the Yolo Bypass over a notched Fremont Weir, Acierto et al. (2014)*. Technical memorandum for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project. Sacramento, California.

California Department of Water Resources. (2016). 2014 *Georgiana Slough Floating Fish Guidance Structure Performance Evaluation Project Report.* Sacramento, CA

California Department of Water Resources. (2015). *2012 Georgiana Slough Non-Physical Barrier Performance Evaluation Project Report.* Sacramento, CA

California Department of Water Resources. (2012). *2011 Georgiana Slough Non-Physical Barrier Performance Evaluation Project Report.* Sacramento, CA

Dinehart, R. L., and J. R. Burau (2005), *Averaged indicators of secondary flow in repeated acoustic Doppler current profiler crossings of bends*, Water Resour. Res., 41, W09405, doi:10.1029/2005WR004050.

Stumpner, P. (In Review). *Hydrology and Hydrodynamics on the Sacramento River near the Fremont Weir: Implications for Juvenile Salmon Entrainment Estimates*. U.S. Geological Survey. West Sacramento, CA.

Figures



Figure 1- Aerial photograph showing the approximate boundary of the USGS study area

The portion of the Sacramento River on the western end of the Fremont Weir where the USGS collected water velocity data and high resolution two dimensional acoustic tag tracks is outlined in red.



Figure 2 - Aerial photograph showing the bathymetry and hydrophone locations in study area

Aerial photo showing the portion of the Sacramento River on the western end of the Fremont Weir where the USGS collected water velocity data and high resolution two dimensional acoustic tag tracks. The photo is overlaid with bathymetry maps in the study area, hotter colors on the bathymetry map denote deeper areas. Hydrophone locations are shown as dots with hydrophone lables.

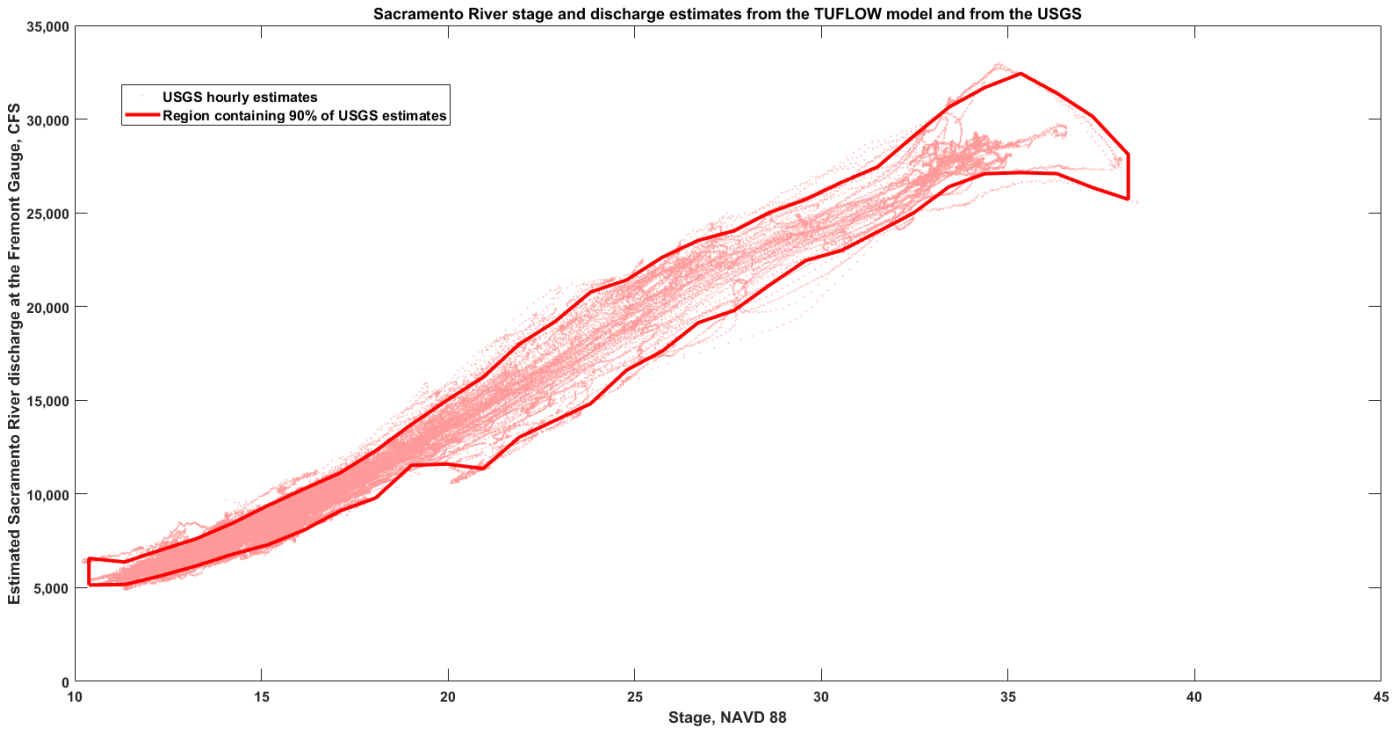


Figure 3 - Plot showing the range of estimated stage-discharge values for the Sacramento River in the vicinity of the western end of the Fremont Weir from 1996 to 2011

Red dots indicate hourly stage-discharge estimates, and the thick red line indicates the region containing 90 % of the discharge observations for any given stage. Because discharge through the proposed notch scenarios will be a function of stage only, the variability in the relationship between Sacramento River stage and Sacramento River discharge will result in variability in the fraction of Sacramento river water diverted under each scenario.



Figure 4 - Aerial photo of the vicinity of the western end of the Fremont Weir overlaid with scenario evaluation locations.

The white box indicates the study area for the simulation entrainment; the black lines indicate evaluation cross-sections where entrainment was estimated for each scenario at each timestep.

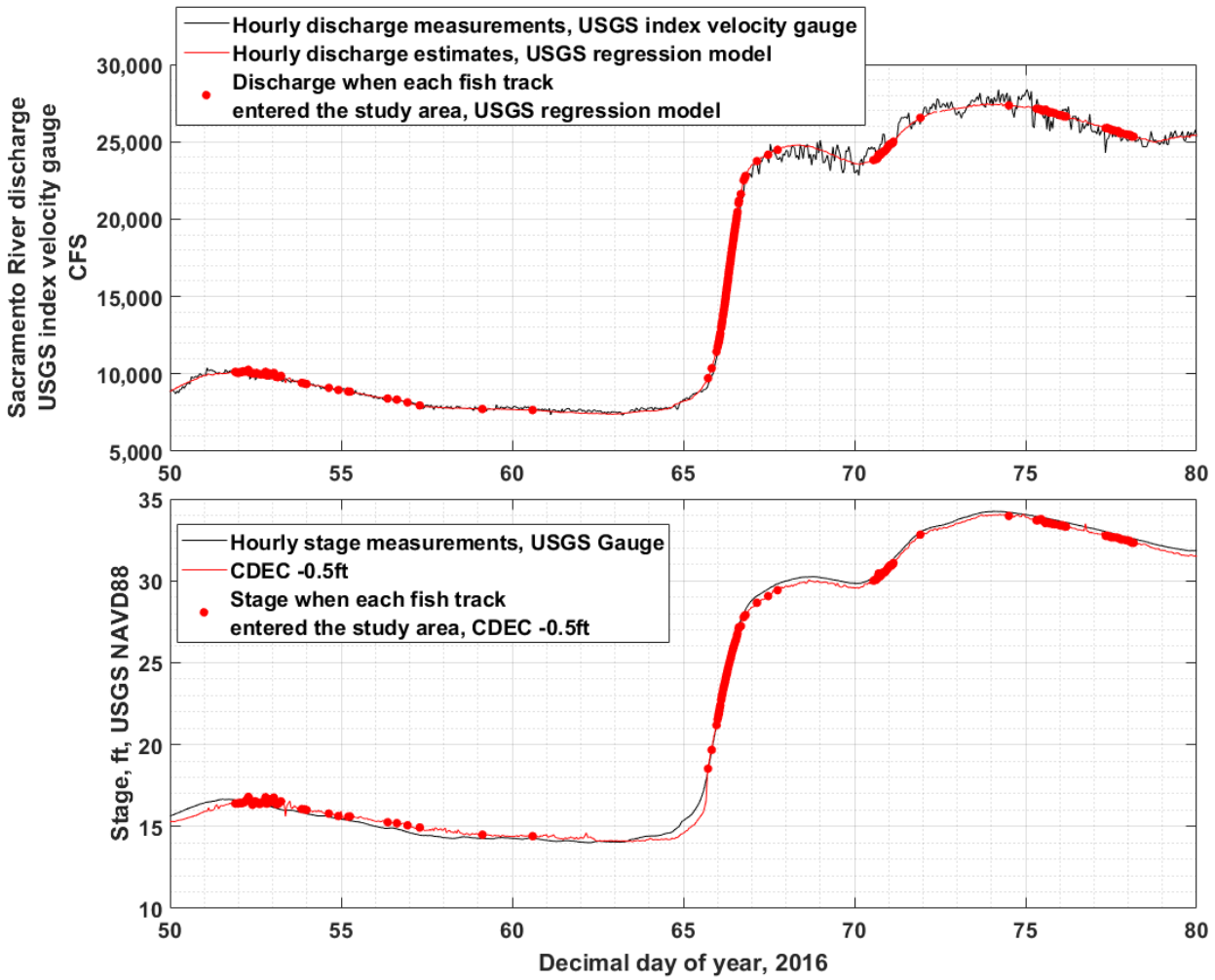


Figure 5 - Plot showing Sacramento River discharge and Sacramento River stage during the time period that 2016 acoustic tag tracks were collected

The top panel shows a time series of Sacramento River discharge measurements and discharge estimates when 2016 acoustic tag tracks were collected, the bottom panel shows time series of Sacramento River stage measurements during time periods when 2016 acoustic tag tracks were collected. Note the rapid rise in stage and discharge following day 65.

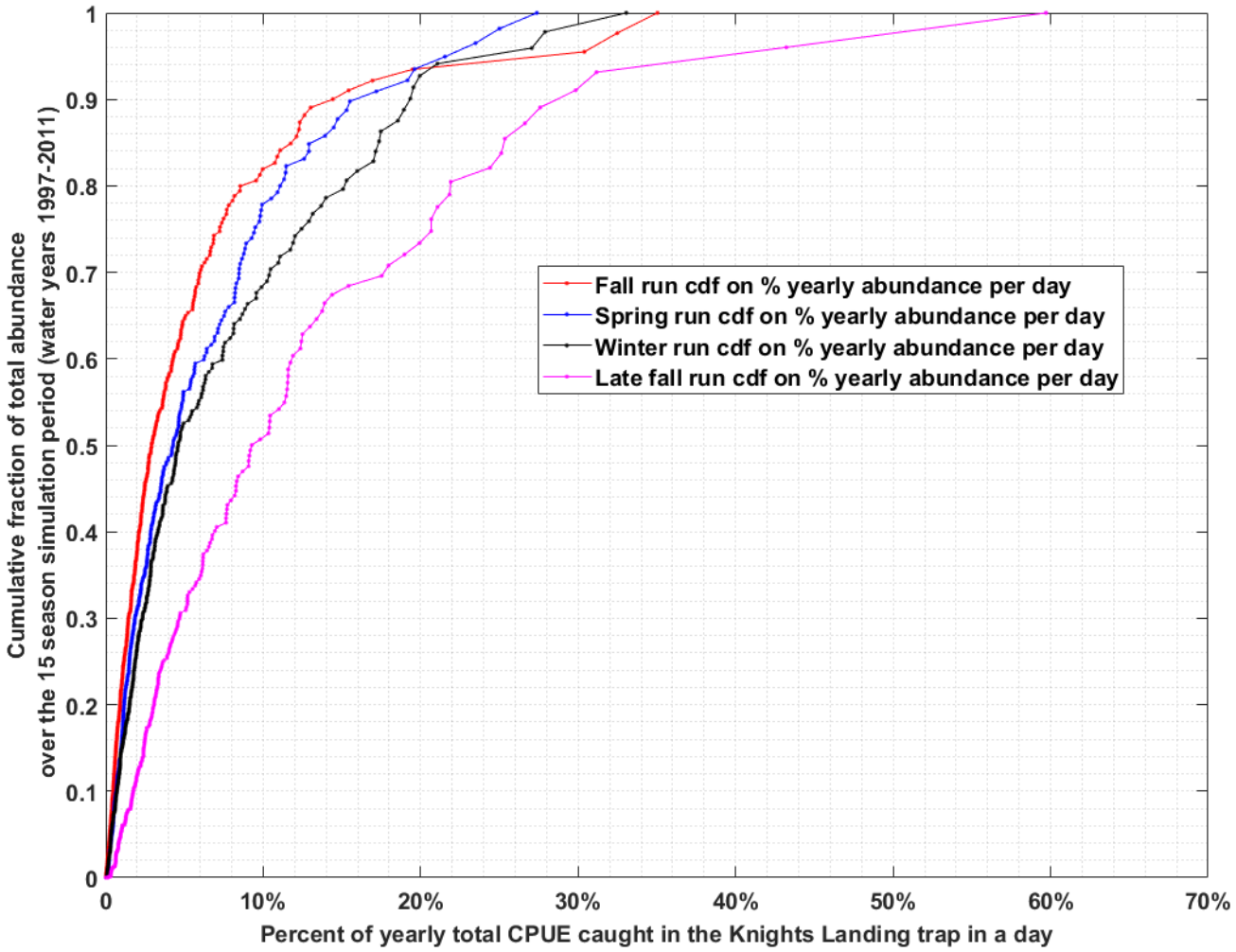


Figure 6 - Plot showing cumulative distribution functions for the daily percentage of yearly catch per unit effort over the 15 year simulation period

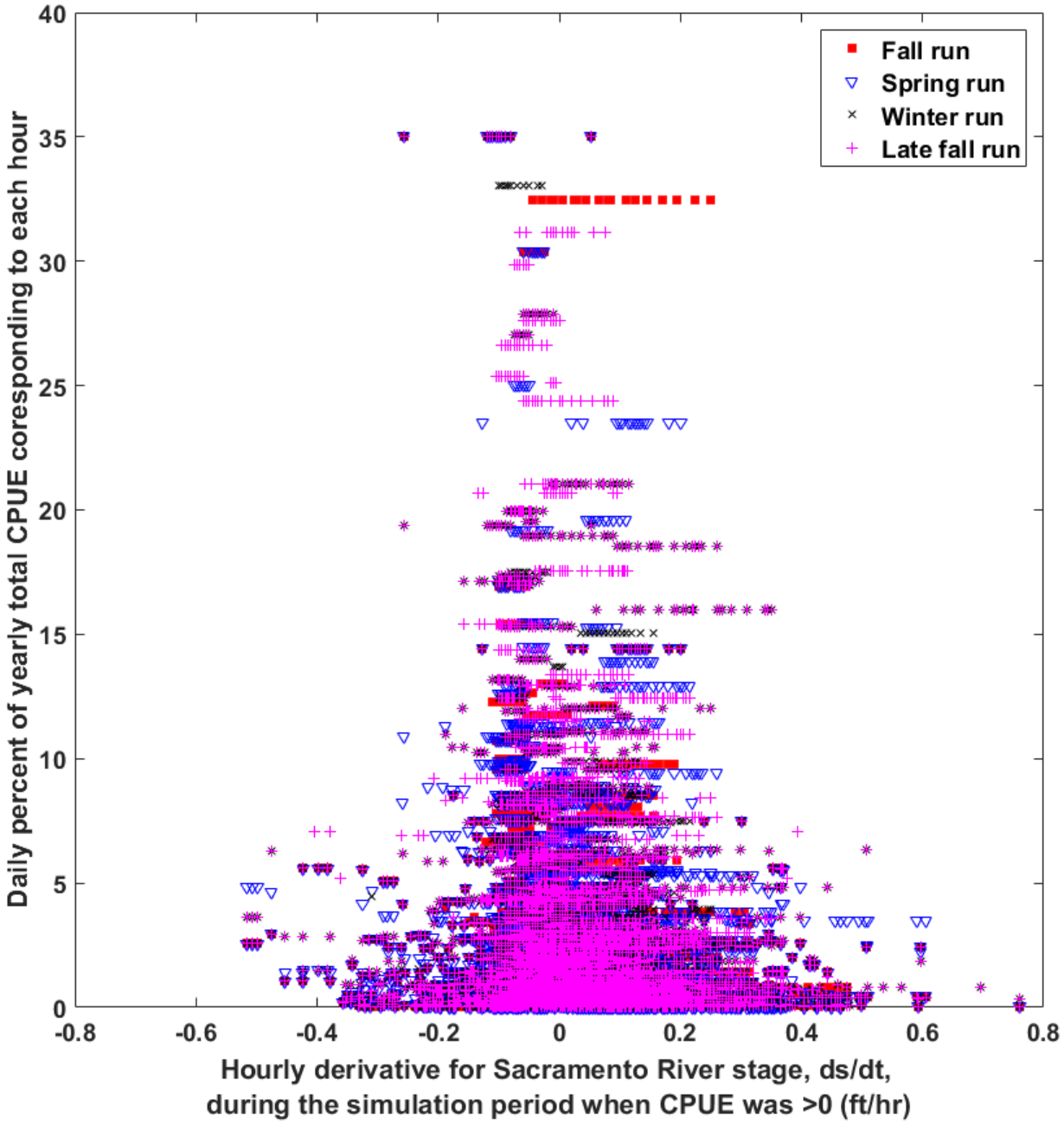


Figure 7 - Plot showing the hourly derivative for Sacramento River stage during the simulation period when Knights Landing catch was greater than zero during the operational window

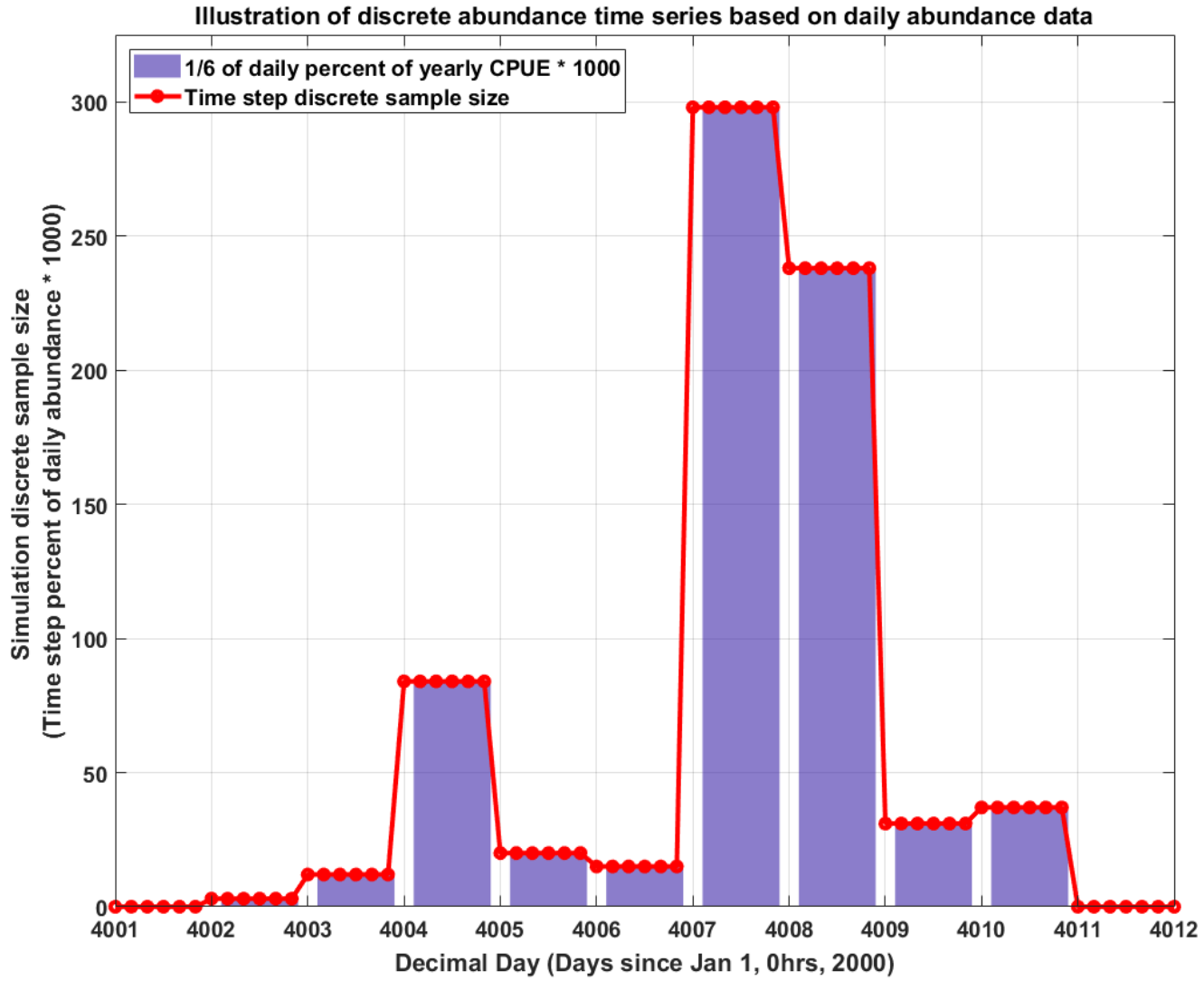


Figure 8 - Plot showing how the daily percent yearly CPUE data was converted into discrete sample sizes for each time step

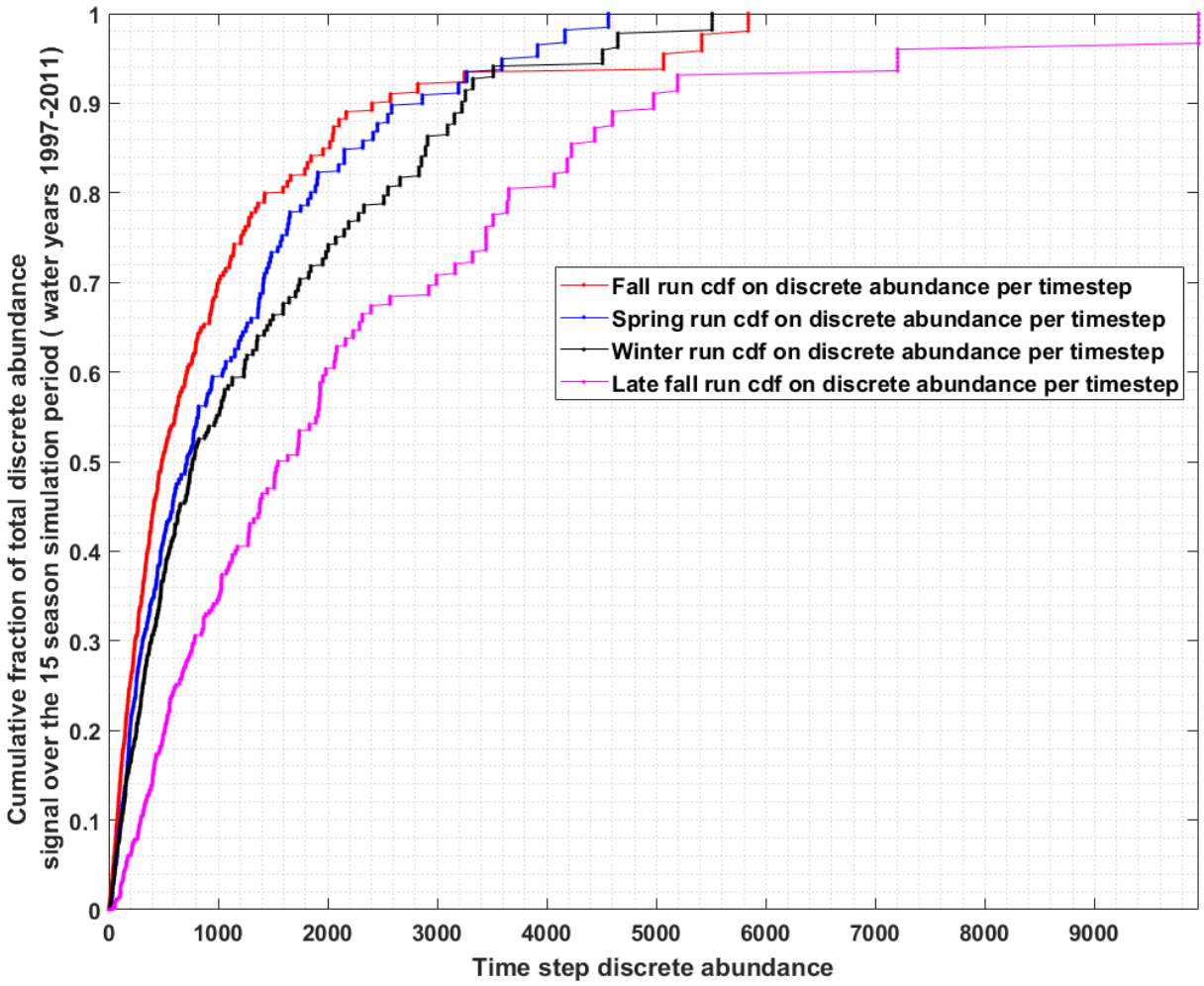


Figure 9 - Plot showing cumulative distribution functions on time step discrete sample size for each run

The lines for each run indicate the fraction of times steps within the 15 water year simulation period that had time steps less than or equal to the sample sizes shown on the x axis.

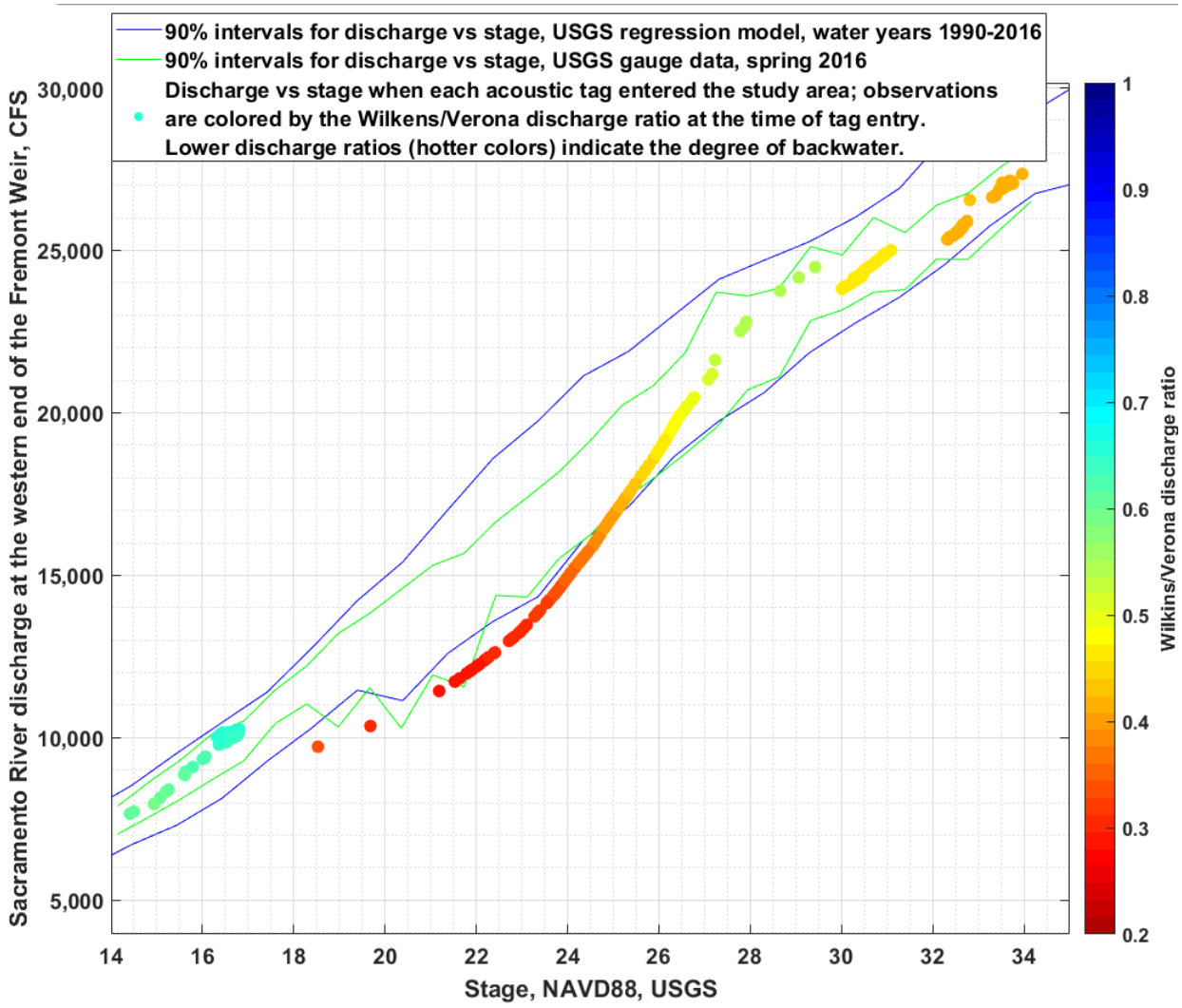


Figure 10 - Plot showing the range of stage and discharge conditions associated with each of the 2016 acoustic tag tracks

The colored lines indicate the 5th and 95th percentiles for discharge vs stage for USGS discharge estimates. The colored dots indicate the stage and discharge value at the time when each acoustic tag entered the study area; the color of the dots indicates the severity of the backwater conditions when each tag entered the study area. Hotter colors indicate more extreme backwater conditions (lower discharge for a given stage).

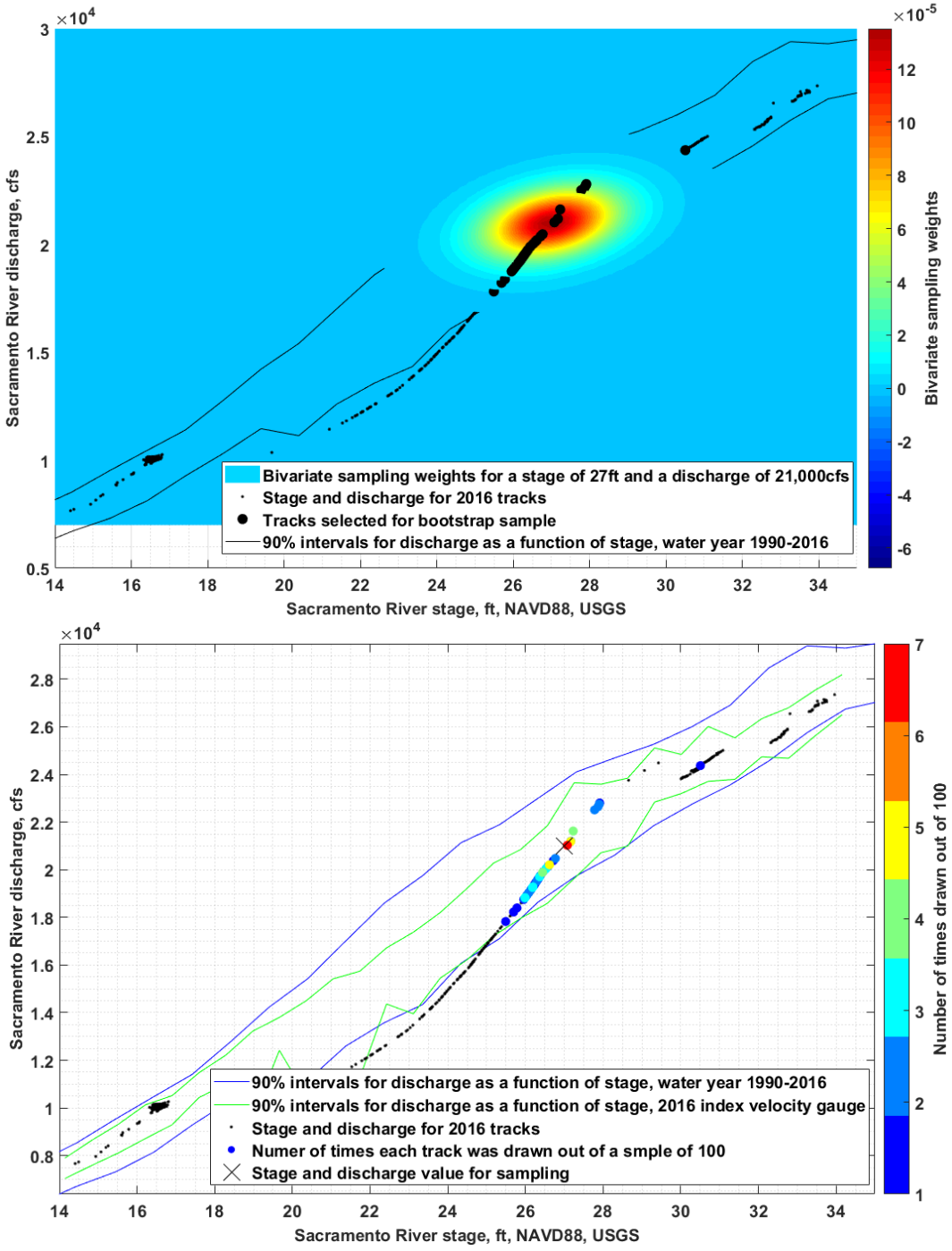


Figure 11 - Plots illustrating the bivariate weighting and the resulting bootstrap sampling for a stage of 27 ft and a discharge of 21,000cfs

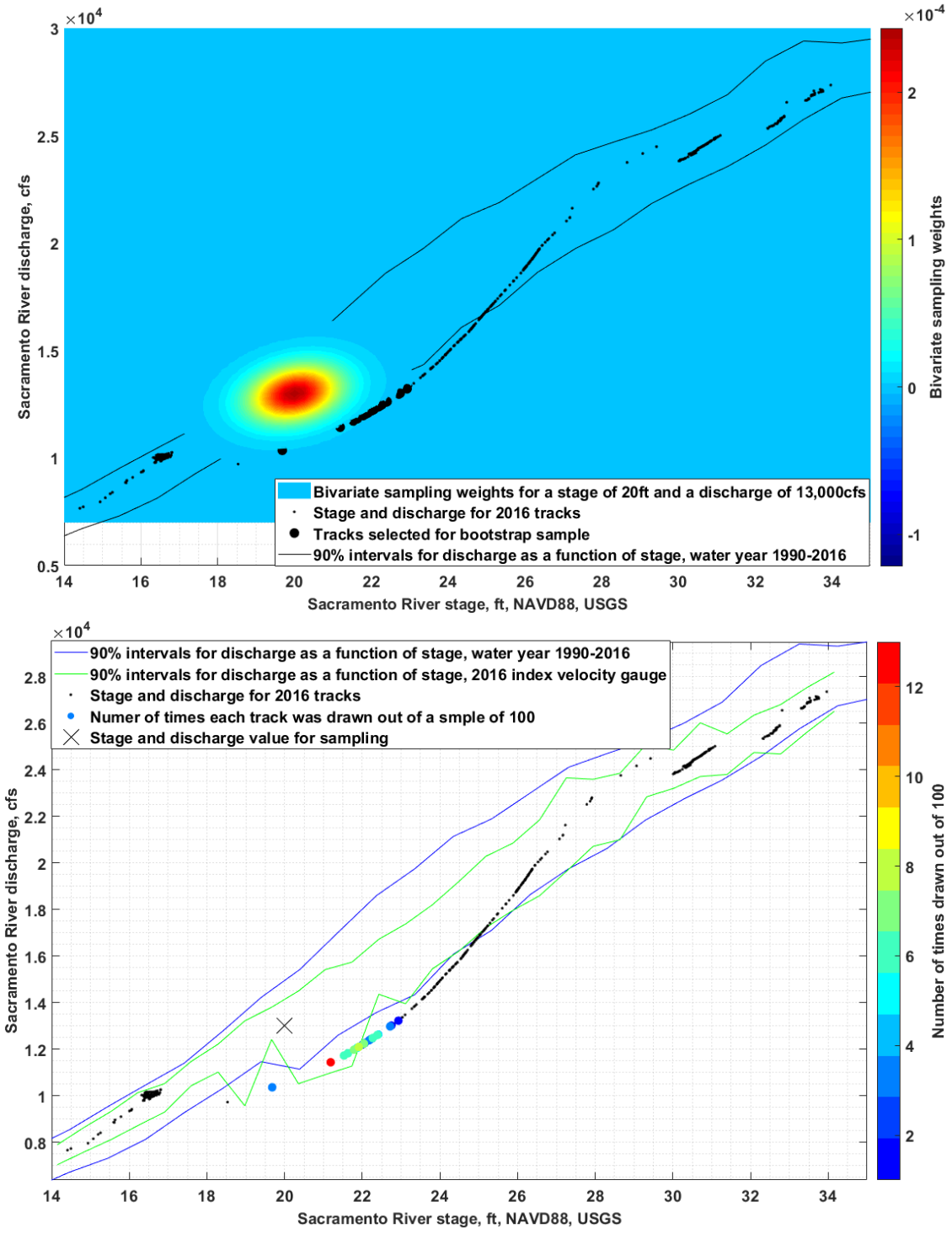


Figure 12 - Plots illustrating the bivariate weighting and the resulting bootstrap sampling for a stage of 20ft and a discharge of 13,000cfs

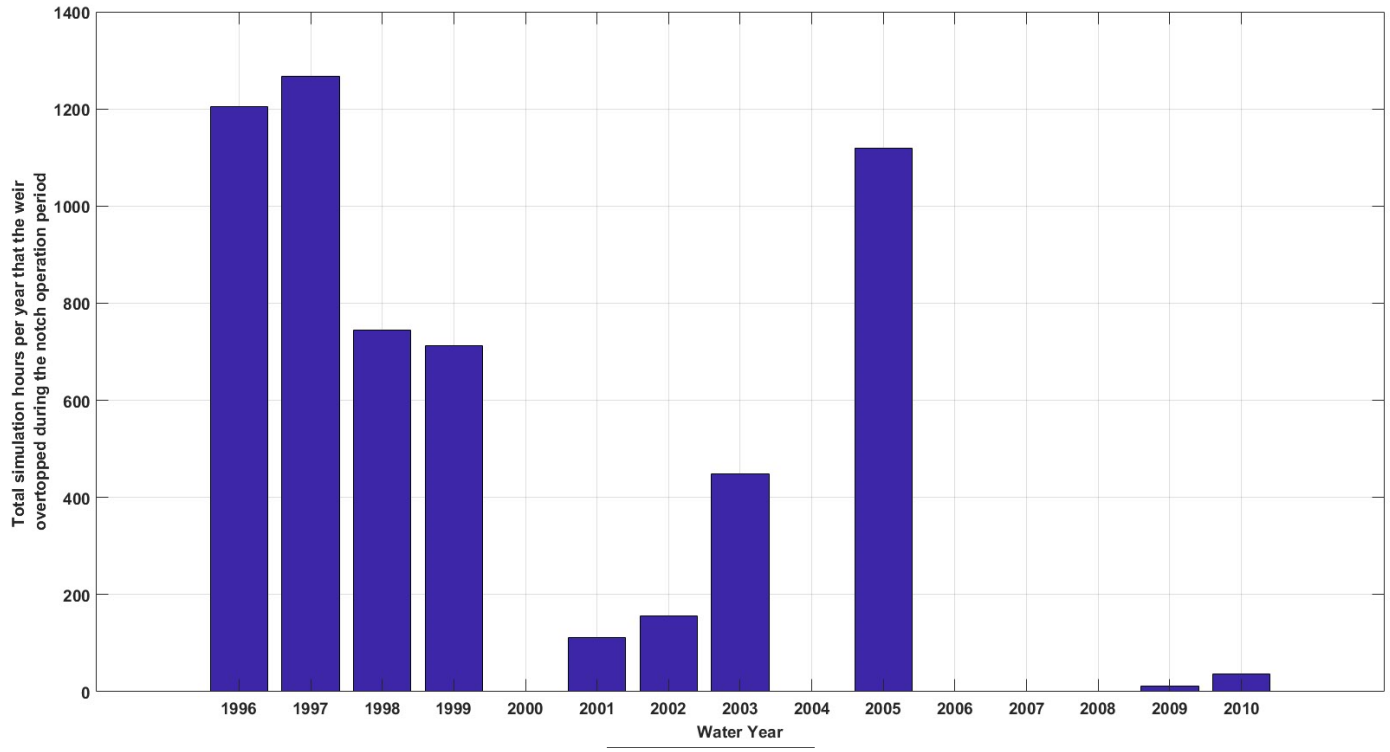


Figure 13 - Number of hours per year that the weir overtopped during the notch operation period

The blue bars indicate the number of hours per season that the weir overtopped during the notch operation period (October 1 - March 15). Missing bars indicate water years when the weir did not overtop during the simulation. For the purposes of the simulation over13 is defined as periods when Sacramento River stage is greater than 32.3 ft, NAVD88, USGS. For the purposes of this plot season years indicated by the year the operation period began.

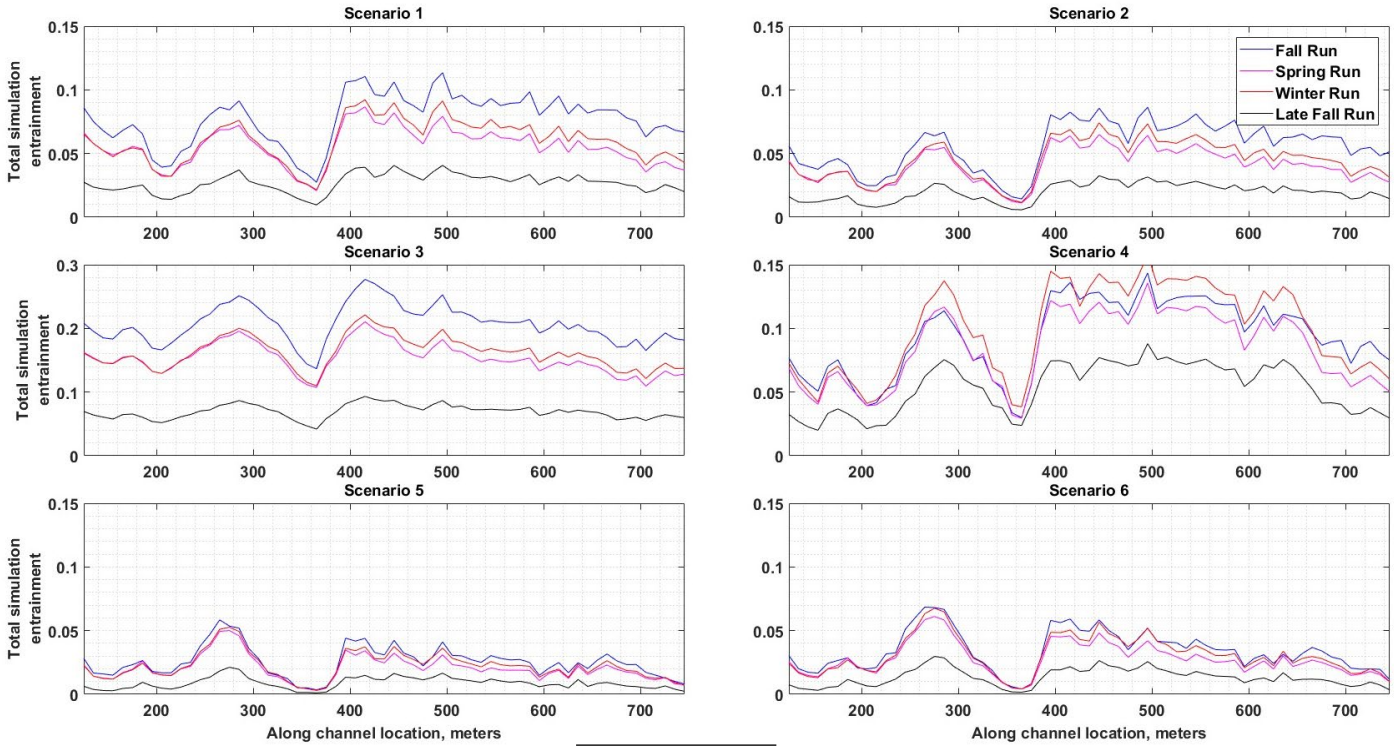


Figure 14 - Total entrainment as a function of notch location for each scenario

Each panel shows the total entrainment for each scenario at each location in the study area, by run. Total simulation entrainment is expressed as the fraction of the total yearly abundance for the entire simulation period entrained in each scenario location. The blue, pink, orange, and black lines indicate the total entrainment for fall run, spring run, winter run, and late fall run, respectively. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data. Also note that the range of the y axis is greater in panel 3 due to the large notch flows for scenario 3.

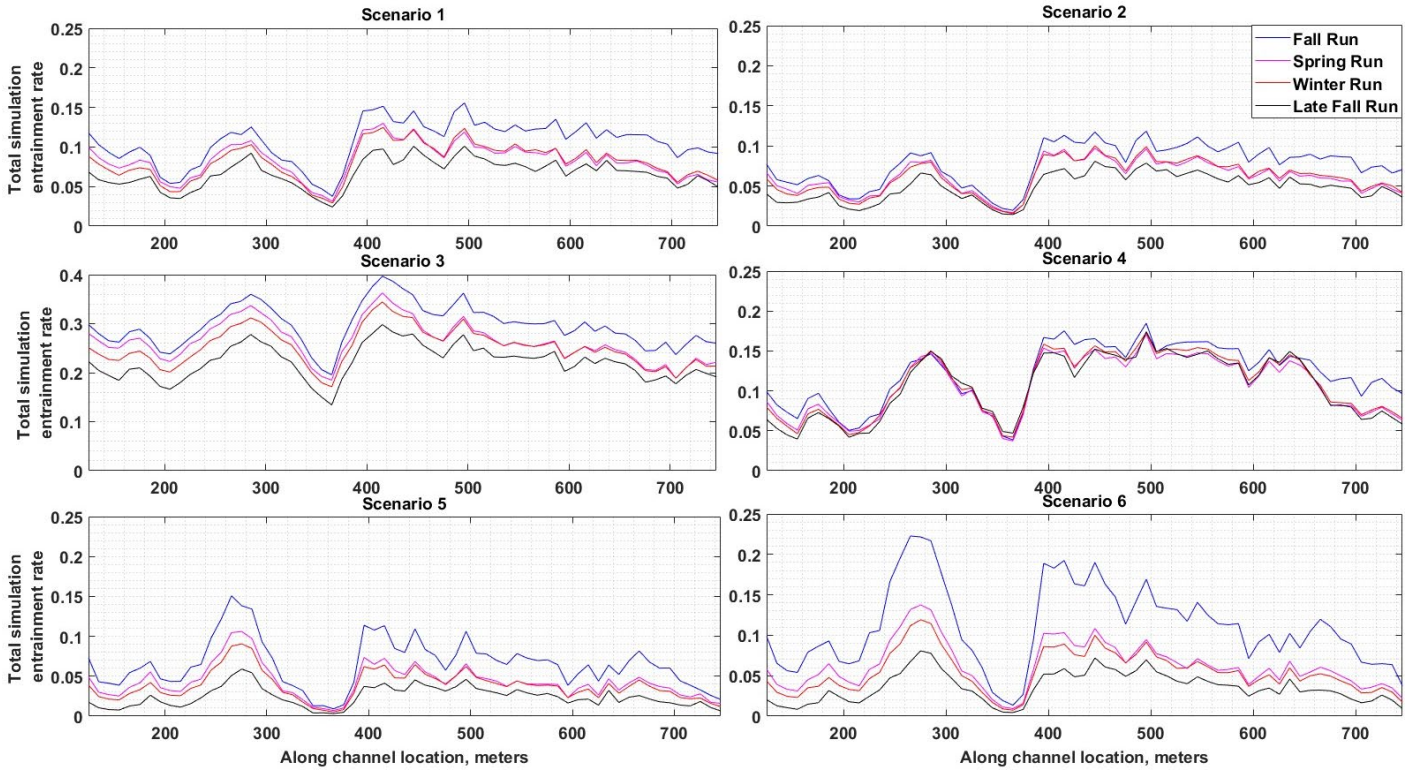


Figure 15 - Total entrainment rate as a function of notch location for each scenario

Each panel shows the total entrainment for each scenario at each location in the study area, by run. Total simulation entrainment rate is expressed as the fraction of fish passing the notch when notch flow was greater than zero entrained for each scenario. The blue, pink, orange, and black lines indicate the total entrainment rate for fall run, spring run, winter run, and late fall run, respectively. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment rate are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data. Also note that the range of the y axis is greater in panel 3 due to the large notch flows for scenario 3.

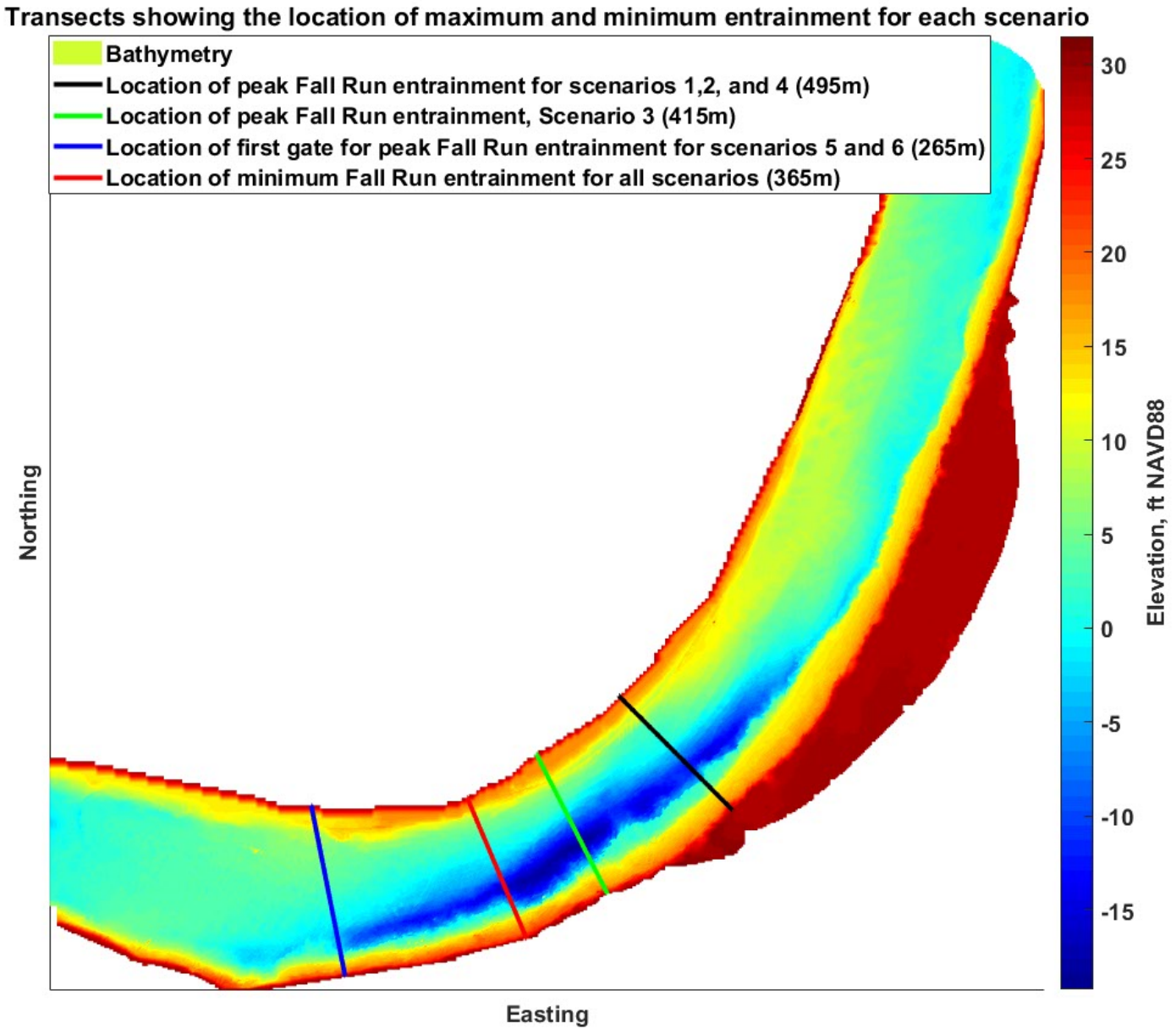


Figure 16 - Figure showing the location of maximum and minimum entrainment for fall run for all scenarios overlaid on the study area bathymetry model used for the entrainment simulation

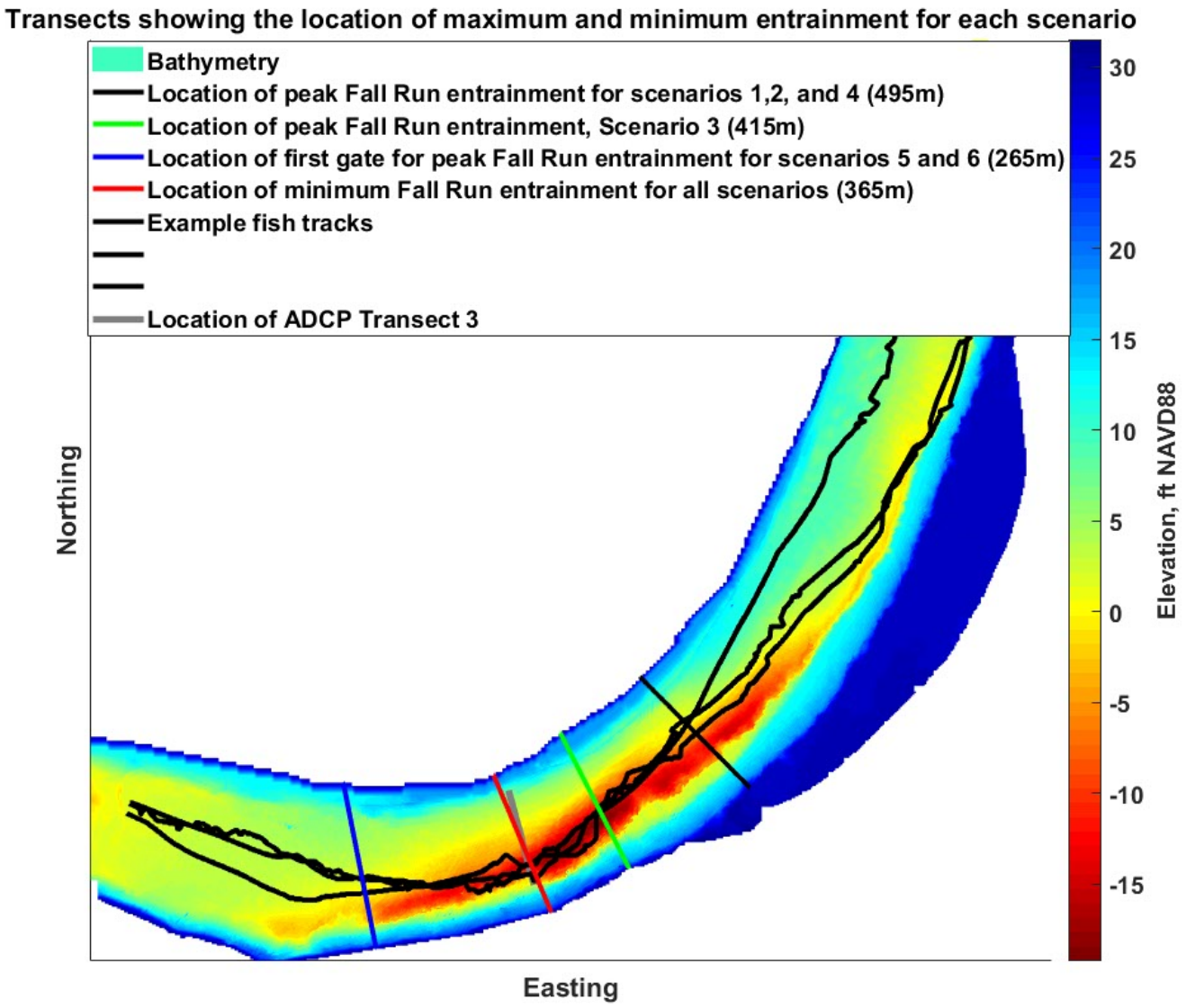


Figure 17 - Plan view of study area showing the location of minimum and maximum entrainment along with example fish tracks.

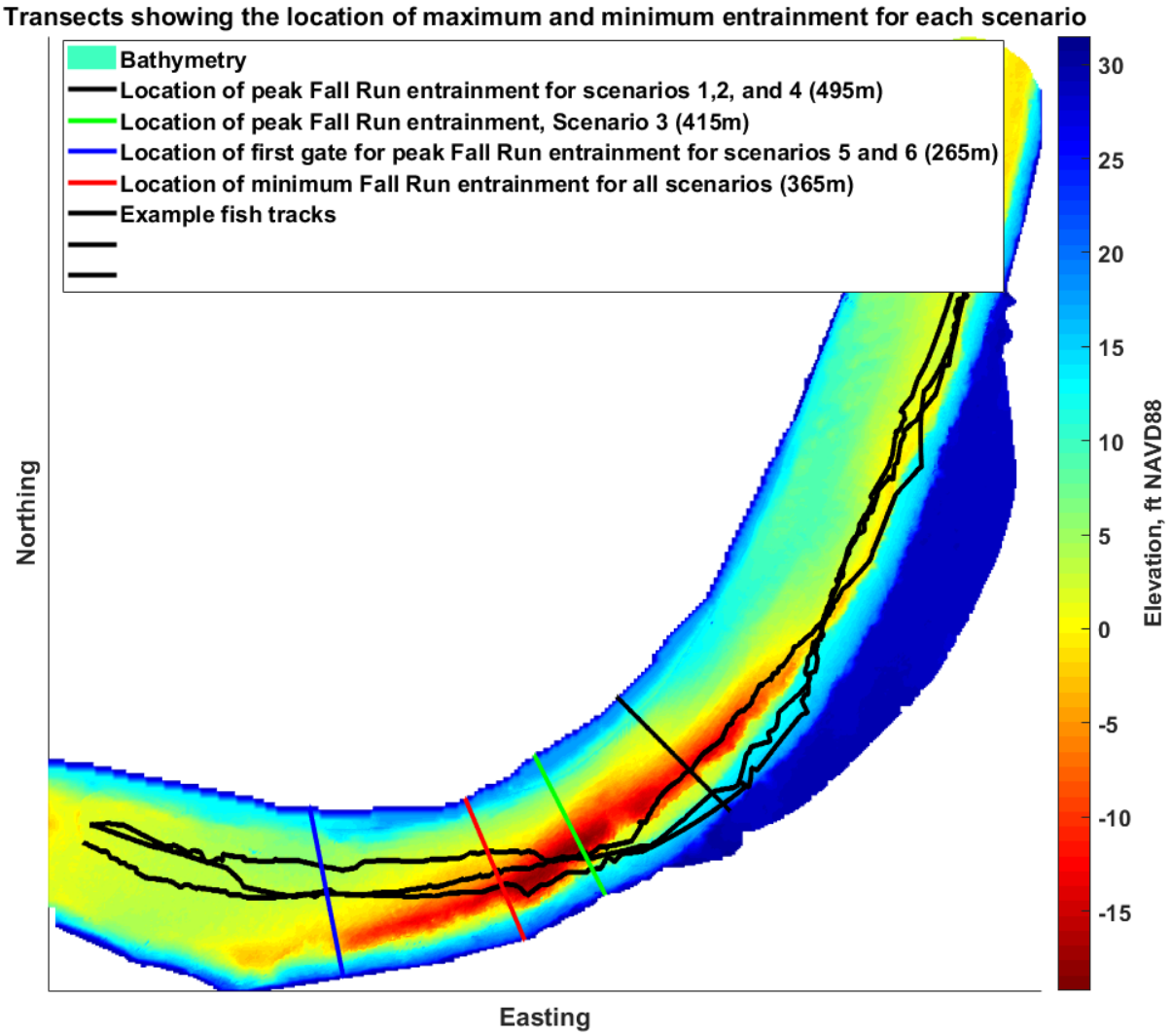


Figure 18 - Plan view of study area showing the location of minimum and maximum entrainment along with example fish tracks

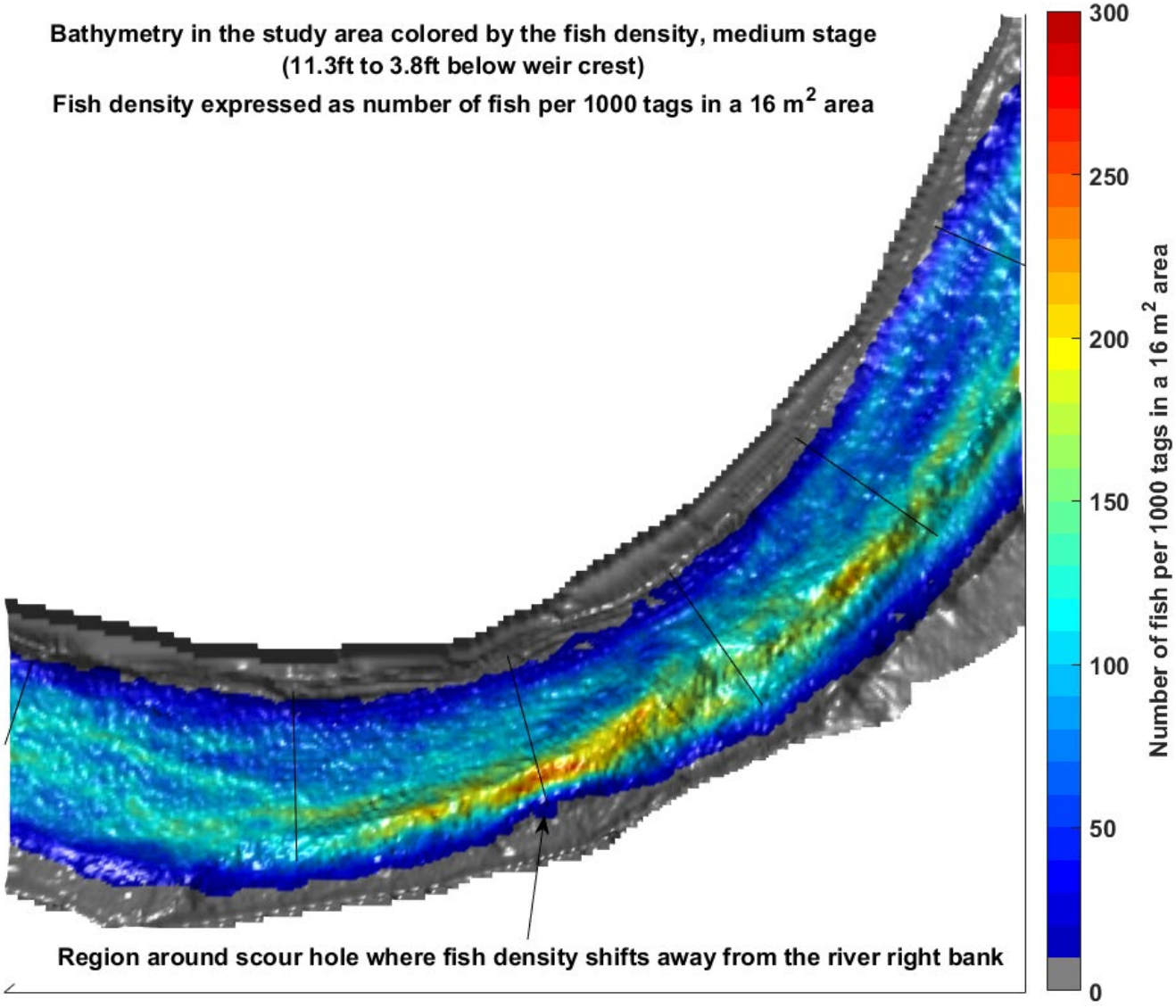


Figure 19 - Plan view of the study area bathymetry colored by fish density

Plan view of a surface representing the study area bathymetry, colored by the spatial density of 2016 fish tracks during medium stage periods. Gray areas on the bathymetry indicate areas where there were no fish tracks. The black arrow indicates the region in the vicinity of along-channel coordinate 370 where fish density near the bank decreases in the vicinity of a scoured section in the levy. Note that in the area around the black arrow the cross-stream gradients in fish density are stronger, and the area where the density colormap transitions from blue (low density) to green (moderate density) shifts towards the center of the channel.

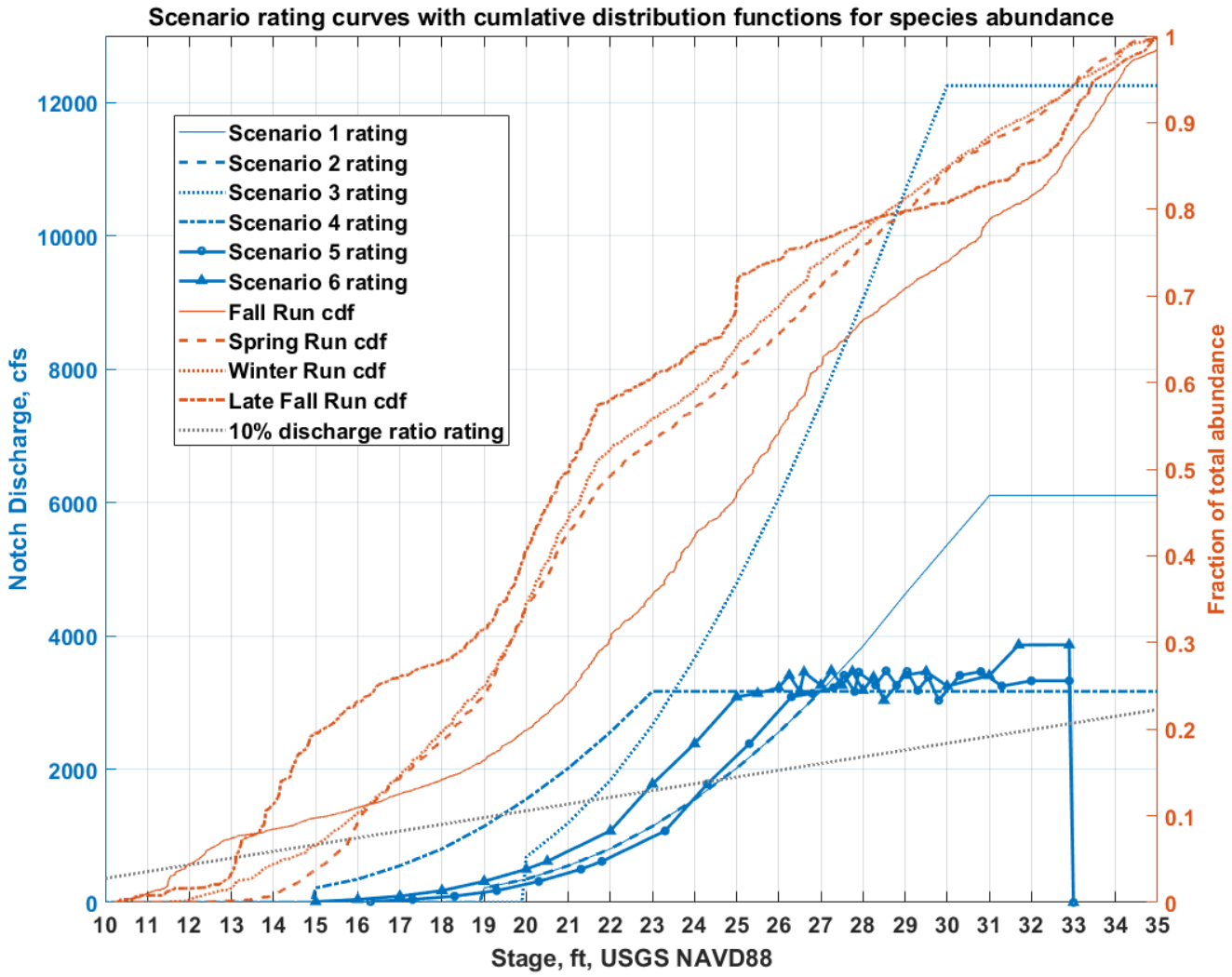


Figure 20 - Stage-discharge curves for each scenario and run abundance cdfs on stage

Stage discharge curves for each scenario are shown in blue, with scenario discharge shown on the left (blue) yaxis. The stage-discharge curves for multi-gate scenarios indicate the total flow through all gates in the scenario at each stage. The rating curves for scenario 1 and scenario 2 overlap for stages below 27'. Cumulative distribution functions for the simulation period showing cumulative run abundance as a function of stage are shown in red, with the cumulative fraction of total abundance shown on the right (red) yaxis. Note the rapid increase in cumulative abundance between 19' and 22' for winter run and spring run. The dotted gray line indicates the amount of notch flow that corresponds to 10% of the Sacramento River stage-discharge rating from the 2016 USGS gauge data. The location of each scenario's rating curve relative to the 10% discharge ratio line is an indicator of the fraction of the Sacramento River flow that is passing through the notch at any stage: if the a rating curve is above the grey line at any stage the notch is likely entraining more than 10% of the sacramento river at that stage.

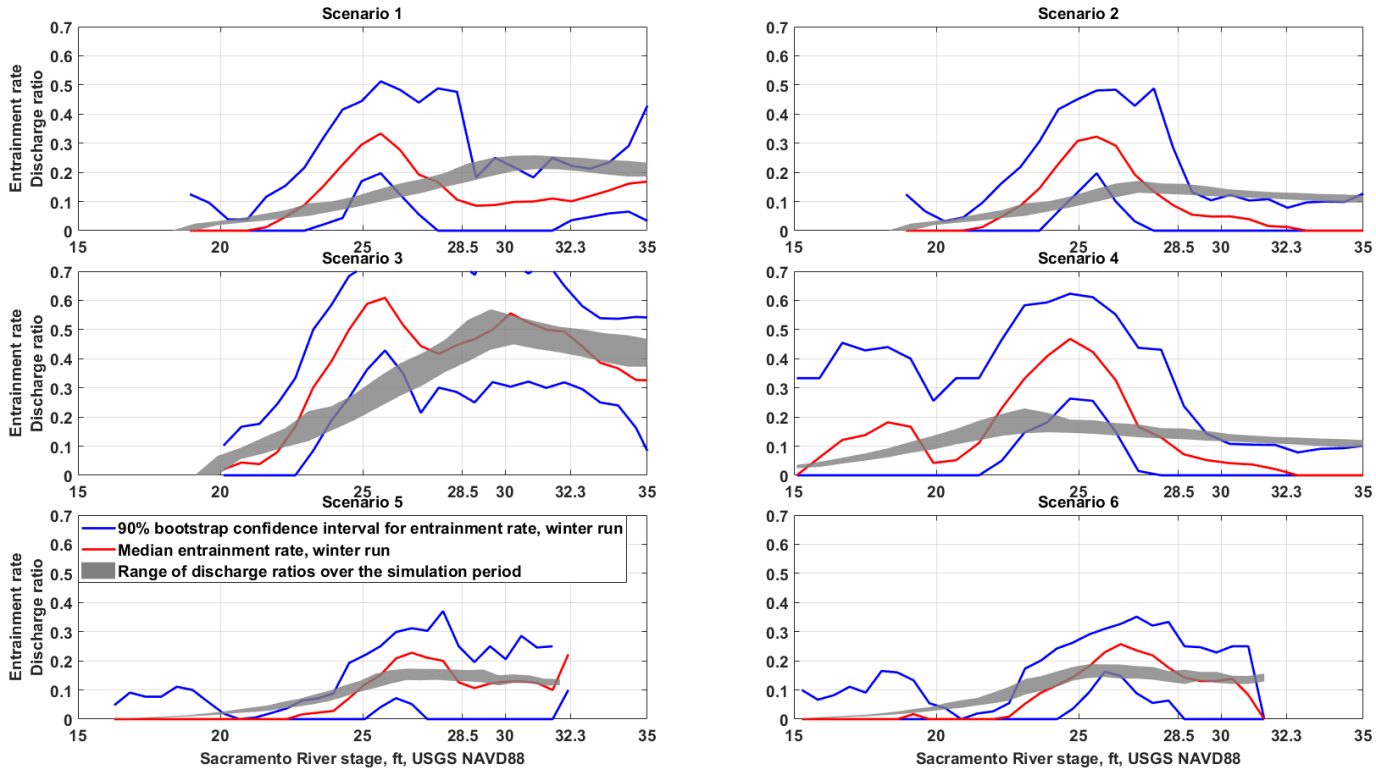


Figure 21 - Entrainment rate and discharge ratio for each scenario as a function of Sacramento River stage.

Panels 1-6 show entrainment rate and discharge ratio as a function of stage for scenarios 1-6, respectively. For each scenario the blue lines indicate the 90% bootstrap confidence interval for entrainment rate at each stage, the red line indicates the bootstrap median entrainment rate for each stage, and the gray region indicates the range of discharge ratios each scenario experienced during the simulation period. The notch discharge ratio indicates the fraction of Sacramento River discharge flowing into each scenario at each stage; because of backwater effects there are a range of possible discharge ratios for each stage, as indicated by the vertical range of the gray band at each stage. When the entrainment rate is greater than the discharge ratio the notch is entraining proportionally more fish than water. Note that the Sacramento River reaches a bankfull state in the study area at a stage value of around 28.5', and the weir overtops at a stage value of 32.3'.

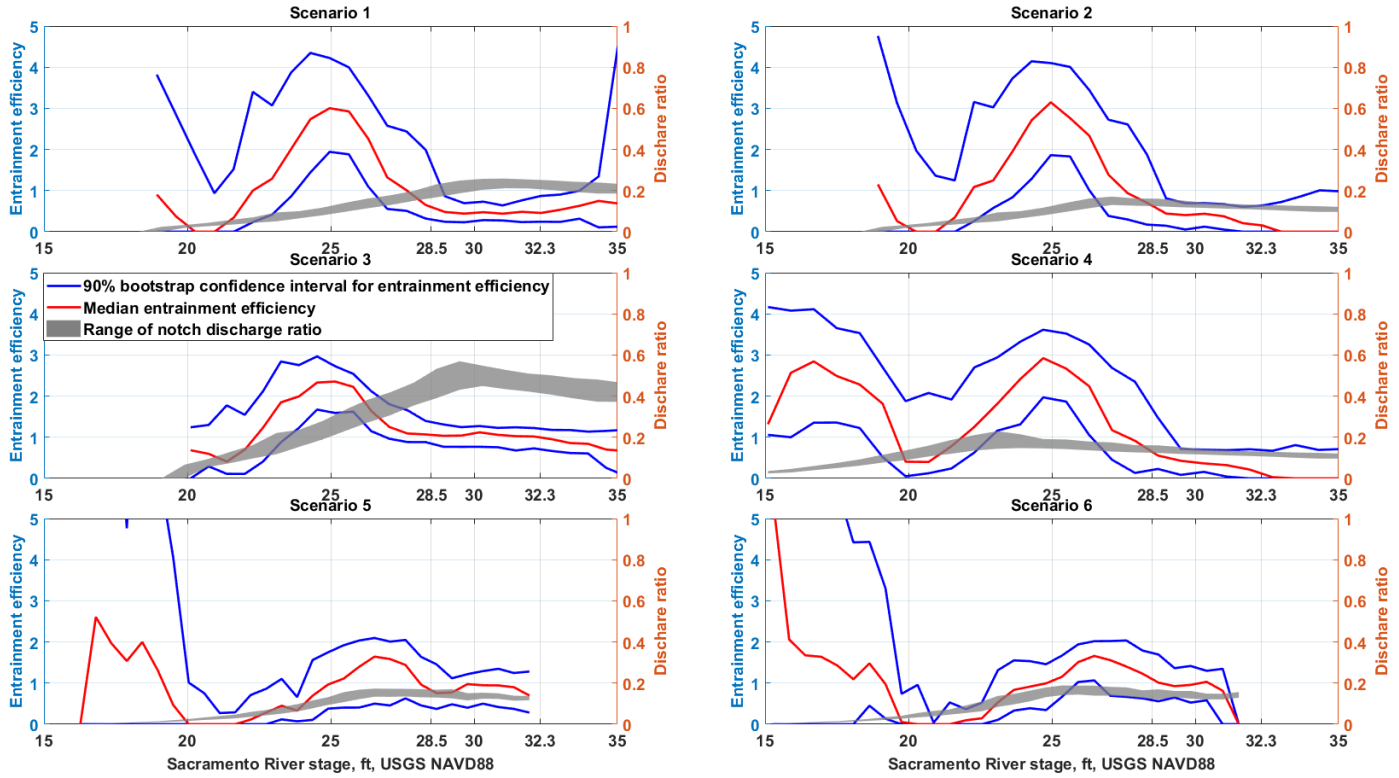


Figure 22 - Entrainment efficiency and discharge ratio for each scenario as a function of Sacramento River stage, with small sample sizes removed

Panels 1-6 show entrainment efficiency and discharge ratio as a function of stage for scenarios 1-6, respectively, for days when more than 0.5% of the yearly total abundance transited the study area. Removing time steps from days when less than 0.5% of the yearly total abundance transited the study area removed 10% of the time step entrainment data from the fall run entrainment estimates used to produce these curves. The yaxis on the left of each panel (blue) indicates the scale for the entrainment efficiency. The yaxis on the right of each panel (red) indicates the scale for the discharge ratio. For each scenario the blue lines indicate the 90% bootstrap confidence interval for entrainment efficiency for each stage, the red line indicates the bootstrap median entrainment efficiency for each stage, and the gray region indicates the range of discharge ratios each scenario experienced during the simulation period. The notch discharge ratio indicates the fraction of Sacramento River discharge flowing into each scenario at each stage; because of backwater effects there are a range of possible discharge ratios for each stage, as indicated by the vertical range of the gray band. When the entrainment efficiency is greater than one the notch is entraining proportionally more fish than water. Note that the Sacramento River reaches a bankfull state in the study area at a stage value of around 28.5', and the weir overtops at a stage value of 32.3'.

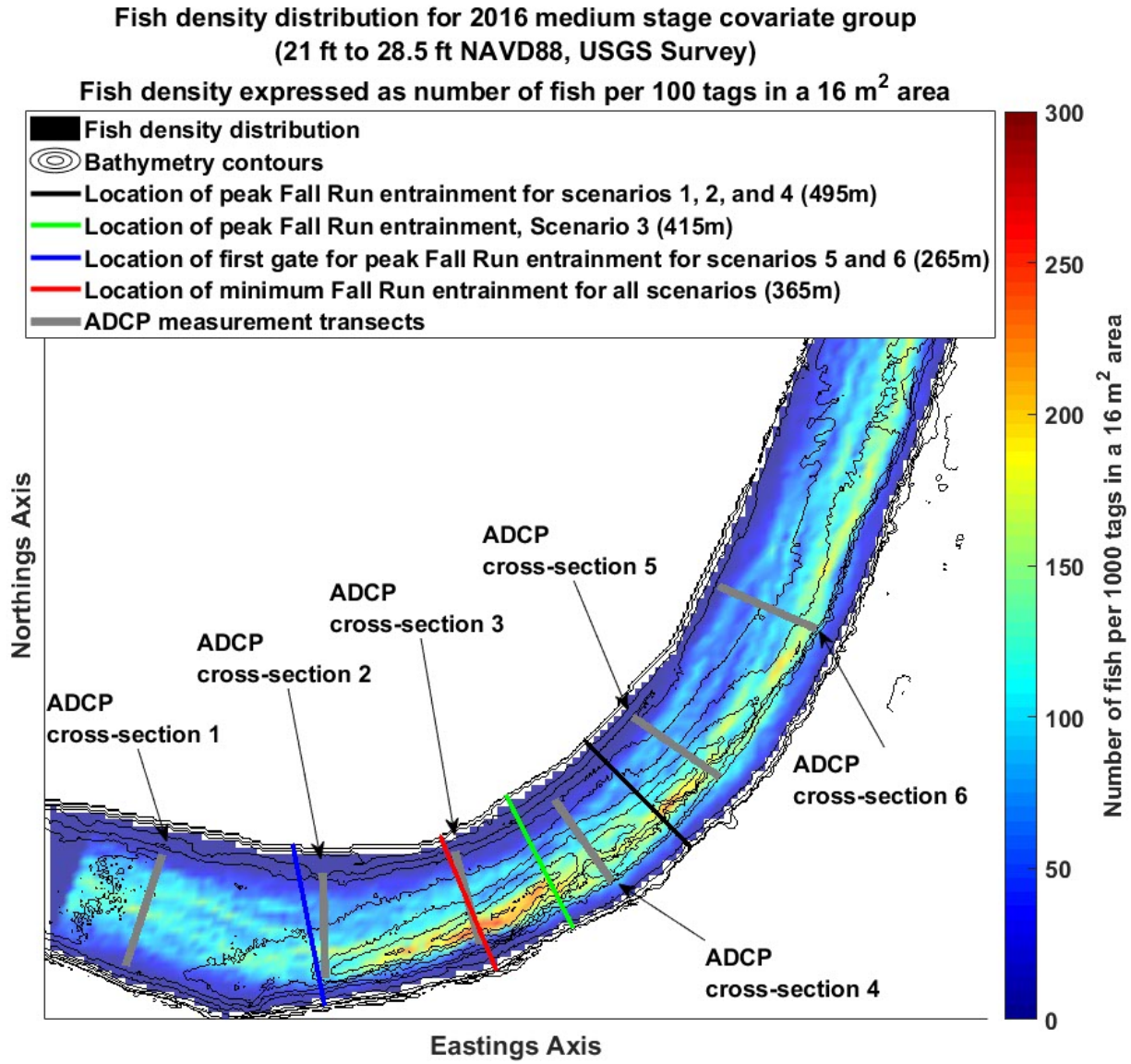


Figure 23 - Figure showing the location of maximum and minimum entrainment for fall run for all scenarios overlaid on fish density distribution

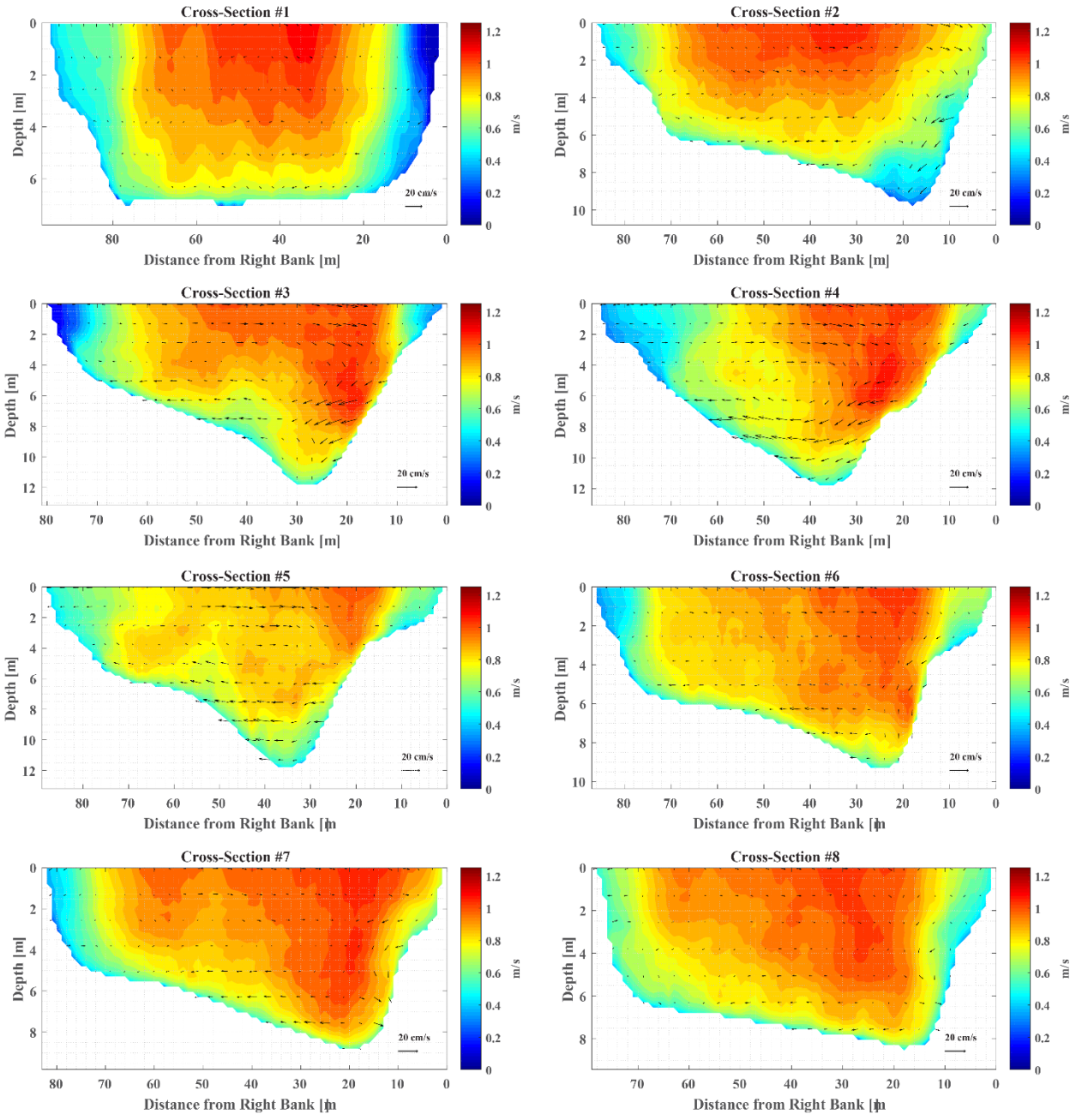


Figure 24 - Figure from cross-channel velocity transect data collected during 2016.

Contour plot showing along-stream velocity magnitude and arrows indicating secondary velocity currents for each velocity cross-sections (1-8) at a stage of 24.2 ft. and discharge of 15,930 cfs. Taken from Stumpner et al., In Review.

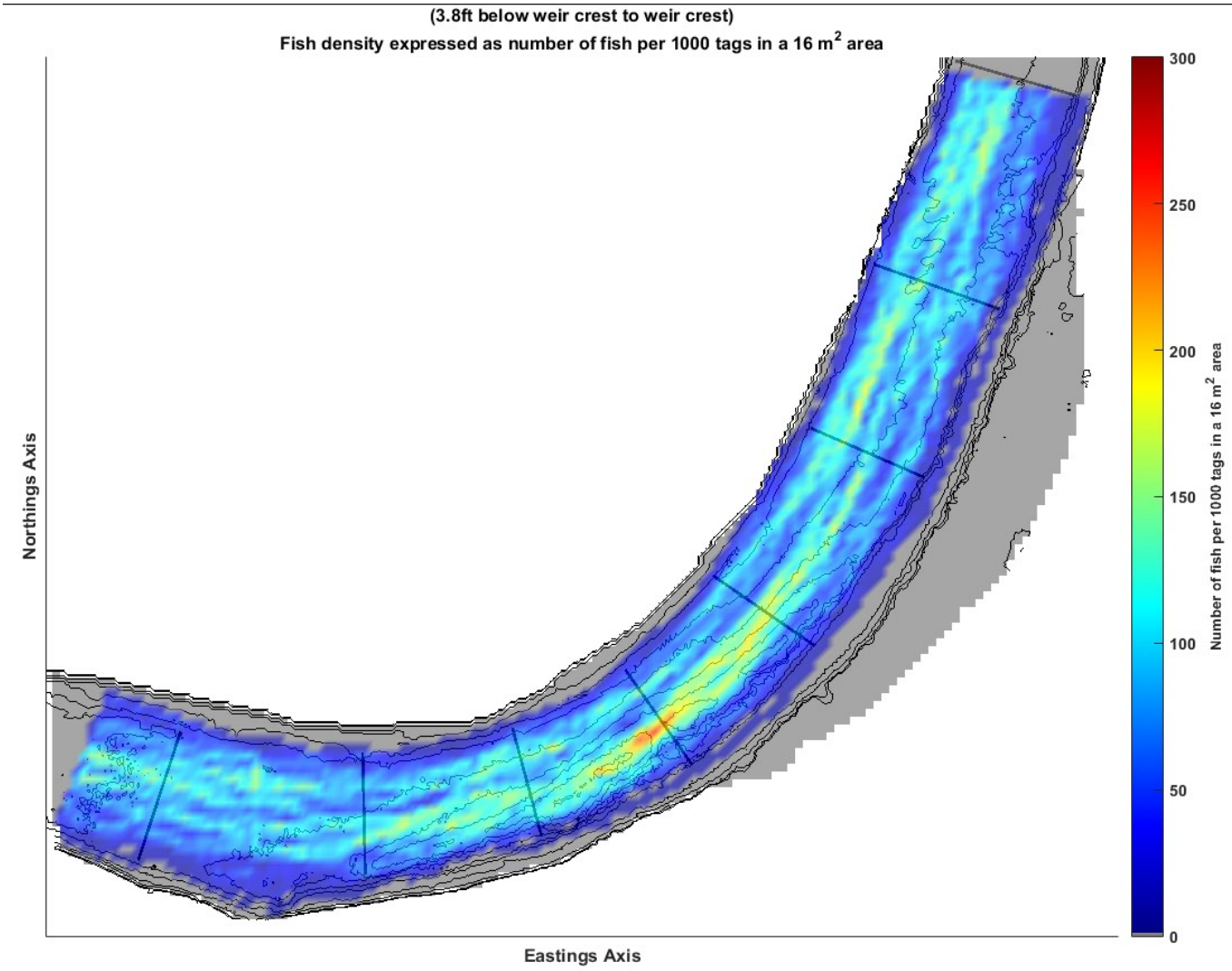


Figure 25 - Spatial distribution of 2016 study fish tracks for periods when Sacramento River was greater than bankfull and below the weir crest

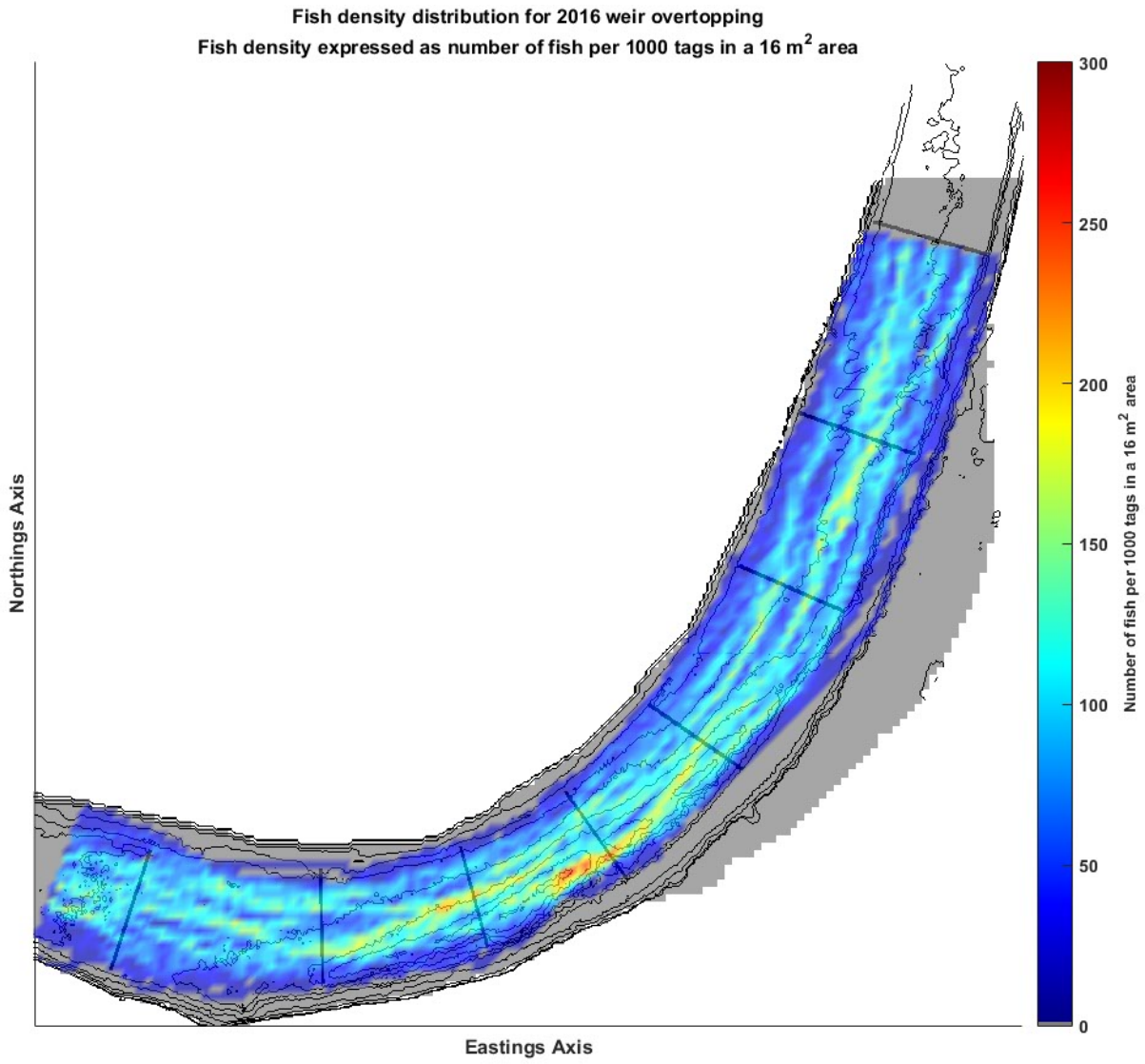


Figure 26 - Spatial distribution of 2016 study fish tracks for periods when the fremont weir was overtopping

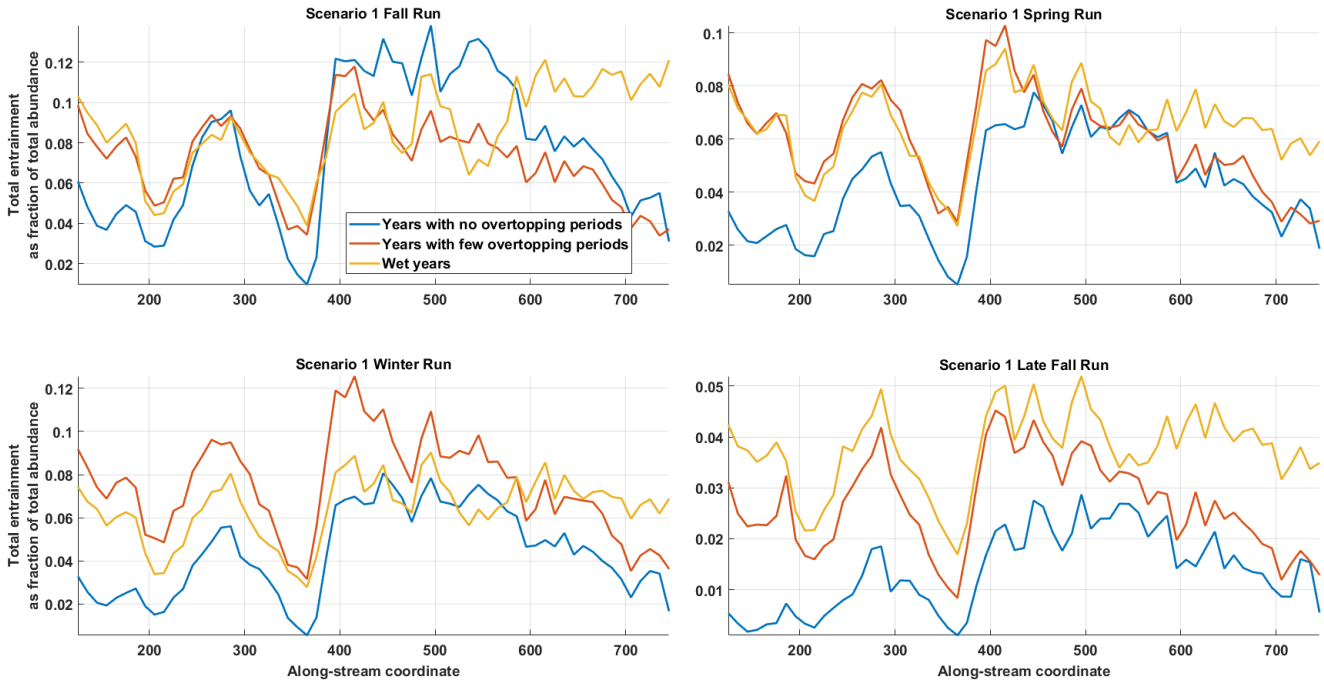


Figure 27- Scenario 1 water year type total entrainment curves

Plots showing total entrainment for each run as a function of notch along-channel location within the study area calculated for three water year types for scenario 1. The blue lines indicates total entrainment over all seasons when fremont weir did not overtop, the red line indicates total entrainment over all seasons when the fremont weir overtopped for fewer than 200 hours, and the gold line indicates total entrainment over all seasons when the fremont weir overtopped for more than 200 hours (wet years). Each panel shows water year entrainment for a run. For the purposes of the simulation weir overtopping was defined as Sacramento River stage exceeding 32.3' NAVD88, USGS datum. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data.

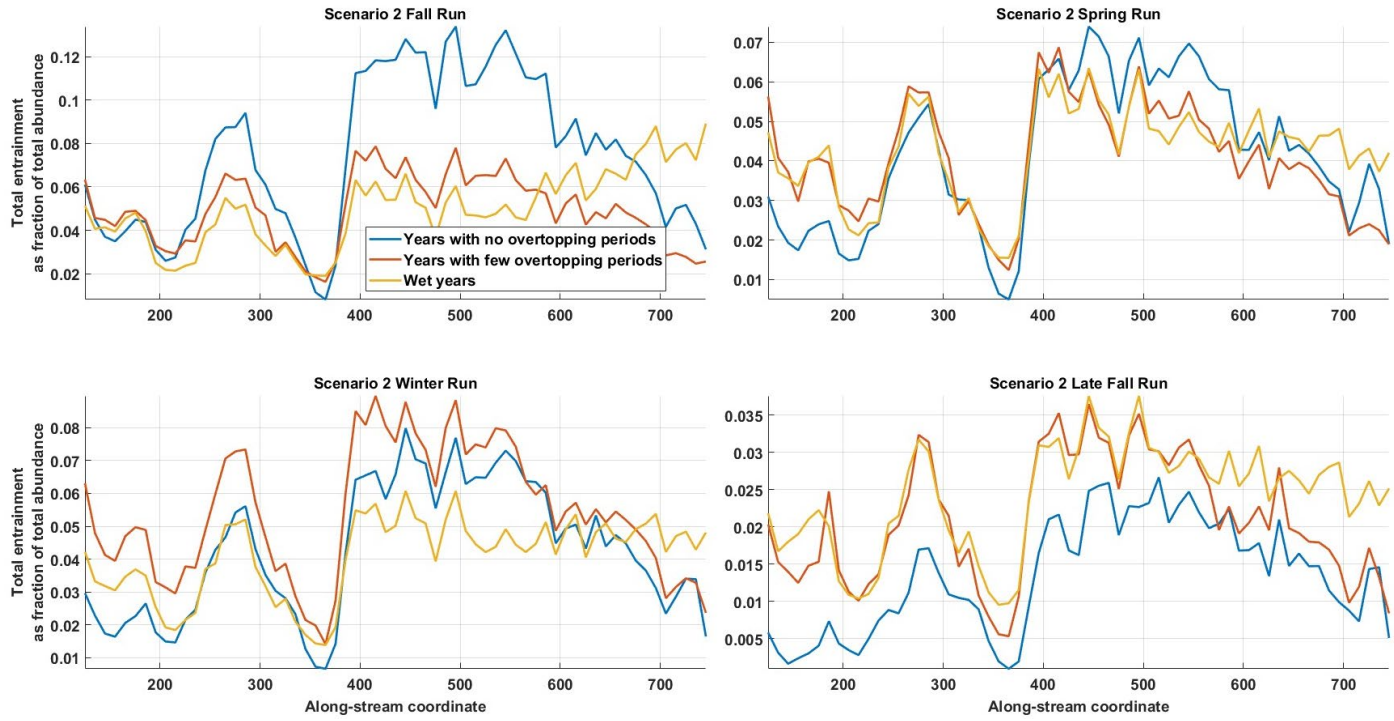


Figure 28- Scenario 2 water year type total entrainment curves

Plots showing total entrainment for each run as a function of notch along-channel location within the study area calculated for three water year types for scenario 2. The blue lines indicates total entrainment over all seasons when fremont weir did not overtop, the red line indicates total entrainment over all seasons when the fremont weir overtopped for fewer than 200 hours, and the gold line indicates total entrainment over all seasons when the fremont weir overtopped for more than 200 hours (wet years). Each panel shows water year entrainment for a run. For the purposes of the simulation weir overtopping was defined as Sacramento River stage exceeding 32.3' NAVD88, USGS datum. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data.

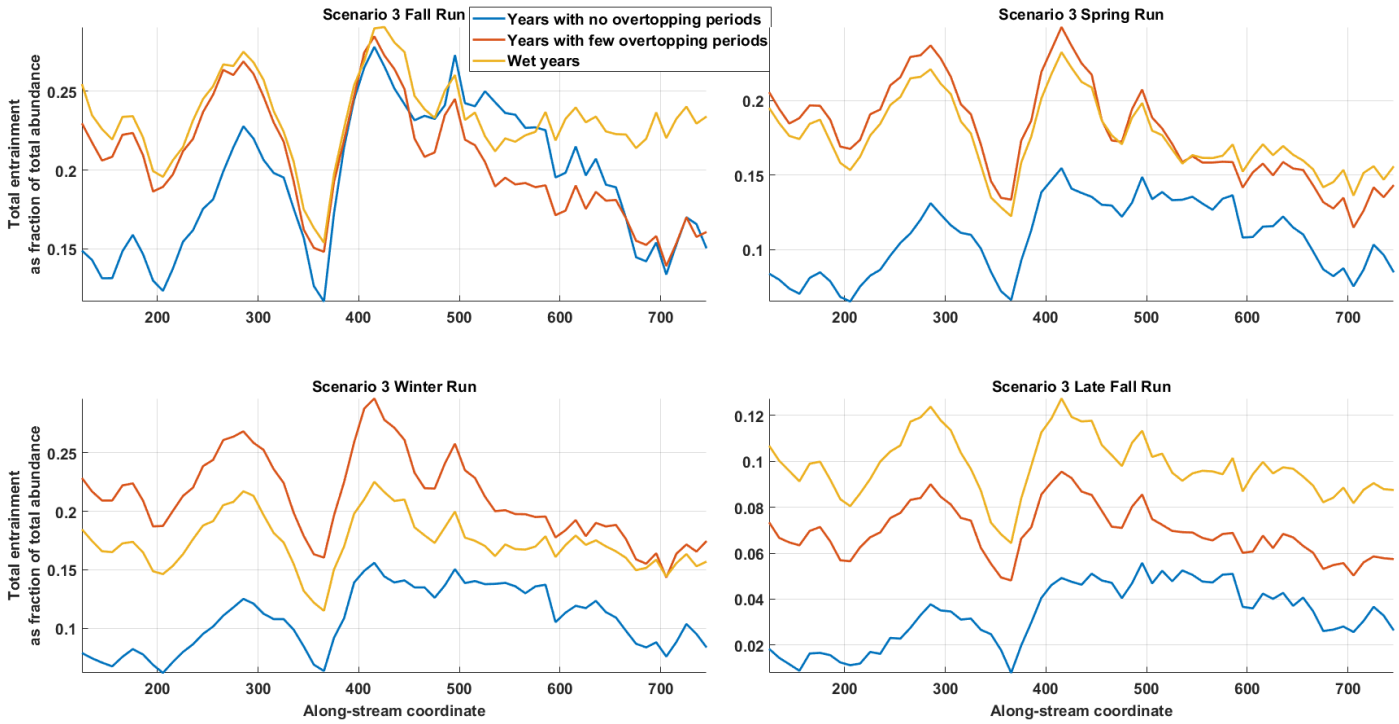


Figure 29- Scenario 3 water year type total entrainment curves

Plots showing total entrainment for each run as a function of notch along-channel location within the study area calculated for three water year types for scenario 3. The blue lines indicates total entrainment over all seasons when fremont weir did not overtop, the red line indicates total entrainment over all seasons when the fremont weir overtopped for fewer than 200 hours, and the gold line indicates total entrainment over all seasons when the fremont weir overtopped for more than 200 hours (wet years). Each panel shows water year entrainment for a run. For the purposes of the simulation weir overtopping was defined as Sacramento River stage exceeding 32.3' NAVD88, USGS datum. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data.

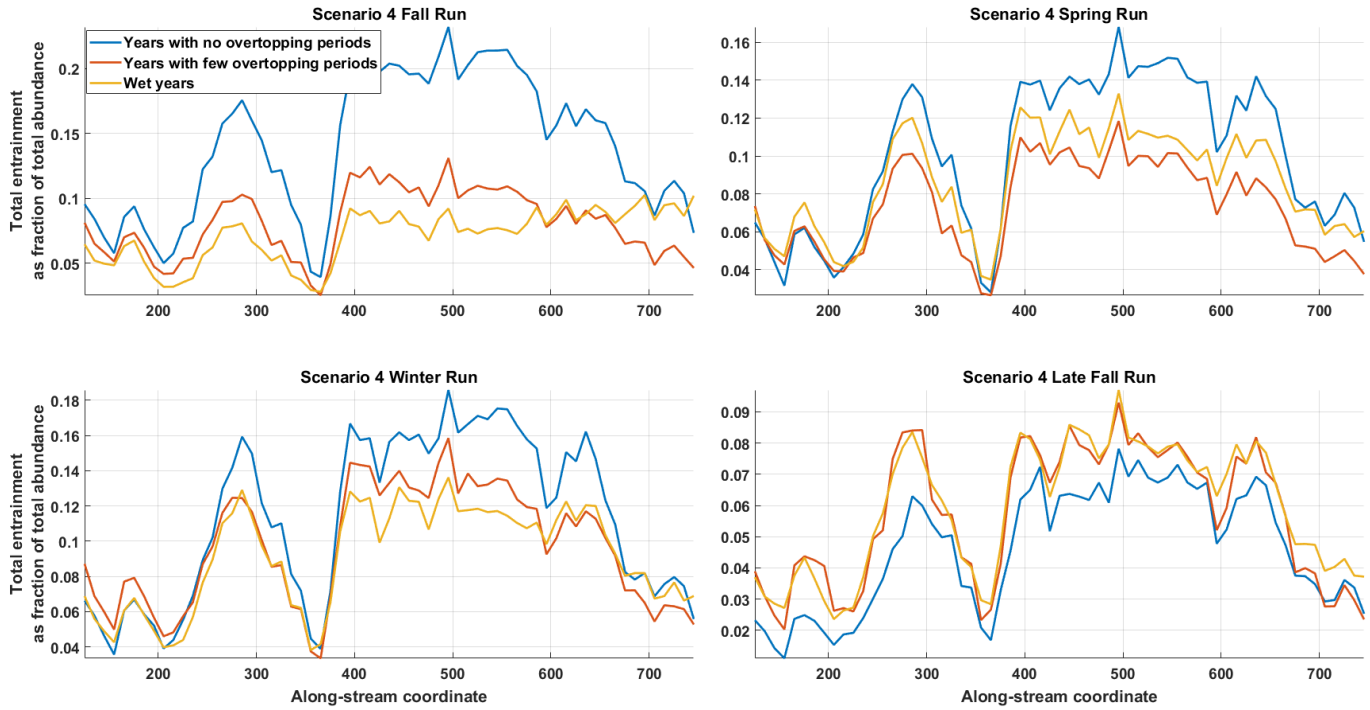


Figure 30- Scenario 4 water year type total entrainment curves

Plots showing total entrainment for each run as a function of notch along-channel location within the study area calculated for three water year types for scenario 4. The blue lines indicates total entrainment over all seasons when fremont weir did not overtop, the red line indicates total entrainment over all seasons when the fremont weir overtopped for fewer than 200 hours, and the gold line indicates total entrainment over all seasons when the fremont weir overtopped for more than 200 hours (wet years). Each panel shows water year entrainment for a run. For the purposes of the simulation weir overtopping was defined as Sacramento River stage exceeding 32.3' NAVD88, USGS datum. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data.

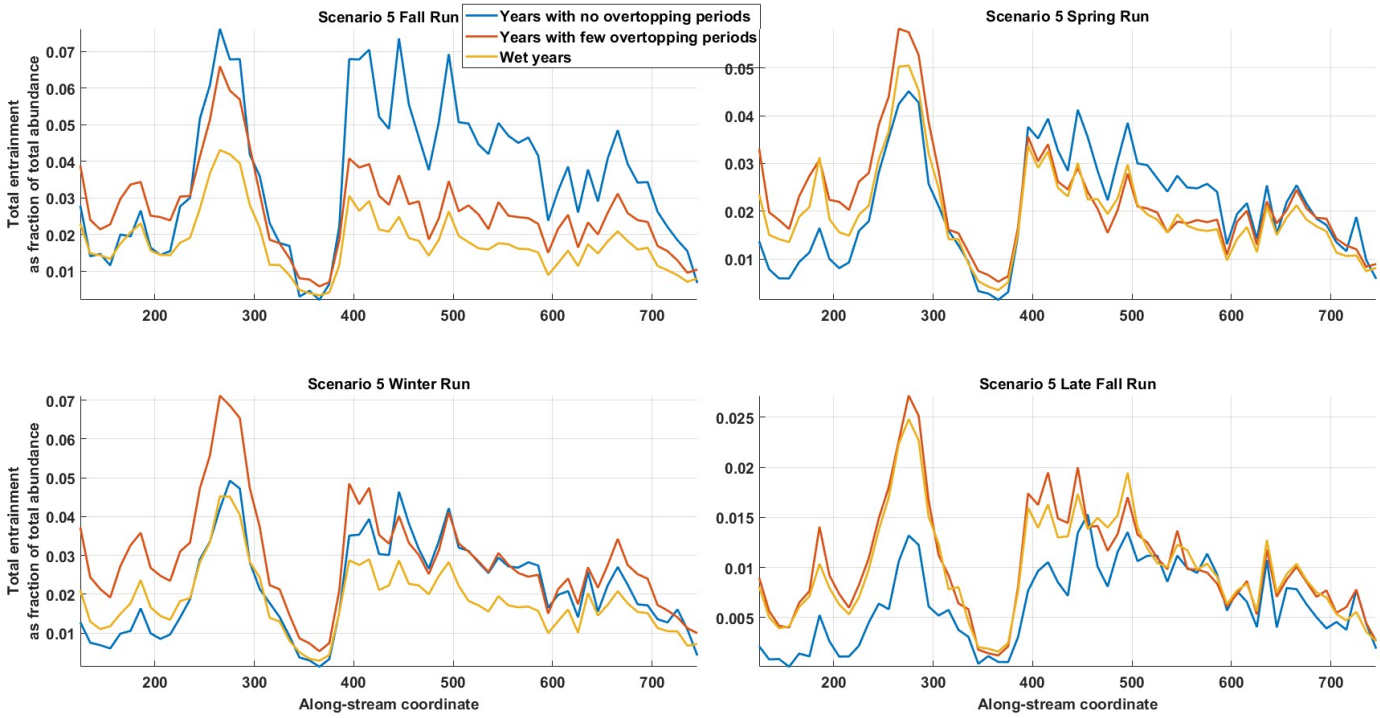


Figure 31- Scenario 5 water year type total entrainment curves

Plots showing total entrainment for each run as a function of notch along-channel location within the study area calculated for three water year types for scenario 5. The blue lines indicates total entrainment over all seasons when fremont weir did not overtop, the red line indicates total entrainment over all seasons when the fremont weir overtopped for fewer than 200 hours, and the gold line indicates total entrainment over all seasons when the fremont weir overtopped for more than 200 hours (wet years). Each panel shows water year entrainment for a run. For the purposes of the simulation weir overtopping was defined as Sacramento River stage exceeding 32.3' NAVD88, USGS datum. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data.

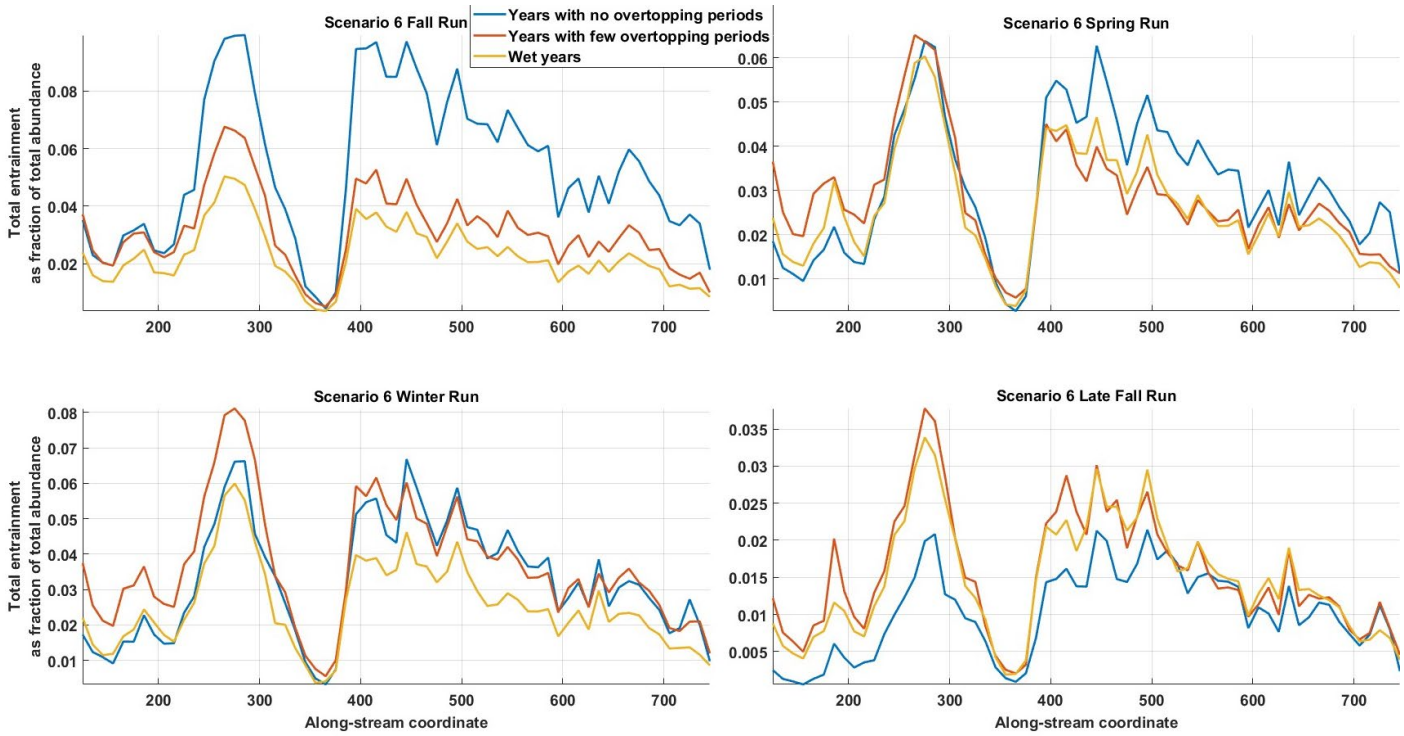


Figure 32- Scenario 6 water year type total entrainment curves

Plots showing total entrainment for each run as a function of notch along-channel location within the study area calculated for three water year types for scenario 6. The blue lines indicates total entrainment over all seasons when fremont weir did not overtop, the red line indicates total entrainment over all seasons when the fremont weir overtopped for fewer than 200 hours, and the gold line indicates total entrainment over all seasons when the fremont weir overtopped for more than 200 hours (wet years). Each panel shows water year entrainment for a run. For the purposes of the simulation weir overtopping was defined as Sacramento River stage exceeding 32.3' NAVD88, USGS datum. Note that the simulation is based on data from acoustically tagged hatchery surrogates, and so differences between run entrainment are entirely driven by differences in the historical timing of run abundance, and are not indicative of behavioral differences in the acoustic tag data.

Appendix A - Table giving the conversion between along stream coordinates and UTM for the River Right bank of the Sacramento River.

Table giving the along stream coordinate and utm coordinates of the river right bank of the Sacramento River at 29 feet stage, NAVD88, USGS, from the bathymetric model used in the simulation.

Notch evaluation location	Along-stream coordinate, m	Easting, m, UTM, NAD83	Northing, m, UTM, NAD83
1	124.9	615497.6	4290880.5
2	134.9	615506.8	4290876.3
3	144.9	615515.8	4290871.8
4	155.0	615524.9	4290868.0
5	165.2	615535.1	4290866.2
6	175.5	615545.3	4290863.8
7	185.6	615555.0	4290860.1
8	195.6	615564.3	4290855.0
9	205.4	615574.7	4290851.9
10	215.3	615585.2	4290852.0
11	225.3	615595.5	4290854.0
12	235.3	615605.6	4290855.1

13	245.3	615615.6	4290857.1
14	255.3	615625.7	4290858.2
15	265.3	615635.7	4290860.0
16	275.4	615645.6	4290861.6
17	285.4	615655.5	4290863.3
18	295.4	615665.6	4290864.3
19	305.4	615675.7	4290865.5
20	315.4	615685.7	4290867.4
21	325.4	615695.4	4290870.7
22	335.3	615705.4	4290873.2
23	345.3	615715.6	4290875.3
24	355.4	615725.6	4290878.1
25	365.4	615735.6	4290880.5
26	375.4	615744.4	4290885.6
27	385.4	615753.4	4290890.3
28	395.4	615761.8	4290896.2
29	405.5	615771.4	4290899.7

30	415.5	615780.0	4290905.4
31	425.5	615789.9	4290908.7
32	435.4	615799.4	4290913.0
33	445.5	615808.6	4290918.1
34	455.4	615818.3	4290922.7
35	465.4	615826.0	4290929.9
36	475.5	615835.5	4290934.8
37	485.6	615841.8	4290943.7
38	495.6	615848.5	4290951.8
39	505.6	615856.9	4290958.3
40	515.5	615864.4	4290965.9
41	525.5	615872.6	4290972.9
42	535.5	615881.0	4290979.3
43	545.6	615887.5	4290986.8
44	555.6	615894.7	4290993.8
45	565.6	615899.9	4291002.6
46	575.6	615904.8	4291011.8

47	585.6	615909.0	4291021.4
48	595.6	615917.0	4291028.5
49	605.6	615920.8	4291038.2
50	615.6	615925.2	4291047.6
51	625.7	615932.2	4291055.5
52	635.7	615935.7	4291065.6
53	645.6	615940.0	4291075.3
54	655.6	615943.3	4291085.4
55	665.6	615947.0	4291095.2
56	675.6	615952.2	4291104.1
57	685.6	615955.0	4291113.7
58	695.6	615957.9	4291123.4
59	705.6	615962.8	4291132.3
60	715.7	615964.9	4291142.1
61	725.7	615967.4	4291151.6
62	735.6	615971.6	4291159.9
63	745.6	615976.1	4291168.1

Appendix B - Detailed rating curves and drawings for Scenario 5 and Scenario 6

Table B1 - Stage - discharge relationships for scenario 5 and scenario 6

Stage, Scenario 6, ft, NAVD88, USGS	Stage, Scenario 5, ft, NAVD88, USGS	Intake A discharge, cfs	Intake B discharge, cfs	Combined Discharge, Intake A and B, cfs	Intake C discharge, cfs	Intake D discharge, cfs
15.00	16.30	12		12		
16.00	17.30	45		45		
17.00	18.30	94	0	94		
18.00	19.30	157	20	177		
19.00	20.30	245	71	316		
20.00	21.30	340	158	498		
20.50	21.80	398	219	617		
22.00	23.30	659	414	1073	0	
23.00	24.30	711	428	1139	636	
24.00	25.30	860	607	1467	915	
25.00	26.30	1025	800	1825	1259	
25.50	26.80	0	1464	1464	1671	

26.00	27.30		1169	1169	2054	
26.25	27.55		1220	1220	2188	
26.50	27.80		672	672	2493	0
26.60	27.90		0	0	2084	1369
27.00	28.30				1400	1859
27.25	28.55				1476	1998
27.50	28.80				1032	2226
27.75	29.05				1084	2381
28.00	29.30				563	2619
28.25	29.55				589	2790
28.50	29.80				0	3032
29	30.30					3407
29.5	30.80					3463
30	31.30					3246
31	32.00					3325
32.3	32.30					0

Table B2 - Gate spacing for scenario 5 and scenario 6

For scenario 5 and Scenario 6 entrainment for each gate is calculated based on the location of the bootstrap sample fish tracks relative to the location of the critical streakline at the along stream location that corresponds to the center of each gate. The location of the center of the downstream gates (Gates B, C, and D) is calculated by adding the offsets listed below to the along-stream location of Gate A.

Gate	Offset from center of Gate A, meters in the along stream direction
A	0
B	12.2
C	133
D	240.5

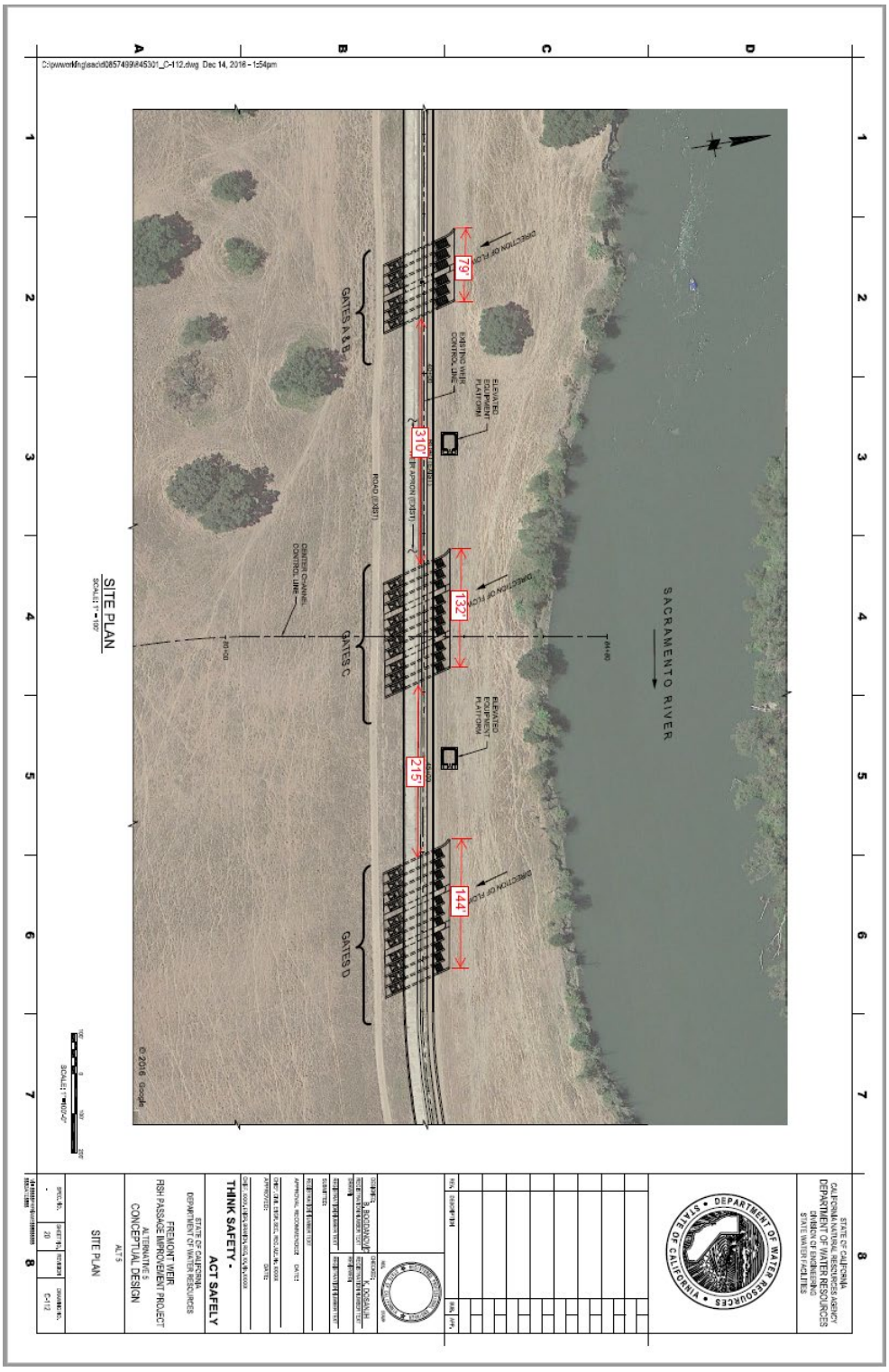


Figure B1 - Conceptual drawing of alternative 5 showing the gate spacing used for scenario 5 and scenario 6

Appendix A

Gate Sizing and Headworks Flow

Appendix A7

RECLAMATION

Managing Water in the West

Technical Report No. ENV-2020-073

Flow Modeling of the Fremont Weir Section of Sacramento River under 2016 Spring Hydrology



U.S. Department of the Interior
Bureau of Reclamation

August 2020

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: Sacramento River bend and adjacent floodplain bench north of Fremont Weir (photo from survey crew)

Technical Report No. ENV-2020-73

Flow Modeling of the Fremont Weir Section of Sacramento River under 2016 Spring Hydrology

Prepared by

yonglai

_____ 8/20/2020

Yong G. Lai, Ph.D., Hydraulic Engineer **Date**
Sedimentation and River Hydraulics Group
Technical Service Center
Denver, Colorado

Peer Reviewed by:

_____ _____

Davis Smith, Ph.D., Ecohydraulist **Date**
United States Army Corps of Engineers
Engineer Research and Development Center
Vicksburg, Mississippi

U.S. Department of the Interior
Bureau of Reclamation

August 2020

Table of Contents

Page

Summary **1**
1. Background **2**
2. About SRH-2D **5**
3. Expanded Fremont SRH-2D Model **6**
3.1 Study Site, Model Domain and Terrain 6
3.2 Mesh Development 9
3.3 Existing-Condition Boundary Conditions 13
4. Model Validation **16**
5. Model Application for Notch Optimization Options **29**
5.1 Notch Configuration and Optimization Options 29
5.2 Flow Scenarios 40
5.3 SRH-2D Model Results 41
5.3.1 Original Notch Option 41
5.3.2 Notch Options 1 and 1B 46
5.3.3 Notch Options 2 and 2B 55
5.3.4 Notch Options 3 and 3B 64
5.3.5 Notch Options 4 and 4B 73
6 References **82**

Index of Figures

Page

Figure 1. The study area is the Fremont Weir section of the Sacramento River in California. 6
Figure 2. The 2017 Fremont model domain (red lines); it includes the within-river flow areas only. 7
Figure 3. The proposed expanded areas in the north and south for the new Fremont model. 7
Figure 4. The actual expanded Fremont model domain (red lines) used in this study. 8
Figure 5. Bed elevation contours of the expanded terrain. 9
Figure 6. An overview of the existing condition mesh. 10
Figure 7. A close-up view of the existing condition mesh at the big bend of the Fremont section. 10
Figure 8. A close-up view of the existing condition mesh at the confluence of the Sacramento River and the Feather River. 11
Figure 9. The expanded Fremont terrain represented by the final, existing-condition 2D mesh: entire domain view. 11
Figure 10. 3D view of the terrain represented by the mesh: upstream section at the big bend area (1:5 vertical distortion). 12
Figure 11. 3D view of the terrain represented by the mesh: downstream section of the big bend area (1:5 vertical distortion). 12
Figure 12. Seven open boundaries of the model domain. 14
Figure 13. The time series flow discharges at Knights Landing (blue), feather river (red), Sutter Bypass (green), Sacramento Slough (Pink), and Natomas (black); these are based on the TUFLOW modeling by Campbell and Cheshier (2019). 14
Figure 14. Verona stage (red) and stage at Tule (blue) as predicted by TUFLOW, and the stage measured at the VON gauge station (green). 15
Figure 15. Predicted stage (red) and measured stage (blue) at the Fremont gauge station in the period of October 2, 2015 to May 30, 2016 using the baseline model (Note: the gauge stage was corrected by -1.45 ft per DWR recommendation). ... 17
Figure 16. Predicted stage (red) and measured stage (blue) at the Fremont gauge station in the period of October 2, 2015 to May 30, 2016 using the baseline model (Note: the gauge stage was corrected by -1.95 ft per USGS suggestion). 17
Figure 17. Predicted (red) and gauge-measured (blue) discharges at the Verona gauge station with the baseline model in the period of October 2, 2015 and May 30, 2016. 18
Figure 18. Predicted (red) and gauge-measured (blue) discharges at the Verona gauge station with the modified model. 19
Figure 19. Predicted (red) and measured (blue) stages at the Fremont gauge station with the modified model in the period of October 2, 2015 to May 30, 2016. 20

Figure 20. Eight transects (red dots) along which ADCP velocity measurement was carried out by USGS in Spring of 2016. 21
Figure 21. Predicted (Red) and ADCP measured (Black) depth-averaged velocity vectors along eight transects of the Sacramento River for three dates in 2016. ... 23
Figure 22. R2 analysis between the model and measured data for all measured points and for three flow scenarios. 27
Figure 23. Three locations of the EIR/EIS notches. 30
Figure 24. Gate geometry of EIR/EIS Alternative 1 viewed in a 1:5 vertical distorted scale; it is based on the CAD model developed by DWR (top is Yolo Bypass side; bottom is Sac River; main gate invert is 14 ft; elevated gate invert is 18 ft). 31
Figure 25. Original option terrain for the EIR/EIS Alternative 1 alternative. 32
Figure 26. A close-up view of the Original option mesh in the notch area. 32
Figure 27. The terrain/geometry of the four optimization options developed by DWR and USACE. 34
Figure 28. Final composite terrains used for the eight optimization options 1 through 4 and 1B through 4B. 38
Figure 29. The terrain of the berm inserted into the river left, opposite to the notch, as developed by DWR and used in the modeling. 38
Figure 30. Two new meshes developed for the eight new optimization options.. 39
Figure 31. Option Original: planar view of the terrain and mesh in the notch area. 42
Figure 32. Option Original: terrain 3D view in the notch area. 42
Figure 33. Rating curve used for the flow through the notch/gate. 43
Figure 34. Predicted flow velocity and pattern near the notch for the Original option. 46
Figure 35. Options 1 and 1B: planar views of the terrain and mesh in the notch area. 47
Figure 36. Option 1 and 1B: 3D views of the terrain in the notch area. 48
Figure 37. Predicted flow velocity and pattern near the notch for Options 1 and 1B. 54
Figure 38. Options 2 and 2B: planar views of the terrain and mesh in the notch area. 56
Figure 39. Options 2 and 2B: 3D views of terrain in the notch area. 57
Figure 40. Predicted flow velocity and pattern near the notch for Options 2 and 2B. 63
Figure 41. Options 3 and 3B: planar views of the terrain and mesh in the notch area. 65
Figure 42. Options 3 and 3B: 3D views of terrain in the notch area. 66
Figure 43. Predicted flow velocity and pattern near the notch for Options 3 and 3B. 72
Figure 44. Options 4 and 4B: planar views of the terrain and mesh in the notch area. 74
Figure 45. Options 4 and 4B: 3D views of terrain in the notch area. 75
Figure 46. Predicted flow velocity and pattern near the notch for Options 4 and 4B. 81

Index of Tables

Page

Table 1. Error indicators of the depth-averaged velocity between the model and measured data for all measured data points: the low flow scenario on February 18, 2016. (velocity unit: m/s) 24
Table 2. Error indicators of the depth-averaged velocity between the model and measured data for all measured data points: the medium flow scenario on March 30 18, 2016. (velocity unit: m/s) 25
Table 3. Error indicators of the depth-averaged velocity between the model and measured data for all measured data points: the high flow scenario on March 9, 2016. (velocity unit: m/s) 25
Table 4. The Nash-Sutcliffe coefficient of the Easting (U) and Northing (V) depth-averaged velocity computed on all measurement points. 26
Table 5. Flow discharges and stages at key locations for the selected six flow scenarios. 40
Table 6. Key discharges and stage used as the boundary conditions at the model open boundaries. 40

Summary

A new expanded Fremont SRH-2D model is developed, validated and applied to predict the flow hydrodynamics along the Fremont Weir section of the Sacramento River, California. The new model is extended from a previous SRH-2D model calibrated and verified already for the same river section; the 2016 spring hydrology is used for the new model validation and application. The primary purpose of the new model is to fine-tune the notch design now that the east location, EIR/EIS Alternative one, has been selected as the tentatively preferred alternative location for the notch placement. The expanded model has the following new features in comparison with the previous 2017 model: (a) the model domain is expanded to include both the Sutter Bypass on the north and the Yolo Bypass to the south so that flood flow conditions may be simulated; and (b) the new set of boundary conditions are adopted which are based on the 2016 flow prediction independently carried out by CBEC using TUFLOW.

The predicted flow hydrodynamics is generated to support the Eulerian Lagrangian Agent Method (ELAM) modeling of fish movement within the river and through the Yolo Bypass Fremont weir so that the effectiveness of different notch optimization options may be evaluated. The ELAM modeling is used to assist the design to achieve the desired fish migration through the Yolo Bypass. This work is part of a larger effort related to the Yolo Bypass EIR/EIS study for fish survival. Participants include Reclamation Bay Delta Office, Department of Water Resources (DWR) of California, USACE ERDC, and USACE Sacramento District.

Three previous modeling studies have been carried out. In 2015, the first SRH-2D model was developed, calibrated and verified under the existing river conditions (Lai, 2015). The 2015 study compared the model results with the available gauge data in 2010-2011 as well as the ADCP velocity data on 42 transects. It was concluded that the model is reliable in simulating the flow hydrodynamics. In 2017, two more modeling studies were carried out with the same 2015 SRH-2D model (Lai, 2017a; b). The model was verified further against the 2015 ADCP velocity data under the existing river condition, and then applied to predict the flow hydrodynamics under the influence of various weir notch locations (west, central and east) and configurations. A total of 16 notch configurations and six EIR/EIS alternatives were simulated using the 2015 flow hydrology.

The expanded model domain encompasses about 10.8 miles (18 km) along the Fremont Weir section of the Sacramento River. The model starts from Knight Landing upstream and ends at Verona gauge station downstream. The inflows include: (a) Sac flow at Knights Landing; (b) the Feather River; (c) Sac Slough; (d) Sutter Bypass; (e) Natomas; and (f) flows through the proposed notch.

1. Background

This work is part of a larger effort related to the Yolo Bypass EIR/EIS study for fish survival. The California Department of Water Resources (DWR) and the Bureau of Reclamation (Reclamation) have been working together on the Yolo Bypass Salmonid Habitat Restoration and Fish Passage project (YBSHRFP), which is working to implement actions in the 2009 National Marine Fisheries Service (NMFS) Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (2009 NMFS BO).

It has been found that operations of the Central Valley Project and State Water Project, if left unchanged, could jeopardize federally-listed species (Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and the Southern Distinct Population Segment of North American green sturgeon). The YBSHRFP project is to reduce effects on these species and focuses on implementing two actions:

- Increase seasonal floodplain habitat in the lower Sacramento River Basin
- Improve fish passage throughout the Yolo Bypass

The biological objectives to implement these actions include:

- Increase access to, and acreage of, seasonal floodplain fisheries (juvenile salmonids)
- Reduce straying, stranding, and presence of migration barriers (juveniles but mostly adult fish)
- Increase aquatic food web productivity
- Improve connectivity between the Sacramento River and Yolo Bypass

This study is carried out to predict flow hydrodynamics along the Fremont Weir section of the Sacramento River using an expanded SRH-2D model and under various notch optimization options. The selected runoff is the 2016 spring hydrology. Flow hydrodynamic variables are generated to support the Eulerian Lagrangian Agent Method (ELAM) modeling of fish movement within the river and through the Yolo Bypass Fremont Weir. The numerical modeling is used to assess the effectiveness of different notch optimization options in increasing fish migration to the Yolo Bypass.

Three previous studies have been carried out. In the 2015 study (Lai, 2015), an SRH-2D Fremont model was developed, calibrated and verified under the existing river condition. Both a 67-mile low-resolution model and a 10.8-mile high-resolution model were developed. Model calibration and verification studies were achieved by comparing the model predictions with the measured discharge and stage and the ADCP velocity data in two time periods - 2010-2011 and 2014-

2015. The results showed that the SRH-2D model produced reliable flow velocities and other hydrodynamic variables. It was concluded that the 10.8-mile high-resolution model was appropriate for the next phase of modeling for notch configuration studies.

Two follow-up studies were carried out in 2017 and documented by Lai (2017a; b). The studies focused on the applications of the verified 2015 model to different notch configurations using the hydrological inputs in the first six months of 2015. In Lai (2017a), a total of 12 configurations were evaluated; in Lai (2017b), four additional configurations and six EIR/EIS alternatives were simulated.

Since the previous studies, additional collection of fish movement data was carried out in 2016 when the stage at the Fremont gauge station was about 18 to 30 ft (NADV88). Significant inflows to the Sacramento River from Sutter Bypass occurred in 2016 while no such high inflows occurred in 2015. Thus, one concern of an external peer review was that the Fremont Weir entrainment analysis based on the 2015 flows as the calibration point might be ineffective at higher stages under the influence of the Sutter Bypass inflow. Recommendation was to simulate additional cases under high flow conditions when there is Sutter Bypass inflow in 2016 and evaluate the 2015 calibrated fish movement model against the 2016 flow conditions. This study is carried out in accordance with the above recommendations.

Flow hydrodynamic variables may have important impacts on fish movement behaviors. In this study, important variables are generated so that the Eulerian-Lagrangian Agent Method (ELAM) modeling of fish movement may be performed at the study site. The fish movement modeling portion of the study is carried out by engineers at the U.S. Army Corps of Engineers (USACE). The ELAM model uses hydrodynamic flow produced by 2D and 3D models and swims fish with those data fields producing simulated fish positions. Output can be summarized as movement statistics and passage statistics. In addition, the numerical model results may also be used in conjunction with the telemetry fish tracking data measured in the field to discern fish behaviors and statistical patterns in relation to flow characteristics. The ELAM modeling results using the 2015 spring season data generated by Lai (2017a; b) were documented by USACE.

This report documents the results of the final phase of the SRH-2D modeling of the Fremont Section of the Sacramento River. The work serves two primary purposes: (a) further validation of the SRH-2D model, per the review team recommendations, using the 2016 spring hydrology - a relatively high flow season; and (b) application simulation of various options for a refined notch optimization. In the previous simulation, the 2015 spring flows were relatively low and only within-river flows were considered. With the present study, the 2016 spring flows were relatively high so the model has to be expanded to include additional terrains to accommodate the flows from the Sutter Bypass as well as

the flows in the Yolo Bypass. Once the model was validated, the 2016 spring flow hydrology is used to predict flow hydrodynamics under various notch optimization options. These flow results are then used by ELAM model to predict the fish movement, and the effectiveness of fish entrainment through the notch may then be compared.

2. About SRH-2D

SRH-2D, Sedimentation and River Hydraulics - Two-Dimension, is used in this study. SRH-2D is a 2D depth-averaged hydrodynamic and sediment transport model for river systems, developed at the Technical Service Center, U.S. Bureau of Reclamation. The hydrodynamic modeling theory and the User's Manual are available from Lai (2008; 2010). SRH-2D has been well calibrated and verified, and used extensively by U.S. governing agencies, universities and private consulting companies for project applications. The model is adopted as the agency model by Reclamation, Federal Highway Administration, and Taiwan Water Resource Agencies. It has also been certified by FEMA.

SRH-2D adopts the arbitrarily shaped cell method of Lai et al. (2003), the finite-volume discretization method, and an implicit time integration scheme. The numerical procedure is very robust that SRH-2D can simulate simultaneously all flow regimes (sub-, super-, and trans-critical flows) and both steady and unsteady flows. A special wetting-drying algorithm makes the model very stable in handling flows over dry surfaces. The mobile-bed sediment transport theory was documented by Greimann et al. (2008), Lai and Greimann (2010), and Lai et al. (2011). The mobile-bed module predicts vertical stream bed changes by tracking multi-size, non-equilibrium sediment transport for suspended, mixed, and bed loads, and for cohesive and non-cohesive sediments. The effects of gravity and secondary flows on the sediment transport are accounted for by displacing the direction of the sediment transport vector from that of the local depth-averaged flow vector. Major capabilities of SRH-2D include:

- 2D depth-averaged solution of the St. Venant or dynamic wave equations for flow hydrodynamics;
- An implicit solution scheme for solution robustness and efficiency;
- Flexible mesh topology with polygonal cell shapes (In most applications, a combination of quadrilateral and triangular meshes works the best);
- Steady or unsteady flows;
- All flow regimes simulated simultaneously: subcritical, supercritical or transcritical flows;
- Mobile bed modeling of alluvial rivers with any hydrograph.
- Non-cohesive or cohesive sediment transport;
- Non-equilibrium sediment transport;
- Multi-size sediment transport with bed sorting and armoring;
- A single total load sediment transport governing equation for both bed load, suspended load, and mixed load.

3. Expanded Fremont SRH-2D Model

The previous Fremont SRH-2D model developed in Lai (2015) and Lai (2017a, b) is expanded in this study. The two main expansions are: (a) the model domain is extended to include both the north and south areas of the Fremont Weir section, and (b) new boundary conditions based on 2016 spring flow hydrology are applied. The 2016 spring flows were relatively high and included the flood flow scenarios. The expanded Fremont model is described below.

3.1 Study Site, Model Domain and Terrain

The site of interest is the section of the Sacramento River along the Fremont Weir as shown in **Figure 1**; it is called the Fremont Section in this report.

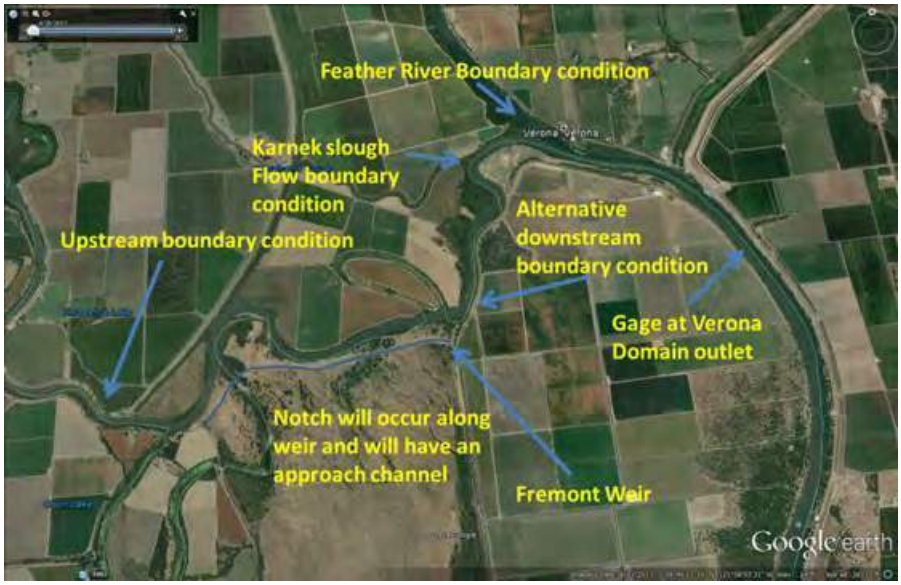


Figure 1. The study area is the Fremont Weir section of the Sacramento River in California.

In previous 2017 studies, the Fremont SRH-2D model was developed to simulate the within-river flows (the model domain is shown in **Figure 2**). In the present study, however, the 2017 model is expanded in spatial coverage and flow ranges, and it is named the expanded Fremont model in this report. With the expanded model, new terrains are added including both the north and south portions of the Fremont section so that flood flows may be simulated properly. The proposed expanded areas are shown in **Figure 3**; while the final model domain is shown in **Figure 4**. The upstream and downstream boundaries of the expanded model are the same as the 2017 model. The upstream is located at Knight Landing and the downstream is at Verona gauge station. In terms of river length, the domain covers about 10.8 miles (18 km).



Figure 2. The 2017 Fremont model domain (red lines); it includes the within-river flow areas only.

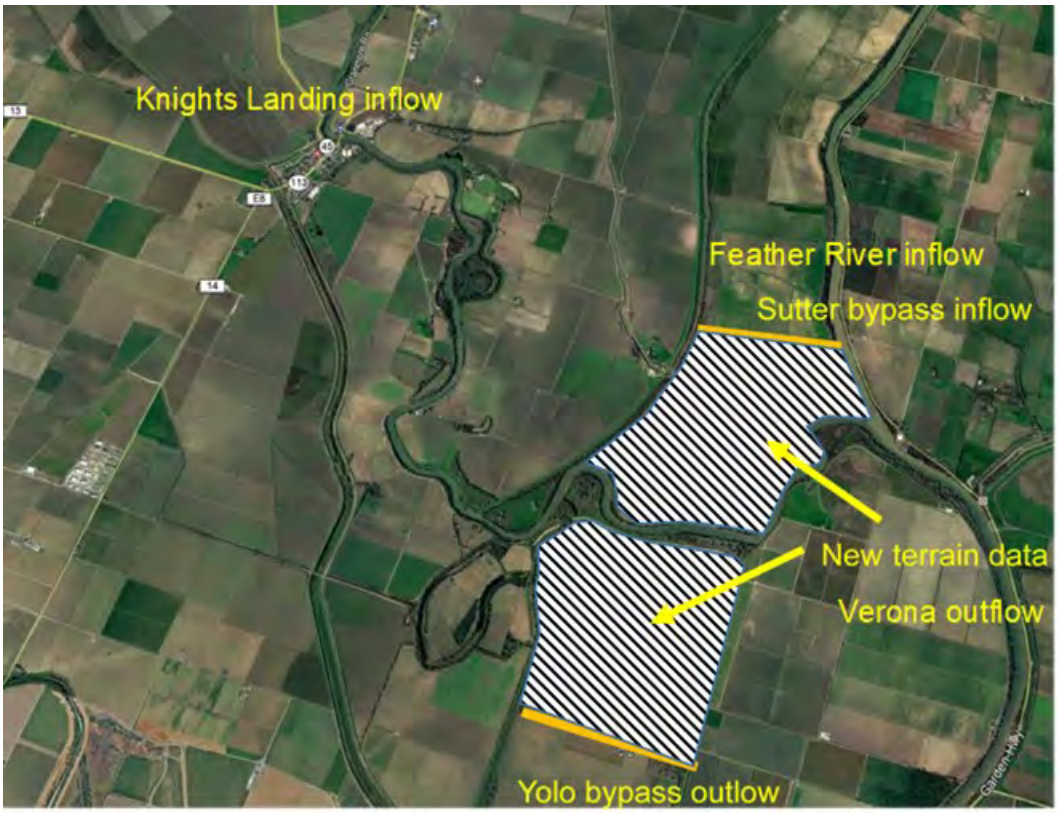


Figure 3. The proposed expanded areas in the north and south for the new Fremont model.



Figure 4. The actual expanded Fremont model domain (red lines) used in this study.

The expanded model terrain is developed as follows.

First, the within-river bathymetry used in the 2017 Fremont model is the starting point. The 2017 terrain data set was developed from a combination of bathymetry and terrain data up to 2015 (see Lai, 2017a; b). The data sets used in the 2017 terrain include the following in decreasing priority: (a) lateral transect bathymetric survey by the Department of Water Resources (DWR), California between January 21 and 27, 2015; (b) longitudinal bathymetric survey by DWR on April 8, 2015; (c) 2008 Lidar data for the terrain of the nearby dry lands; (d) terrain data of the high resolution ADH model described by Hammack et al. (2013).

Second, the bathymetry/terrain of the 2017 Fremont model is updated using the new 2016 bathymetric data surveyed by USGS in March and April, 2016. This updated terrain data set represents the within-river 2016 terrain.

Third and final, the terrain is expanded into Sutter Bypass in the north and Yolo Bypass in the south. The new terrain of the north and south areas is based on the data supplied from CBEC (Campbell and Cheshier, 2019).

A composite, continuous 2016 terrain is developed by combining all the above data sets, and it is used in the present study. The data set is named the 2016 expanded terrain. This terrain represents the existing condition of the study

domain; additional geometry data representing the notch configurations will be described later when modeling of notch configurations is presented.

Terrain data synthesis and processing are carried out with the tool named SMS. The 2016 expanded terrain is shown in **Figure 5**.

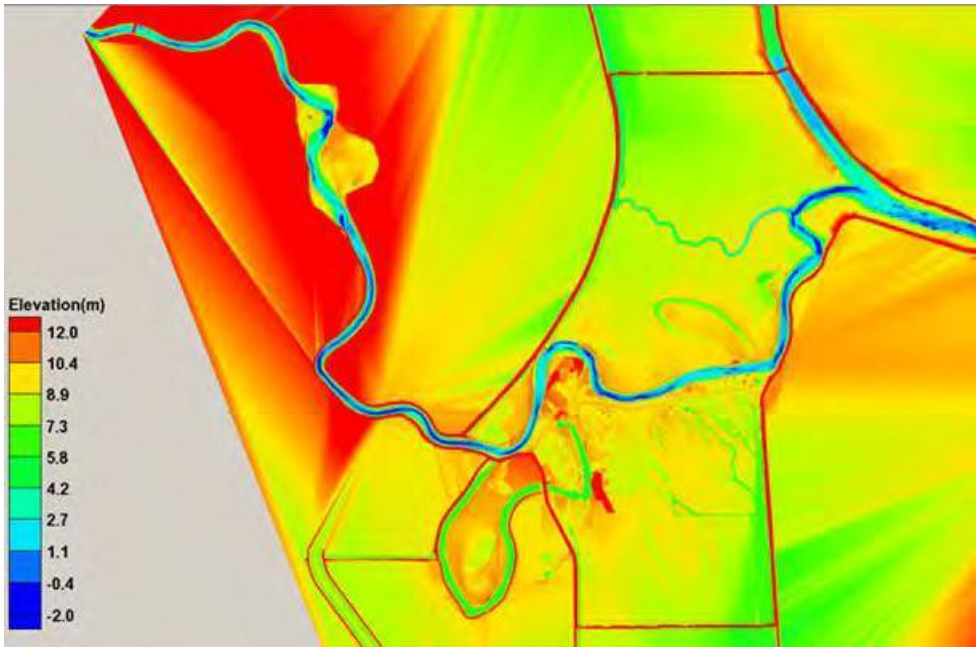


Figure 5. Bed elevation contours of the expanded terrain.

3.2 Mesh Development

2D meshes are developed to carry out the flow modeling and SMS is the tool of our choice. Under the existing condition, the final developed 2D mesh is displayed in **Figure 6** through **Figure 8** - one overview and two close-up views. The existing-condition mesh consists of 74,350 cells of mixed quadrilaterals and triangles (43,859 triangles and 30,491 quadrilaterals).

Once the 2D mesh is developed, the expanded Fremont terrain discussed above is interpolated onto the mesh. The terrain represented by the mesh is shown in **Figure 9**, while 3D close-up views of the same terrain at two locations are displayed in **Figure 10** and **Figure 11**.

2D meshes for notch optimization modeling are modified from the above existing-condition mesh. Primary changes are due to the placement of the notch geometry into the river section. Both the terrain and mesh are changed primarily around the notch area, which will be discussed later in the report when notch optimization simulation is presented.

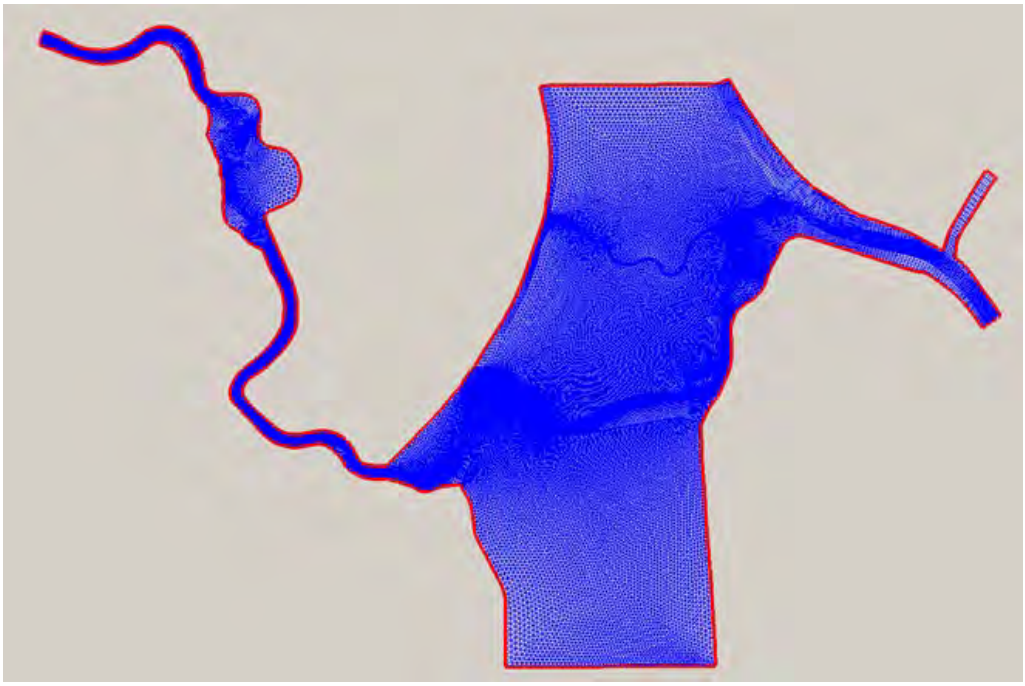


Figure 6. An overview of the existing condition mesh.

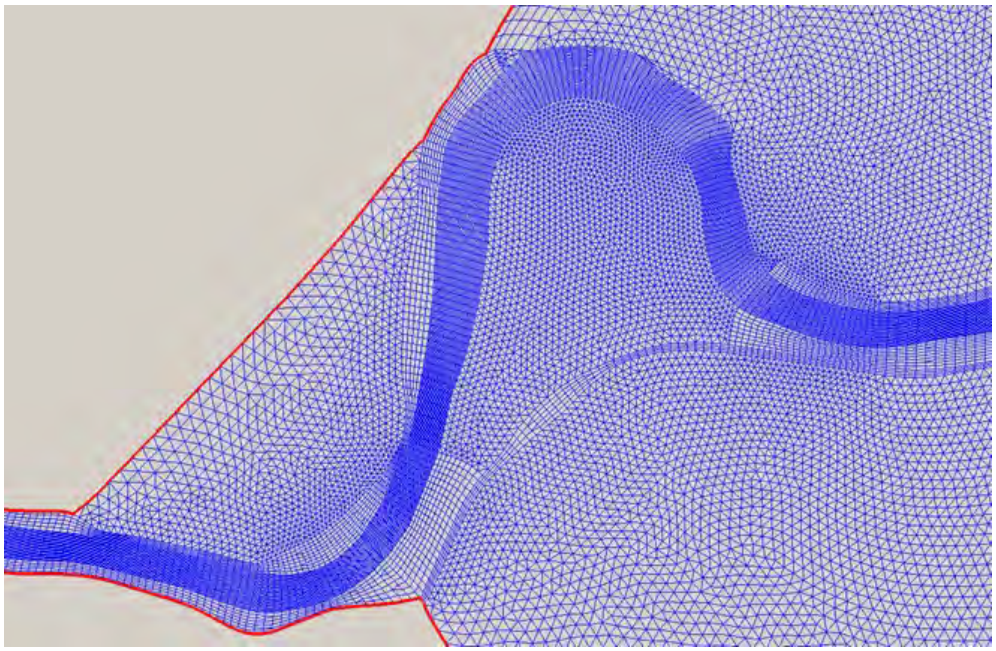


Figure 7. A close-up view of the existing condition mesh at the big bend of the Fremont section.

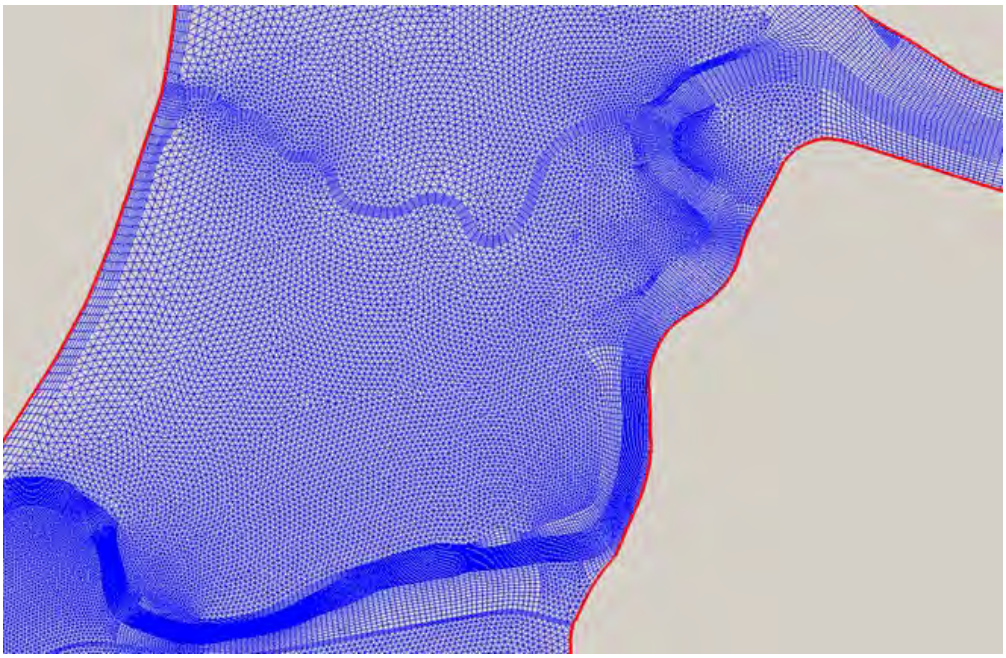


Figure 8. A close-up view of the existing condition mesh at the confluence of the Sacramento River and the Feather River.

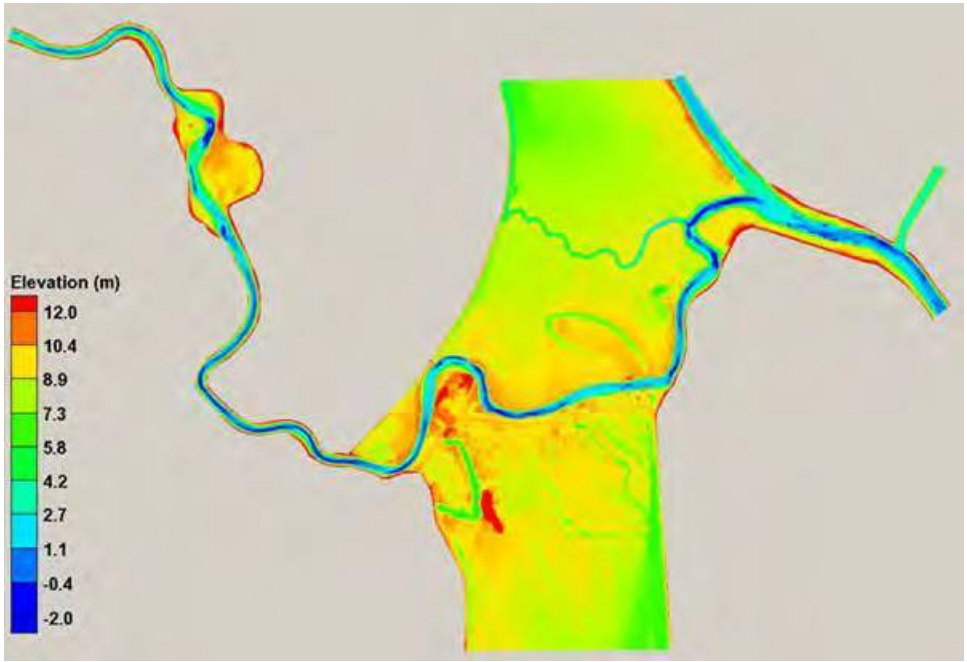


Figure 9. The expanded Fremont terrain represented by the final, existing-condition 2D mesh: entire domain view.

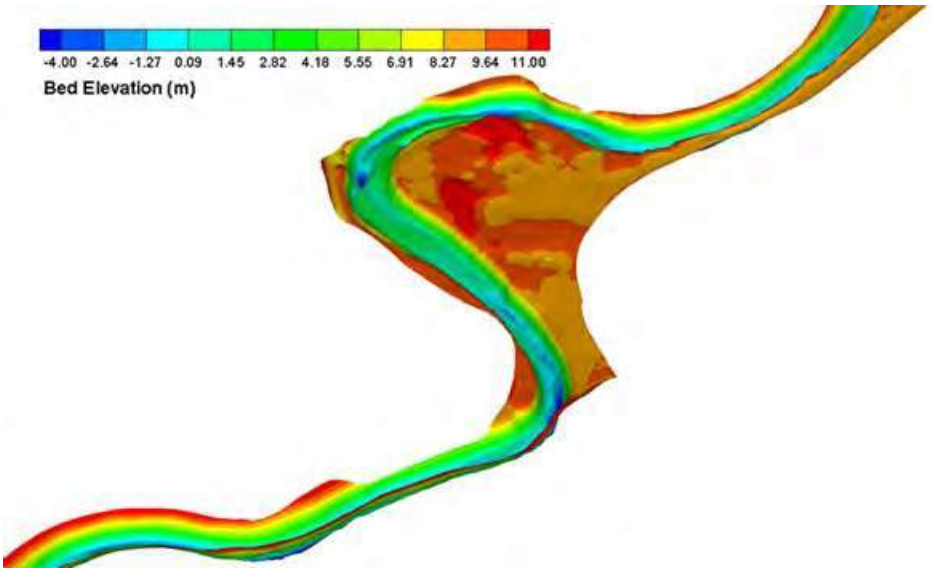


Figure 10. 3D view of the terrain represented by the mesh: upstream section at the big bend area (1:5 vertical distortion).

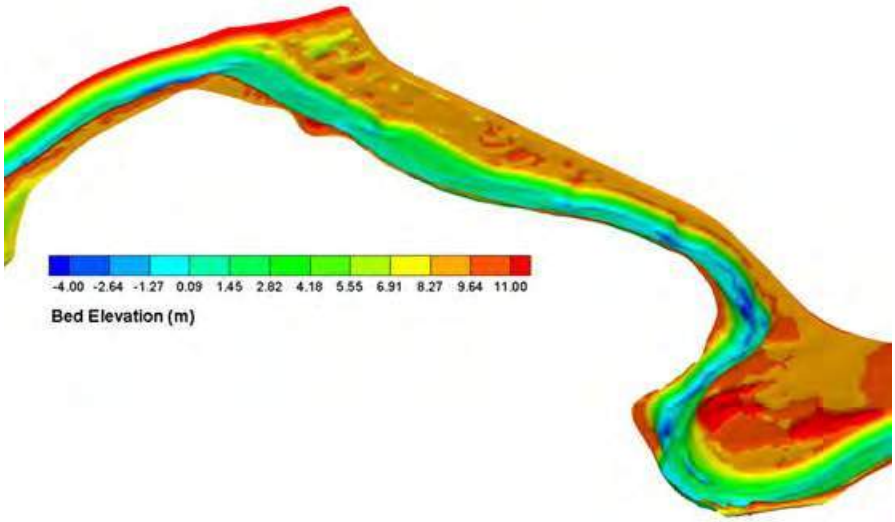


Figure 11. 3D view of the terrain represented by the mesh: downstream section of the big bend area (1:5 vertical distortion).

3.3 Existing-Condition Boundary Conditions

Flow boundary conditions are needed at all open boundaries of the model domain. The expanded Fremont model has a total of seven open boundaries (see **Figure 12**): Knights Landing inflow, Feather River inflow, Verona outflow, Sacramento Slough inflow, Sutter Bypass inflow, Natomas Cross-Cut inflow, and Yolo Bypass outflow. If EIR/EIS notch options are simulated, additional internal boundary condition is imposed so that the flow though the notch to the Yolo Bypass may be taken into account. A gate rating curve, representing the gate discharge versus the upstream stage relation, is used to implement the boundary conditions at the notch gate. This is discussed when the EIR/EIS modeling is presented later.

Unsteady simulation is carried out by the expanded Fremont model for the period of October 2, 2015 to May 30, 2016 – the 2016 spring runoff hydrology. The time series flow discharges at all inflow boundaries for the period are obtained from CBEC who carried out an independent TUFLOW modeling as reported by Campbell and Cheshier (2019). The TUFLOW was a 1D modeling for a much large domain simulation of the Sacramento River. The inflow discharges into the domain at five open boundaries are displayed in **Figure 13**.

The time series stages (water elevations) at Verona and Yolo Bypass exit (named Tule) may also be from TUFLOW model and they are shown in **Figure 14**. The stage at Verona, however, may use the Verona station recoded data; so the Verona stage based on the gauge is also shown in the figure. It is seen that TUFLOW predicted stage at Verona agreed with the gauge data well most of the times. However, the stage was over-predicted when there were flood flows.

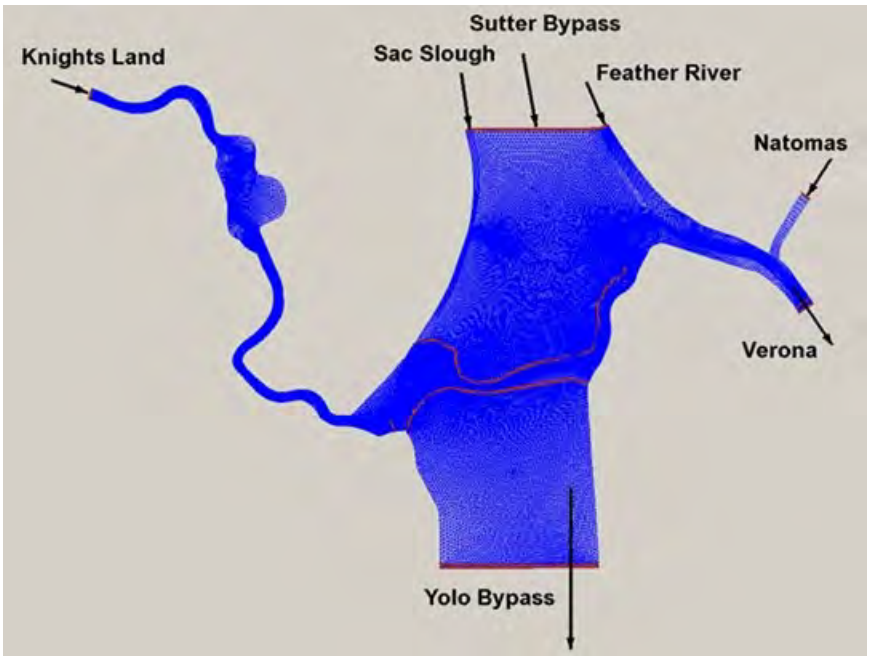


Figure 12. Seven open boundaries of the model domain.

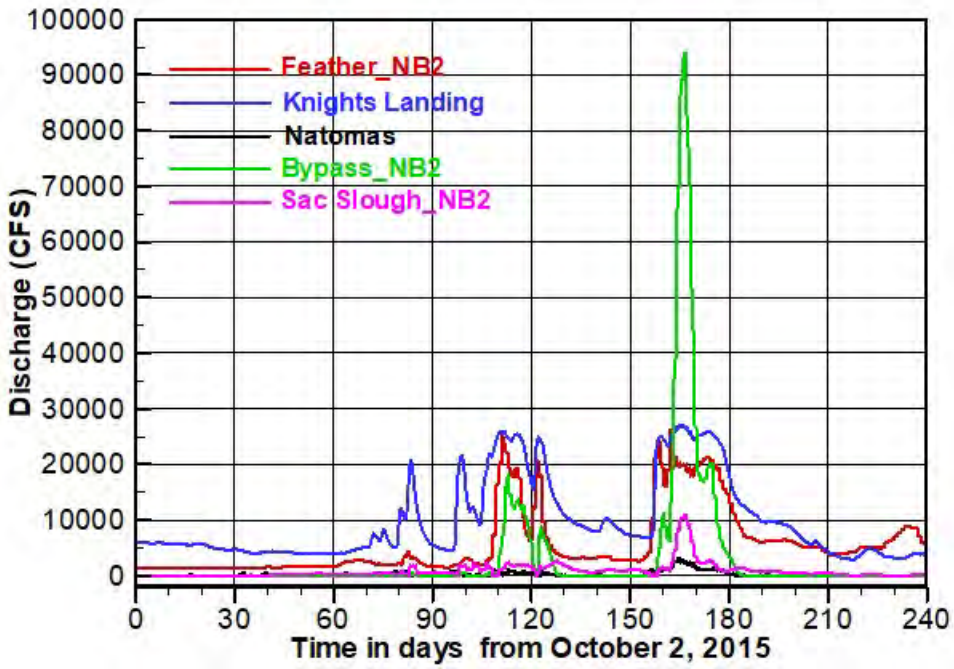


Figure 13. The time series flow discharges at Knights Landing (blue), feather river (red), Sutter Bypass (green), Sacramento Slough (Pink), and Natomas (black); these are based on the TUFLOW modeling by Campbell and Cheshier (2019).

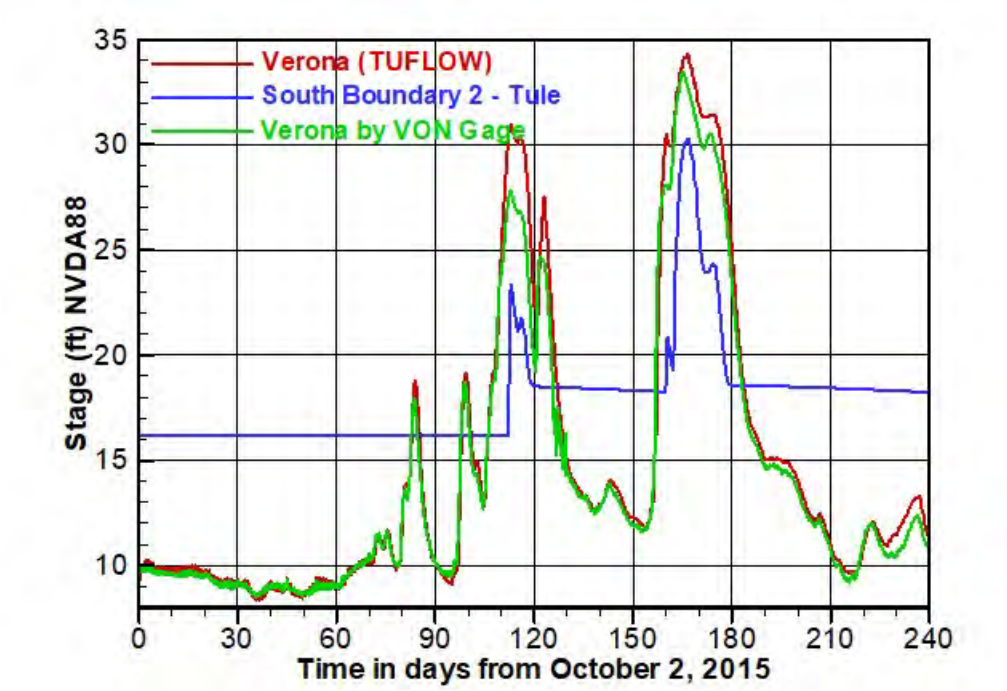


Figure 14. Verona stage (red) and stage at Tule (blue) as predicted by TUFLOW, and the stage measured at the VON gauge station (green).

4. Model Validation

The previous Fremont SRH-2D model has been calibrated and verified using a number of field measured data sets; results were documented in Lai (2015) and Lai (2017a). In this study, the expanded Fremont model is validated further using the 2016 field data. The validation results are discussed in this chapter. Note that all model inputs of the expanded model are the same as the previous calibrated/verified model except that a new set of boundary conditions are used in the present model to reflect the 2016 spring flow hydrology.

The baseline model adopts the following model inputs: all boundary conditions at the open boundaries are from TUFLOW results except at Verona. The stage measured at the Verona gauge (VON) is used as the stage boundary condition. These boundary conditions have been discussed in Section 3.3.

The stage at the Fremont gauge station predicted by the baseline model is compared with the gauge data in **Figure 15** and **Figure 16** over the period of October 2, 2015 to May 30, 2016. Note that the FRE gauge data downloaded from the DWR website needs to be corrected to arrive at the NAVD88 datum. DWR and USGS have recommended different conversions. DWR suggested -1.45 ft correction in stage while USGS recommended -1.95 ft. Both corrections are compared with the model results in **Figure 15** and **Figure 16**. The DWR conversion leads to a good match between the model and the gauge data for both lowest and highest stages; the difference is no more than 1.5 feet anywhere (see **Figure 15**). The USGS correction leads to less favorable agreement at low flows.

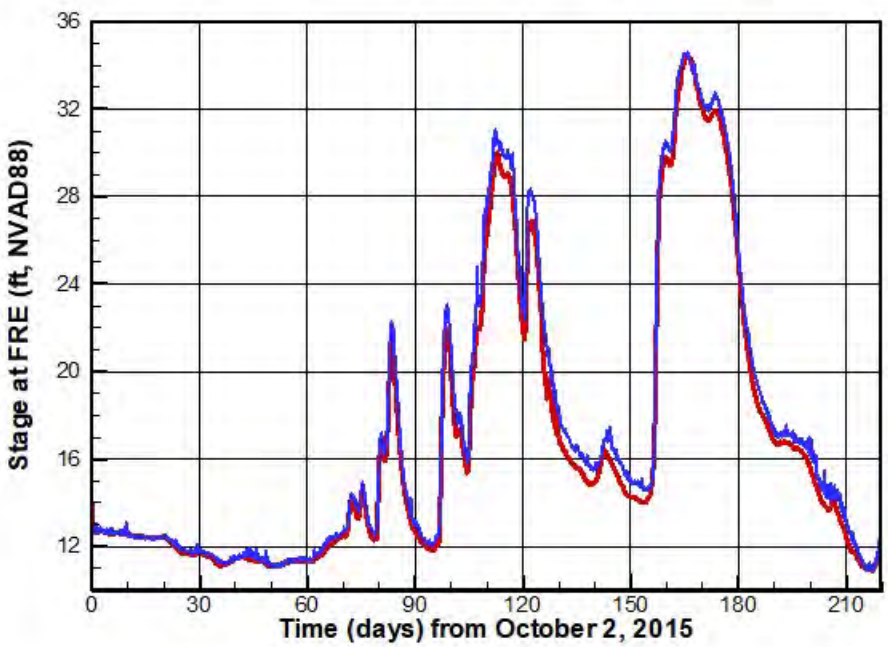


Figure 15. Predicted stage (red) and measured stage (blue) at the Fremont gauge station in the period of October 2, 2015 to May 30, 2016 using the baseline model (Note: the gauge stage was corrected by -1.45 ft per DWR recommendation).

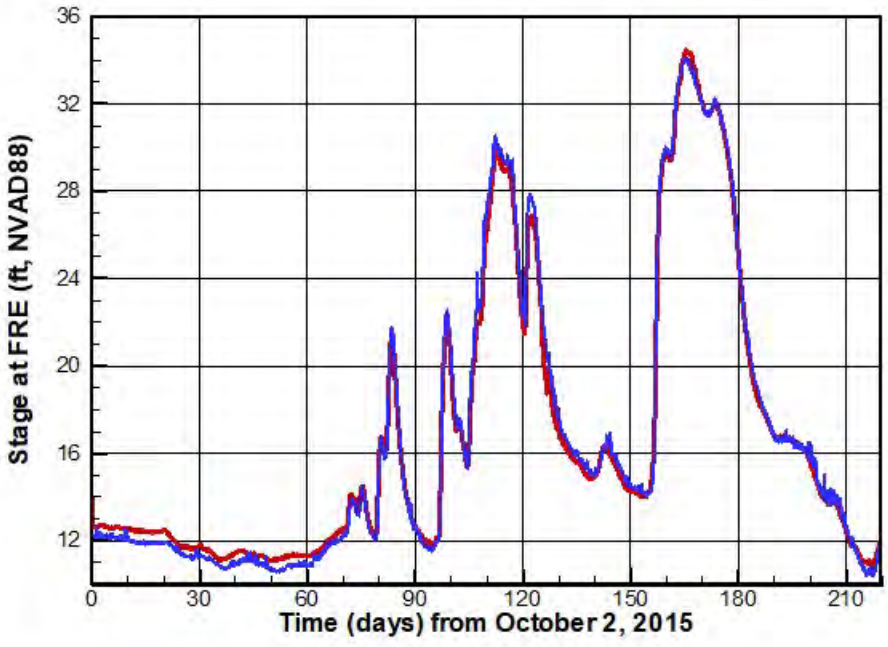


Figure 16. Predicted stage (red) and measured stage (blue) at the Fremont gauge station in the period of October 2, 2015 to May 30, 2016 using the baseline model (Note: the gauge stage was corrected by -1.95 ft per USGS suggestion).

The flow discharge predicted by the baseline model is compared with the measured data at the Verona gauge station (VON) in **Figure 17**. It is seen that the discharge is over-predicted during the two high flow peaks. If the baseline model is modified by adopting the Verona stage predicted by TUFLOW (called modified model in this report), the discharge comparison at the high-flow periods is much improved as shown in **Figure 18**. In fact, the modified model result in **Figure 18** is similar to the TUFLOW result reported by Campbell and Cheshier (2019) (see the method 2 TUFLOW results in Figure 4 of the CBEC report). This demonstrates that similar model results are obtained between SRH-2D and TUFLOW if the same boundary conditions are used. We, however, decide to use the baseline model (i.e., using the VON gauge stage as the boundary condition). There are two reasons. First, the VON gauge data is deemed more accurate and preferred as the boundary condition although the discharge prediction is less satisfactory at the VON location. As a comparison, the stage at VON was over-predicted by TUFLOW (Figure 3 of the Campbell and Cheshier (2019) report). Second, the predicted stage at FRE gauge station using the baseline model agrees with the gauge data better than the modified model. It can be seen by comparing the baseline model results in **Figure 15** and **Figure 16** with the modified model in **Figure 19**. A good prediction of the stage is deemed more important for the present project than predicting the discharge at VON, as the flow through a notch is largely determined by the stage.

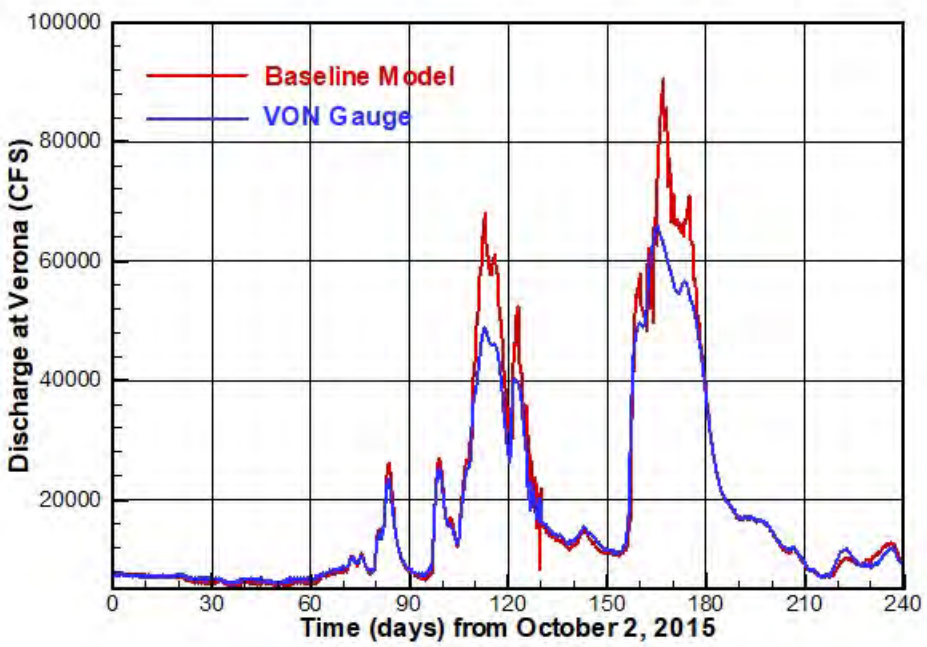


Figure 17. Predicted (red) and gauge-measured (blue) discharges at the Verona gauge station with the baseline model in the period of October 2, 2015 and May 30, 2016.

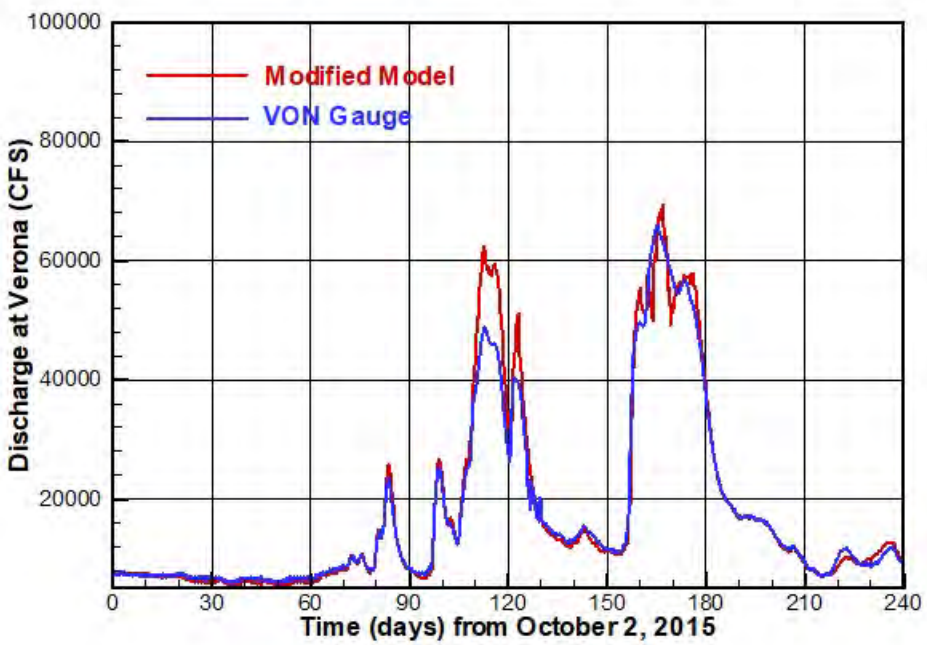
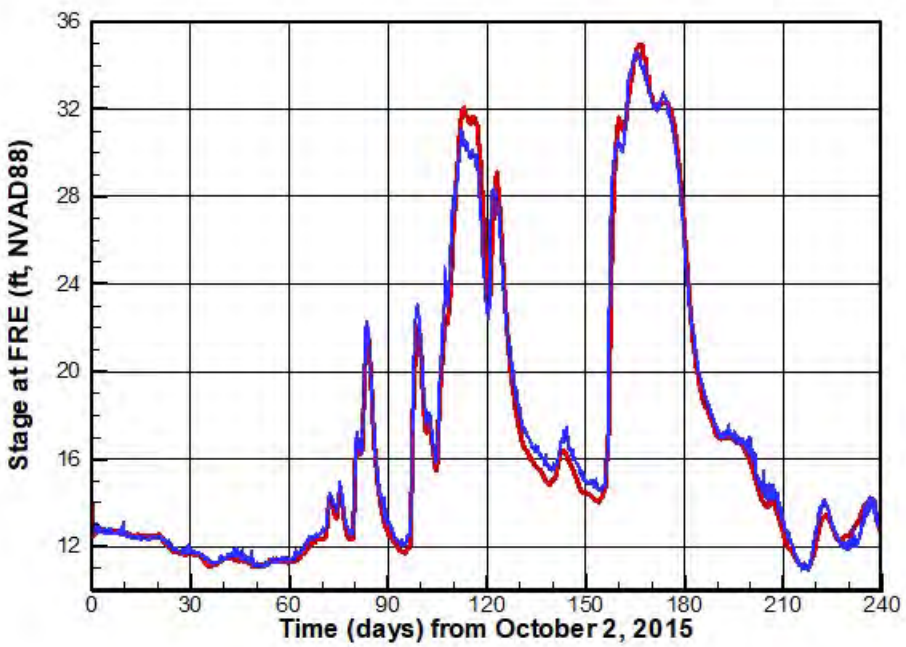
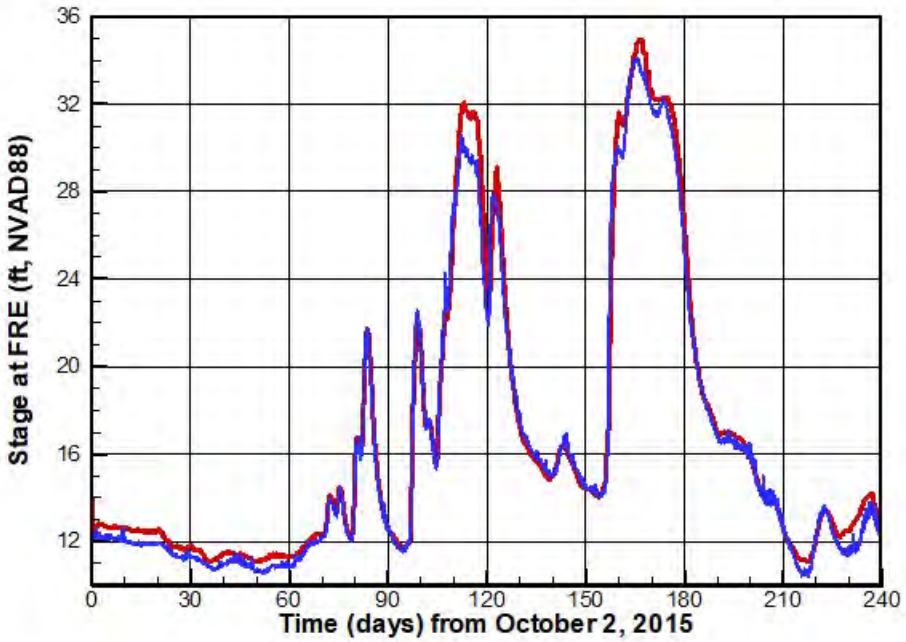


Figure 18. Predicted (red) and gauge-measured (blue) discharges at the Verona gauge station with the modified model.



(a) Per DWR suggestion by using -1.45 ft conversion



(b) Per USGS suggestion by using -1.95 ft conversion

Figure 19. Predicted (red) and measured (blue) stages at the Fremont gauge station with the modified model in the period of October 2, 2015 to May 30, 2016.

Over the years, a number of ADCP velocity measurements have been carried out at selected river transects (cross sections) of the study reach. For example, ADCP velocities were measured at 42 transects by USACE between December 2010 and February 2011. Another set of ADCP velocity measurements were carried out on 10 transects along the Fremont Weir section in February and March, 2015 by DWR. Both data sets have been used to calibrate and verify the Fremont SRH-2D model in the past. The results were reported in Lai (2015) and Lai (2017a).

In this study, further model validation is carried out by comparing the model results with a new set of ADCP velocity data. The ADCP velocity measurement was carried out by USGS (Stumpner et al., 2018), and the data set were processed and provided to this study by Paul Stumpner. In general, numerical model uncertainty may be attributed to two primary sources: (a) model uncertainty and (b) input uncertainty. The model uncertainty is related to that wrong equations may be solved (e.g., processes are only approximated and bugs in the code), and/or the right equations are solved incorrectly (e.g., mesh discretization errors, non-convergent results). The input uncertainty refers to errors due to the unknown inputs such as boundary conditions. In this study, validation is intended to minimize the input uncertainty. We are relatively confident in the model with regards to the model uncertainty as SRH-2D has been verified and validated in the past with numerous projects. In particular, the Fremont model has been verified already in our previous studies.

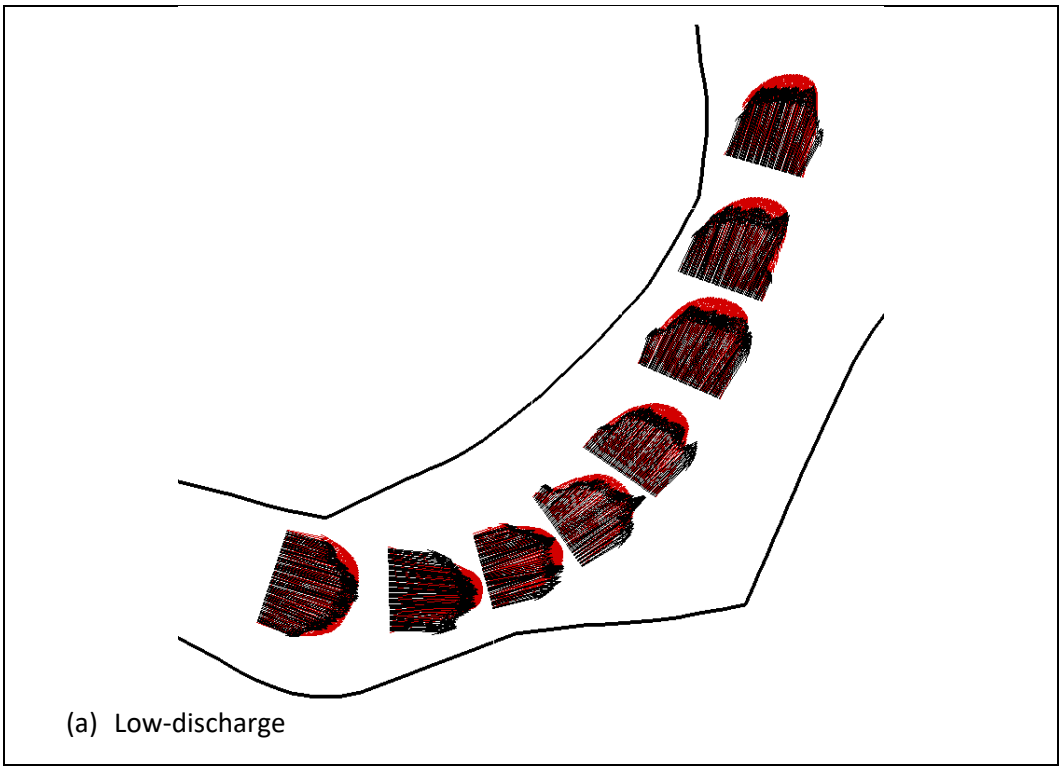
The ADCP measurement was carried out over a period of February 4 to March 30, 2016 and focused on eight (8) transects within the sharp bend of the Fremont Weir section. The transect locations are shown in **Figure 20**.



Figure 20. Eight transects (red dots) along which ADCP velocity measurement was carried out by USGS in Spring of 2016.

Three sets of 2016 ADCP data were selected for model validation (out of 5 sets): February 18, March 30, and March 9. The three represent different flow scenarios in the Sacramento River through the Fremont section: the discharge at the Knights Landing is 7,990, 15,200 and 25,000 cfs, respectively. The corresponding stage (NAVD88) at the Fremont gauge station is approximately 15, 24, and 30 ft, respectively. They are labeled as low-, medium-, and high-discharge in this report, respectively.

A comparison of the SRH-2D model predicted and ADCP measured depth-averaged velocity vectors is shown in **Figure 21** along the eight transects for the three flow scenarios in the Spring, 2016. A visual inspection shows the agreement between the two is good, which is typical between numerical models and ADCP data. The average flow magnitude and velocity maximum shift in a bend match between the two. The ADCP velocity shows less smooth variation across the river (along transects) which cannot be replicated by the model. It is expected for any numerical models based on the Reynolds averaged flow equations: large turbulence eddies are time averaged. The non-smoothness may be attributed to a number of factors. One of them is the presence of very large, slowly-varying turbulence eddies which may be present due to local flow features such as vegetation along the banks or rock outcrops or other hard points.



(a) Low-discharge

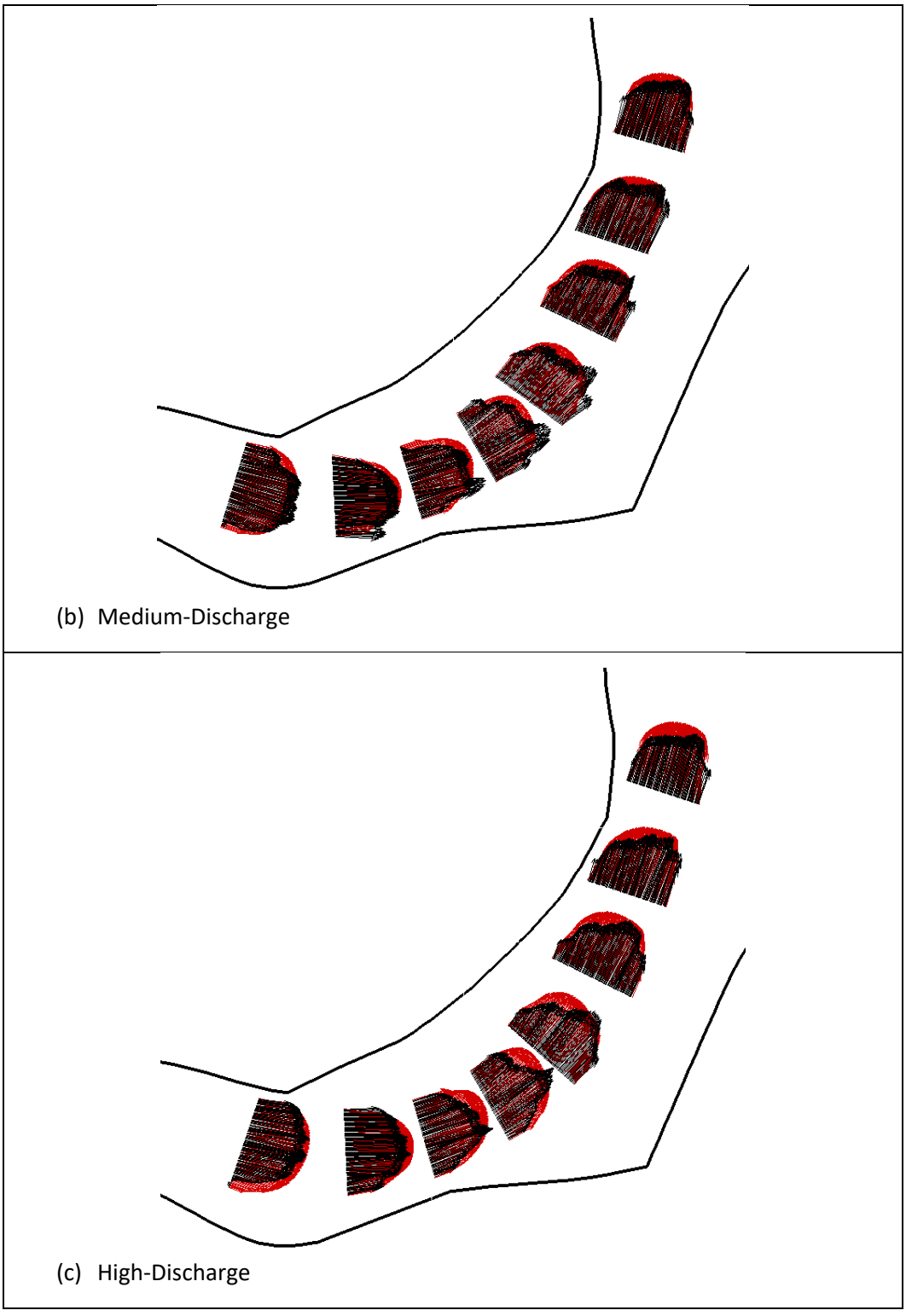


Figure 21. Predicted (Red) and ADCP measured (Black) depth-averaged velocity vectors along eight transects of the Sacramento River for three dates in 2016.

Next, a quantitative evaluation of the model agreement with the ADCP data is carried out. Statistical values of the differences between the model and measured data are computed and reported.

Three error indicators are used to quantify the differences and they are as follows:

(1) Mean Error (ME)

$$ME = \frac{\sum_1^n (data - model)}{n}$$

(2) Absolute Mean Error (AME)

$$AME = \frac{\sum_1^n ABS(data - model)}{n}$$

(3) Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{\sum_1^n (data - model)^2}{n}}$$

In the above n = the number of measurement points, data = the measured values of the variable of interest (e.g., flow velocity), and model = the predicted values of the variable of interest.

The above three error indicators are computed for the two velocity components in the Easting and Northing directions using all data points of the measurement transects. The results are reported in **Table 1** through **Table 3**. The target AME values are usually taken to be 10% of the range of the observed values. It is seen that this target has been met by the present model.

Table 1. Error indicators of the depth-averaged velocity between the model and measured data for all measured data points: the low flow scenario on February 18, 2016. (velocity unit: m/s)

Velocity along the Easting (U)

n points	min	max	range	ME	AME	RMSE
557	0	0.904	0.904	-0.016	0.063	0.090

Velocity along the Northing (V)

n points	min	max	range	ME	AME	RMSE
557	-0.242	0.883	1.125	-0.038	0.068	0.091

Table 2. Error indicators of the depth-averaged velocity between the model and measured data for all measured data points: the medium flow scenario on March 30 18, 2016. (velocity unit: m/s)

Velocity along the Easting (U)

n points	min	max	range	ME	AME	RMSE
689	0.070	0.949	0.879	-0.007	0.066	0.094

Velocity along the Northing (V)

n points	min	max	range	ME	AME	RMSE
689	-0.240	0.971	1.212	-0.0523	0.067	0.085

Table 3. Error indicators of the depth-averaged velocity between the model and measured data for all measured data points: the high flow scenario on March 9, 2016. (velocity unit: m/s)

Velocity along the Easting (U)

npoints	min	max	range	ME	AME	RMSE
719	0.039	1.178	1.140	-0.102	0.119	0.148

Velocity along the Northing (V)

npoints	min	max	range	ME	AME	RMSE
719	-0.288	1.207	1.495	-0.056	0.105	0.126

A popular model evaluation parameter used in the hydraulic modeling community is the so-called Nash-Sutcliffe coefficient of efficiency. It is defined as:

$$E = 1.0 - \frac{\sum_1^n (data - model)^2}{\sum_1^n (data - data\_mean)^2}$$

In the above, *data_mean* is the mean value of all data. The Nash-Sutcliffe efficiency (E) may range from negative infinity to 1.0, and it determines the relative magnitude of residual variance to the measured data variance. The closer E is to 1.0, the more accurate the model is. A value of 1.0 corresponds to a perfect match between the model and observed data. A value of 0.0 suggests that the model prediction is as accurate as the mean of the observed data. If E < 0, the observed mean is a better predictor than the model. The computed E for the present validation modeling is shown in Table 4. The E value is between 0.768 to 0.946 for the two velocity components, respectively, for all three flow scenarios, and it is deemed very good agreement has been achieved.

Table 4. The Nash-Sutcliffe coefficient of the Easting (U) and Northing (V) depth-averaged velocity computed on all measurement points.

	Low-Discharge	Medium-Discharge	High-Discharge
U (Easting)	0.821	0.851	0.768
V (Northing)	0.919	0.946	0.901

In addition, regression analysis is also performed at each measurement transect to compute the correlation coefficient R^2. Plots of the observed versus the predicted velocities may be generated and fit with a straight line, ideally with a slope near one and y-intercept near zero. For velocity, the target R^2 values should be above 0.4, which indicates good agreement between the observed data and the model. It is commented that the Nash-Sutcliffe coefficient E is comparable to R^2, but R^2 is better suited to evaluate goodness-of-fit because R^2 is insensitive to the differences between model simulations and observations (Legates and McCabe Jr., 1999). E value may become too sensitive to extreme values. In the event that a dataset does contain extreme values, a modified approach as suggested by Harmel and Smith (2007) may be adopted (not used in this study).

The R^2 analysis plots are shown in **Figure 22**. The R^2 values for all six plots range from 0.843 to 0.969, which again points to a good overall agreement between the model and the measured data. These plots are particularly noteworthy as measured data were taken across the river width and thus include near bank values. Near bank values are often not measured or included because such values often are not replicated well by models due to underlying bathymetry data limitations. Thus, the 2D model output is representative of the magnitude and even direction of the measured velocity field.

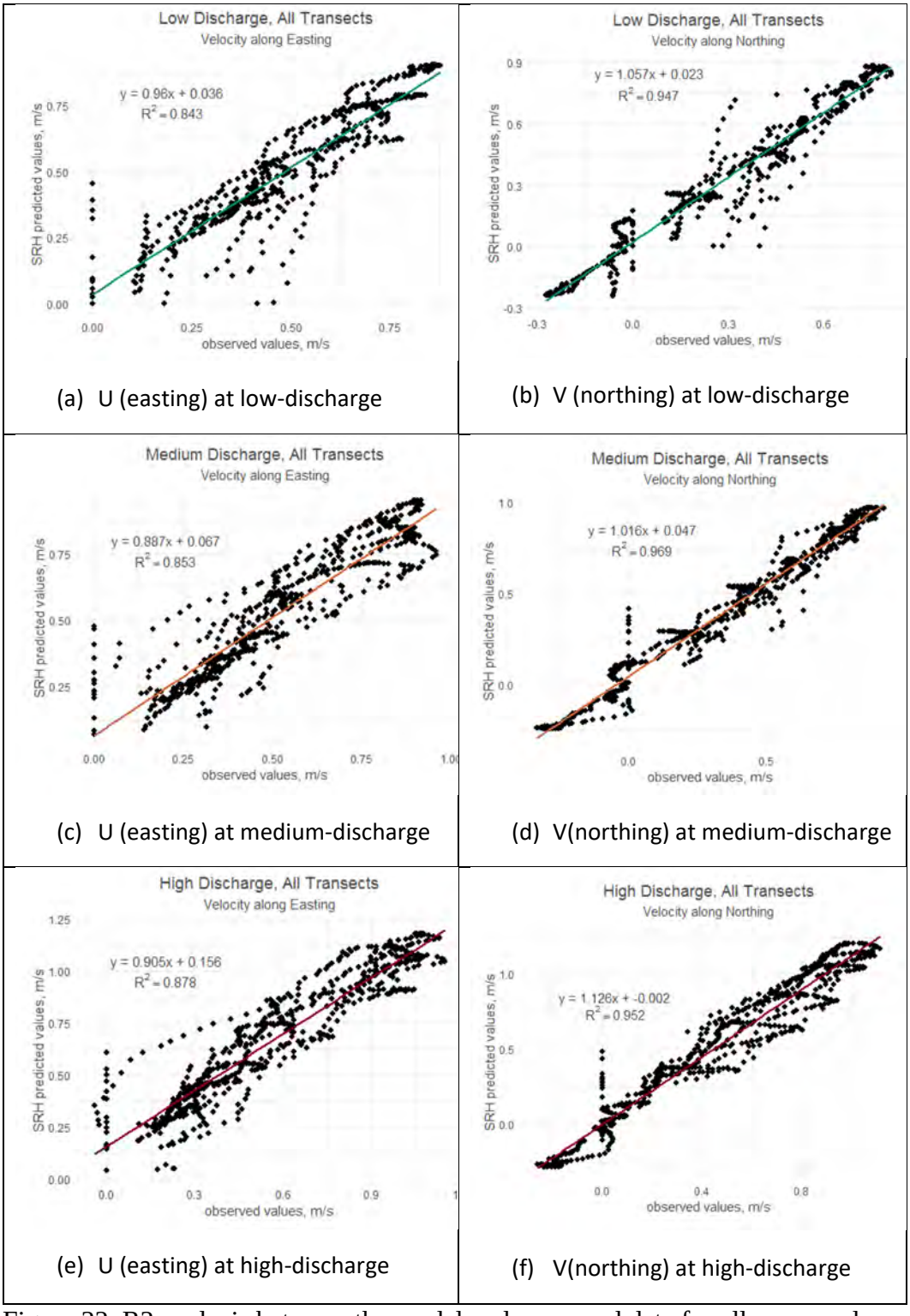


Figure 22. R2 analysis between the model and measured data for all measured points and for three flow scenarios.

In summary, both qualitative and quantitative analyses show that that the expanded Fremont model is reliable in predicting the flow discharge, river stage, and the velocity distributions in the river. Even velocity in the sharp bend may be predicted well by the present model.

5. Model Application for Notch Optimization Options

In this chapter, the expanded Fremont model is applied to compute the flow hydrodynamics of different options of the notch placed to increase fish entrainment from the Sacramento River to Yolo Bypass, now that the model is developed and validated. The simulated results are used by ELAM to predict the fish movement and entrainment through the notch of different options. Such application modelling is predictive and cannot be verified against measured data at the site.

5.1 Notch Configuration and Optimization Options

A general description of the original EIR/EIS notch alternative was provided in Lai (2017a; b). Basically, each EIR/EIS alternative includes a floodplain inundation channel at a unique location on the Fremont Weir connecting the Sacramento River to the Yolo Bypass. The intent is to purposely entrain juvenile salmon from the Sacramento River and pass them to the Yolo Bypass floodway. A specific location has been selected by the team for further optimization studies: the EIR/EIS Alternative 1 on the east location of the Fremont Weir (depicted in **Figure 23**). Note that three alternative locations and six total alternative designs were proposed and investigated in our previous studies (see **Figure 23** for their locations); but this study has narrowed down to only one. At the east location, a number of channel optimization options were developed by DWR and USACE based on the previous modeling study results and they are simulated.

Previous modeling efforts by DWR concluded that 6,000 cfs was the preferred maximum flow amount used for floodplain inundation in coordination with other programs such as Cal Waterfix. If up to 6,000 cfs were maintained to enter the Yolo Bypass at Fremont Weir, there would be a control structure with components such as inlet transition, gates, head works structure, access structure (pedestrian, vehicle), and outlet transition. The gate details are based on the 2017 study; only the inundation area and approach channel are optimized in this study.



Figure 23. Three locations of the EIR/EIS notches.

The EIR/EIS Alternative 1 is located on the east section of the Fremont Weir (see **Figure 23**) and consists of two parts: the approach channel and the gate. The gate is the same as that reported in Lai (2017b), while the approach channel design is different. A total of nine (9) channel optimization options are simulated. The invert of the gate is 14 ft and 18 ft on the right and left entries, respectively (looking towards Yolo Bypass), as shown in **Figure 24**. It is the same for all approach channel options.

Nine model terrains are developed for the application modeling; they are developed by combing the existing-condition model terrain discussed in Chapter 3 with the nine optimization options of the approach channels. The nine terrains are labeled as Original, optimization Options 1 through 4, and optimization Options 1B through 4B. Each terrain option is discussed below.

The terrain of the Original option is developed by combing the notch geometry of EIR/EIS Alternative 1 studied in Lai (2017b) (see **Figure 24**) with the expanded Fremont existing-condition terrain discussed in Chapter 3. The final terrain of the Original option in the notch area is displayed in **Figure 25**. This terrain is named Original notch option. The 2D mesh of the Original option is generated by modifying the existing-condition expanded model. A close-up view of the mesh is shown in **Figure 26**.

The terrain of the optimization Options 1 through 4 are developed by DWR and USACE; the raw data are shown in **Figure 27**. These terrains are merged into the Original option terrain (**Figure 25**) to produce the final terrains for each channel optimization options. Close-up views of the final terrains in the notch area for Options 1 through 4 are shown in **Figure 28**.

The terrain of the channel Options 1B through 4B are the same as the corresponding Options 1 through 4 except that a berm is added on the left bank of the Sacramento River opposite to the notch. The berm terrain is shown in **Figure 29**. The final terrains for Options 1B through 4B are developed from the corresponding Options 1 to 4 by adding the berm terrain in place of the existing terrain. The final terrains of Option 1B through 4B are also displayed in **Figure 28**.

2D meshes are developed for the eight new optimization options. Actually, only two new distinctive meshes are needed: one mesh is used for Options 1, 1B, 2, 2B, 4 and 4B and the other is for Option 3 and 3B. Close-up views of the two meshes in the notch area are shown in **Figure 30**.

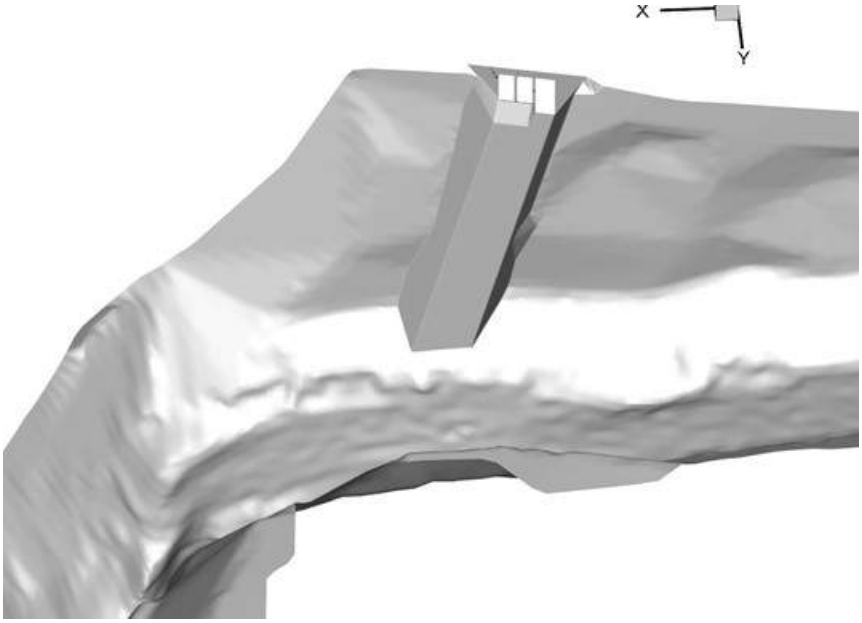


Figure 24. Gate geometry of EIR/EIS Alternative 1 viewed in a 1:5 vertical distorted scale; it is based on the CAD model developed by DWR (top is Yolo Bypass side; bottom is Sac River; main gate invert is 14 ft; elevated gate invert is 18 ft).

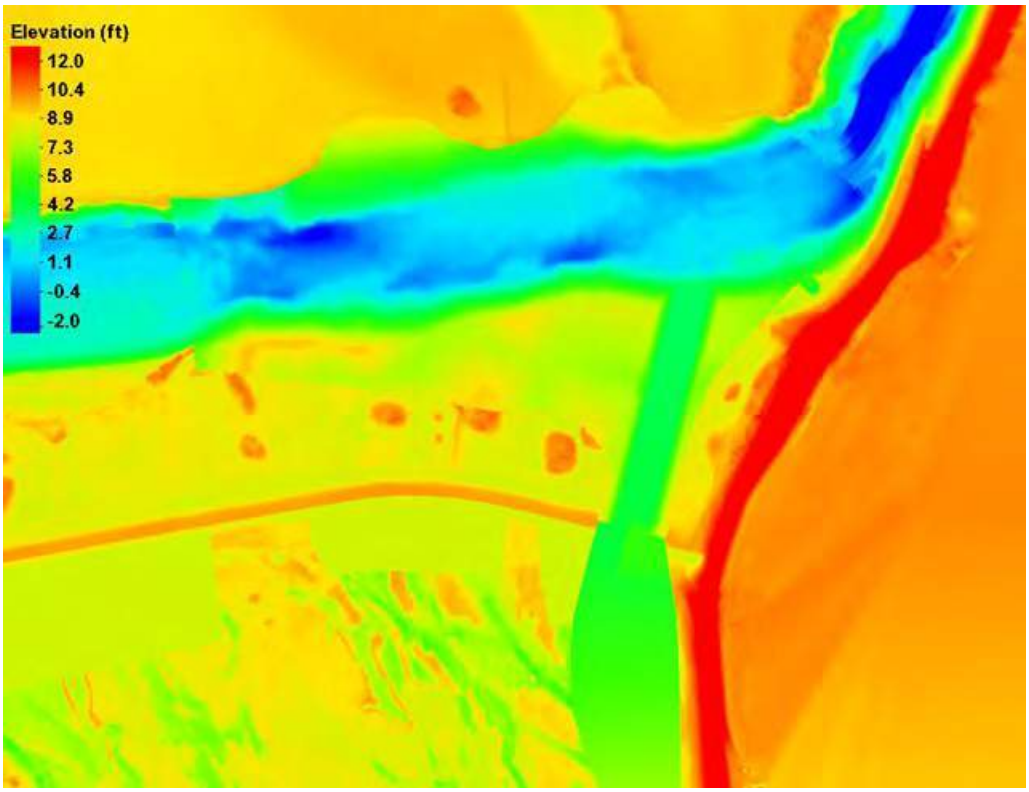
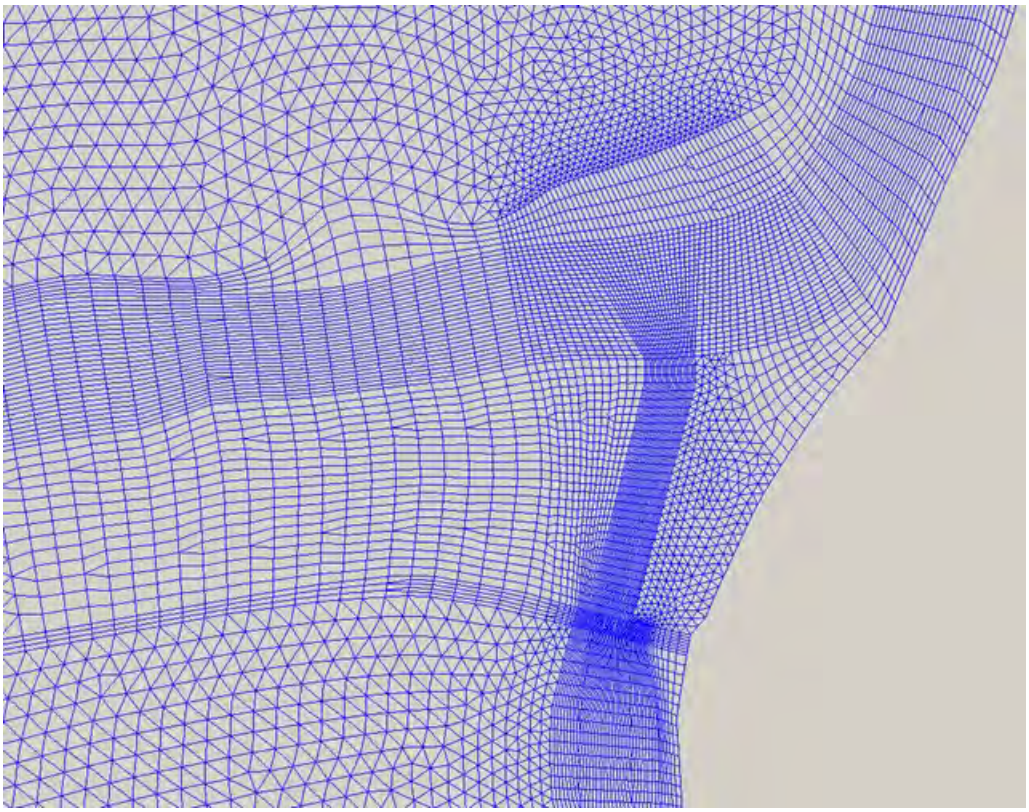
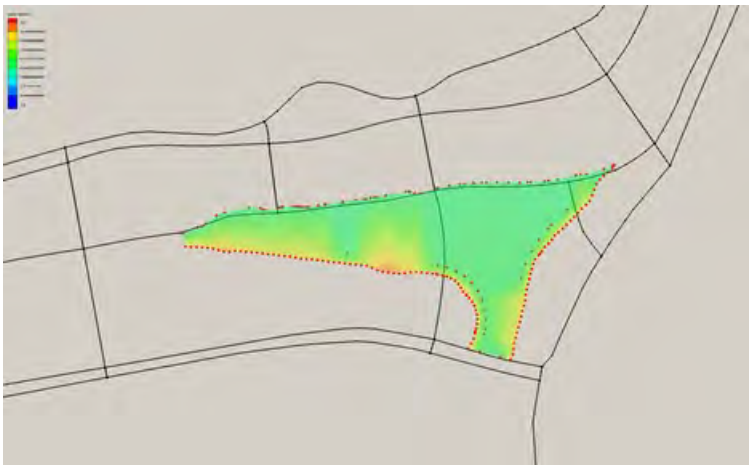


Figure 25. Original option terrain for the EIR/EIS Alternative 1 alternative.

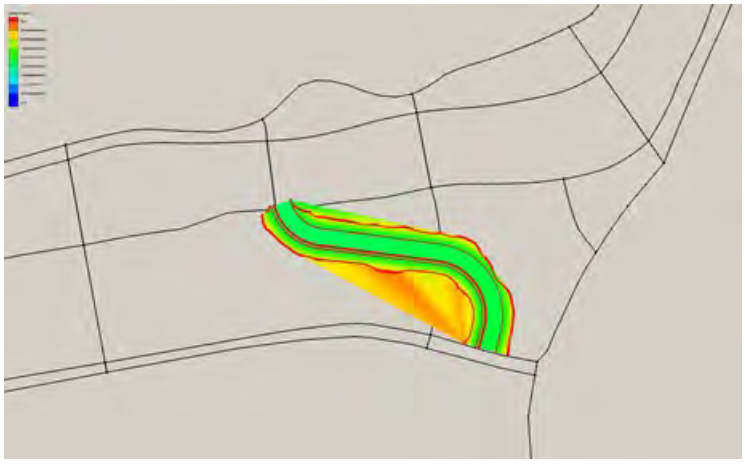

Figure 26. A close-up view of the Original option mesh in the notch area.



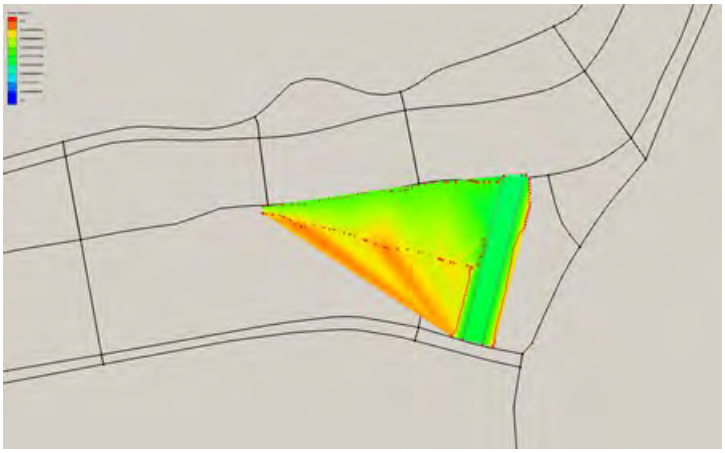
(a) Option 1



(b) Option 2

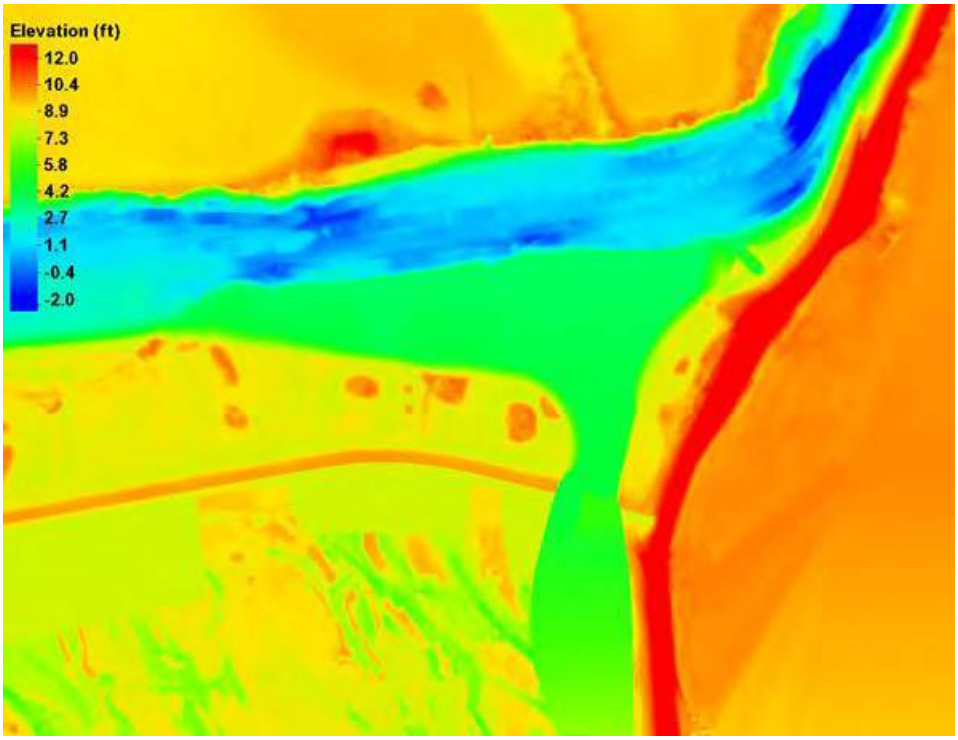


(c) Option 3

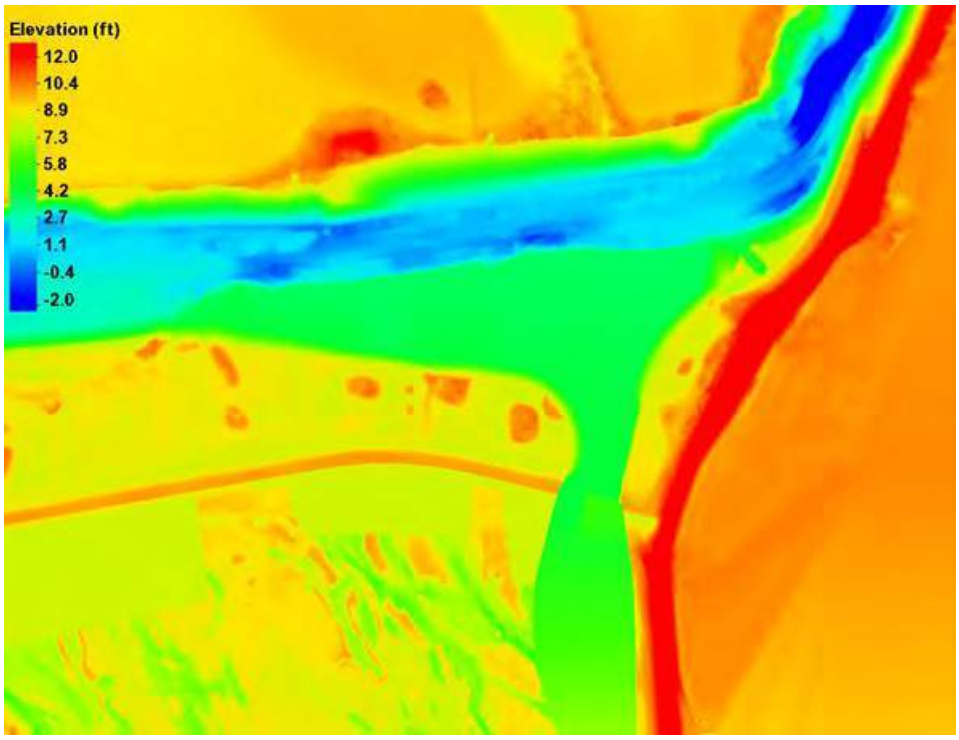


(d) Option 4

Figure 27. The terrain/geometry of the four optimization options developed by DWR and USACE.



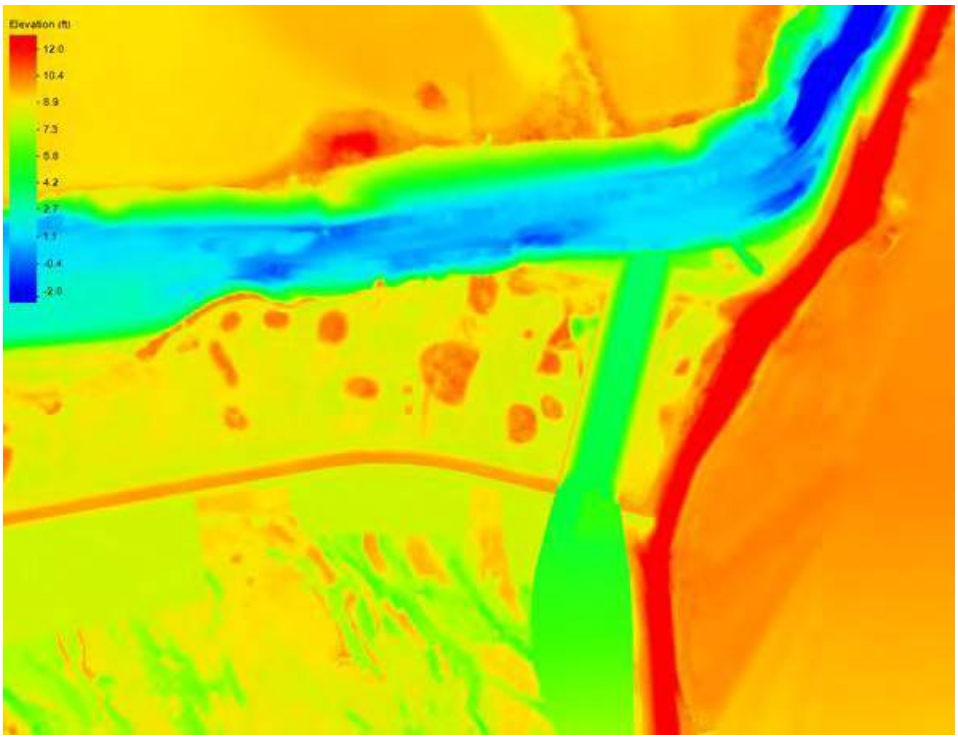
(a) Option 1



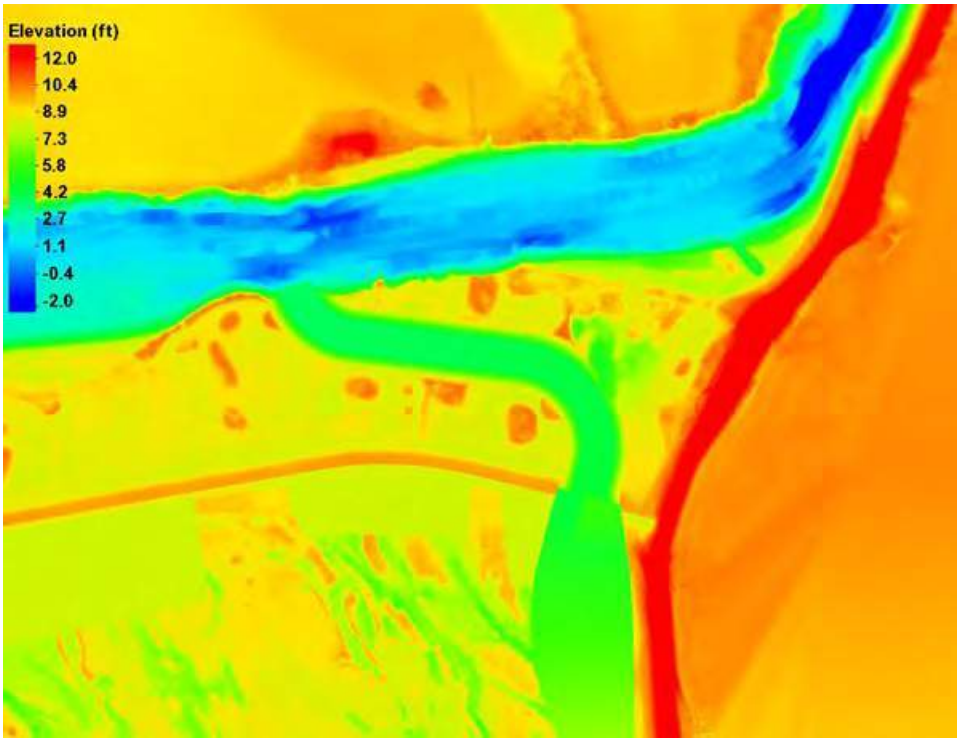
(b) Option 1B



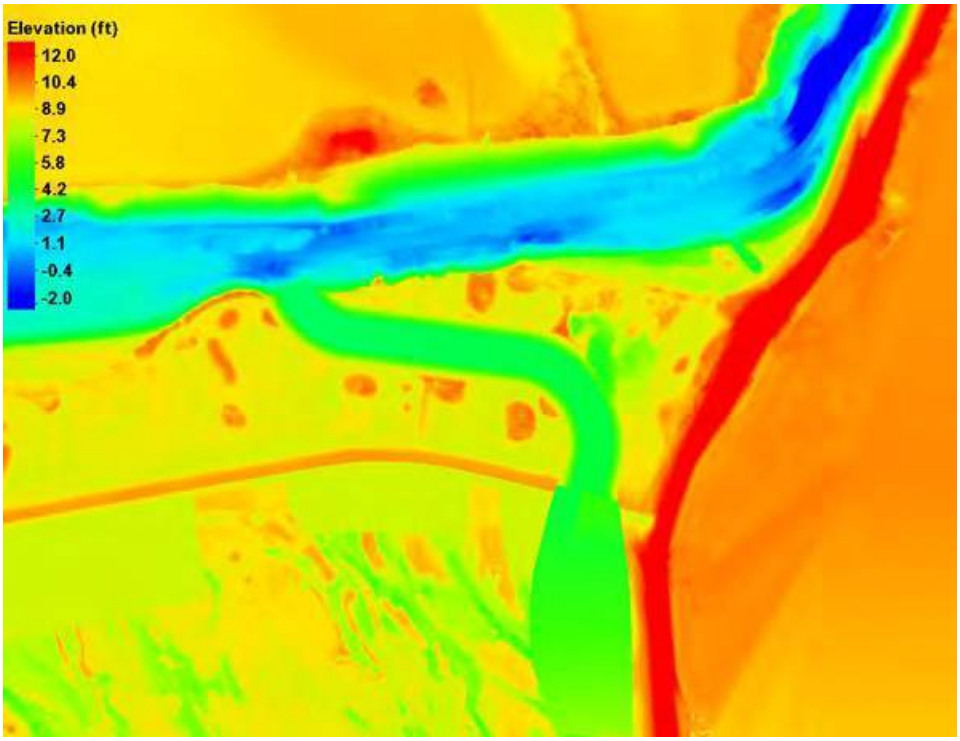
(c) Option 2



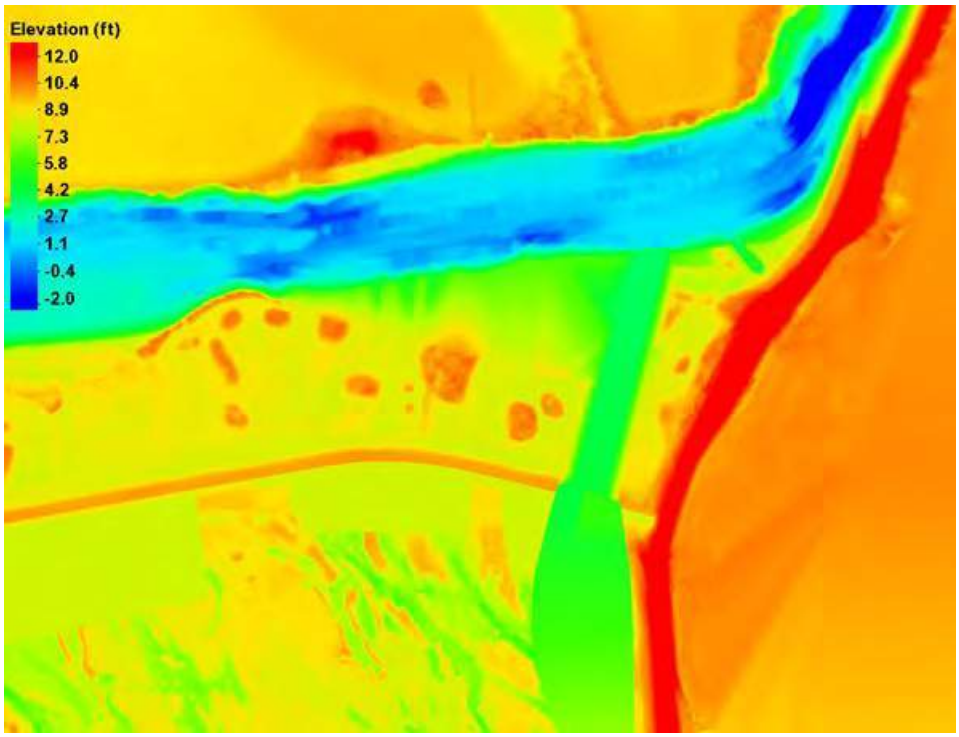
(d) Option 2B



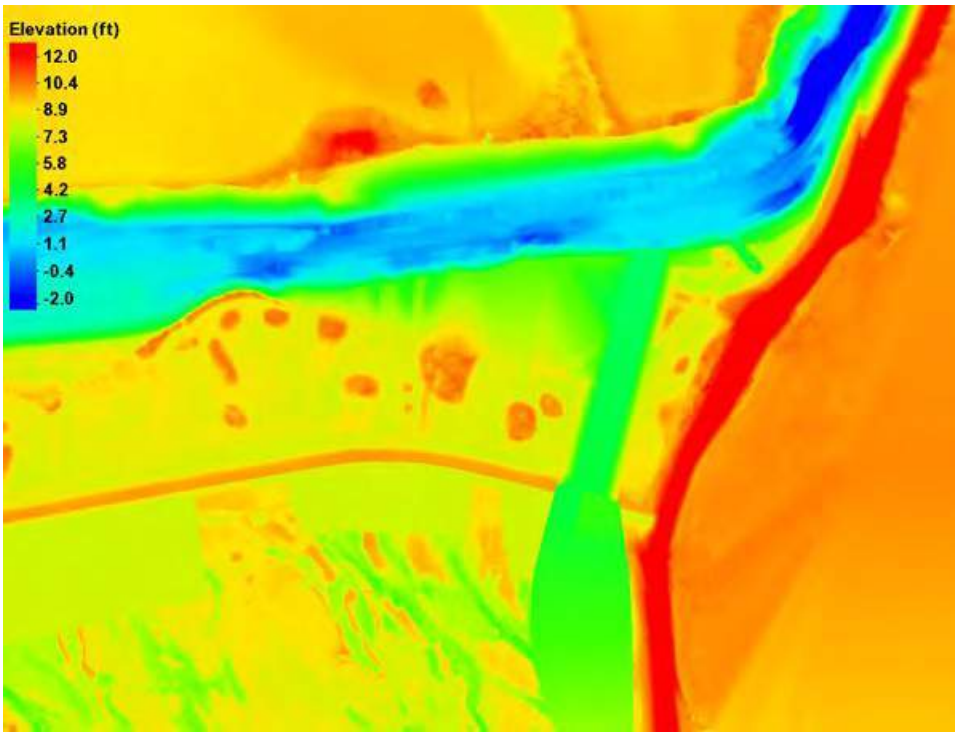
(e) Option 3



(f) Option 3B



(g) Option 4

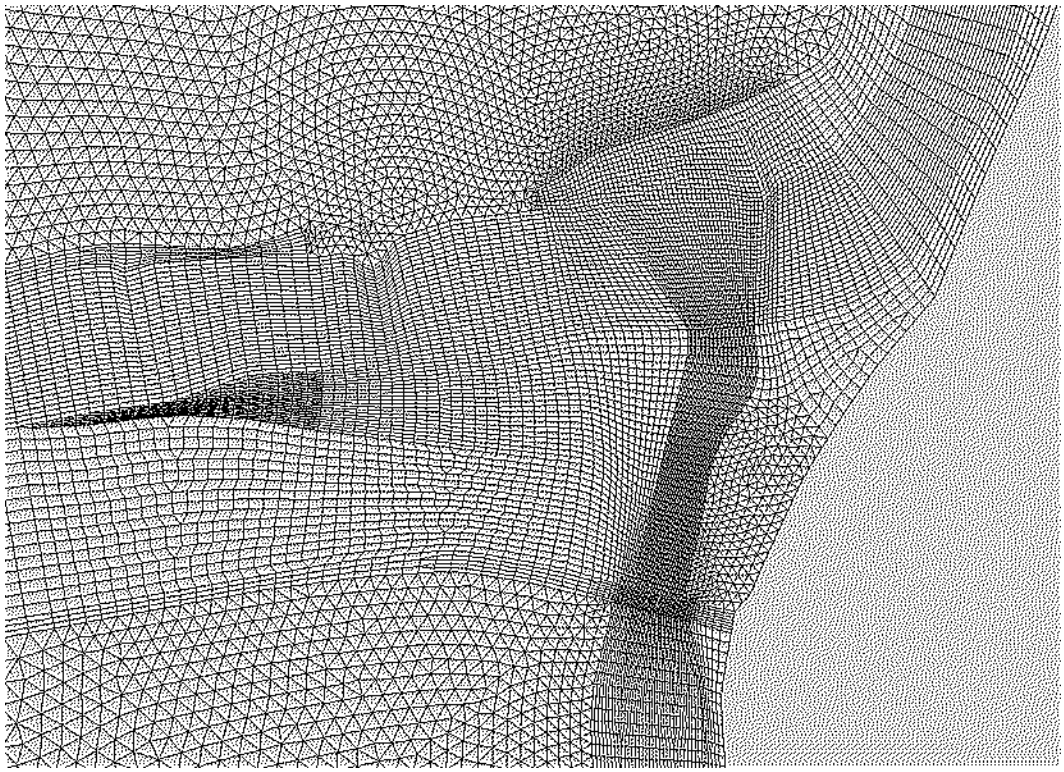


(h) Option 4B

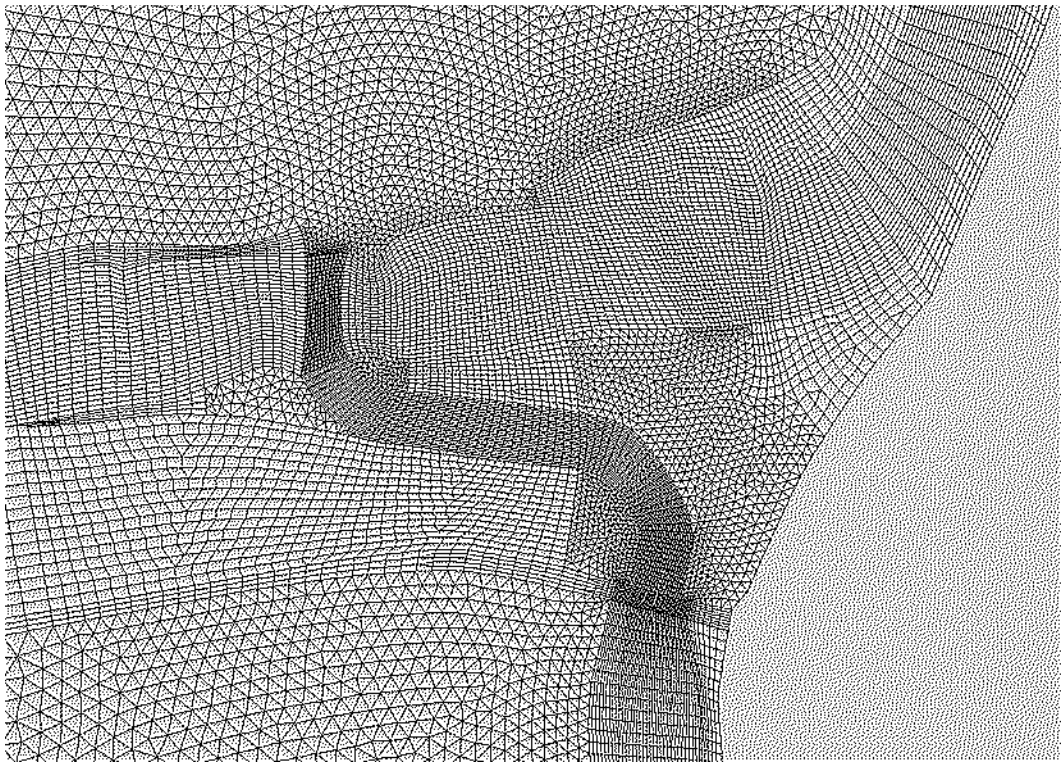
Figure 28. Final composite terrains used for the eight optimization options 1 through 4 and 1B through 4B.



Figure 29. The terrain of the berm inserted into the river left, opposite to the notch, as developed by DWR and used in the modeling.



(a) Option 1, 1B, 2, 2B, 4 and 4B



(b) Option 3 and 3B

Figure 30. Two new meshes developed for the eight new optimization options.

5.2 Flow Scenarios

Six flow scenarios are selected for modeling for each approach channel optimization options, leading to a total of 54 model runs. These flow scenarios represent the actual flow conditions at the study reach at different times of the 2016 Spring flow period. The six flows are such determined that the discharges through the notch are approximately 1,000, 2,000, 3,000, 4,000, 5,000 and 6,000 cfs. They correspond to the following times in the 2016 flow hydrograph: (1) 8:00 am, January 18; (2) 1:00 am, January 19; (3) 18:00 pm, January 19; (4) 10:00 am, January 20; (5) 0:00 am , January 21; and (6) 14:00 pm, January 21.

Key flow discharges and stages for the six scenarios are tabulated in Table 5. Note that the stage is based on the NAVD88 datum and comparable to the Fremont Weir gauge data. The other discharges at the open boundaries are tabulated in Table 6 as they are used as the boundary conditions.

Table 5. Flow discharges and stages at key locations for the selected six flow scenarios.

	Approximate discharge (cfs) through the Notch	Discharge (cfs) at Knights Landing	Stage (ft) upstream of the gate	Stage (ft) at the Fremont Gauge Station
Scenario 1	1,000	22,029	21.67	22.74
Scenario 2	2,000	23,869	23.47	24.70
Scenario 3	3,000	25,258	24.67	25.84
Scenario 4	4,000	25,696	25.88	26.93
Scenario 5	5,000	25,988	26.98	27.95
Scenario 6	6,000	25,846	27.89	28.81

Table 6. Key discharges and stage used as the boundary conditions at the model open boundaries.

	Stage (ft) at VON	Discharge (cfs) at Feather	Discharge (cfs) at Sutter	Discharge (cfs) at Sac Slough	Discharge (cfs) at Natoma
Scenario 1	20.04	7,297	0.0	0.0	1,048
Scenario 2	22.64	7,329	164	177	858
Scenario 3	23.70	16,464	723	175	1,034
Scenario 4	24.90	20,234	3,971	948	652
Scenario 5	26.20	20,290	5,342	1,024	793
Scenario 6	27.10	24,644	8,142	1,290	401

5.3 SRH-2D Model Results

A total of nine notch optimization options are studied and each is simulated with six flow conditions as described above. A large amount of hydrodynamic data sets have been generated with the SRH-2D simulation. A primary purpose of the hydrodynamic modeling is to predict the flow field under different notch options so that ELAM modeling may be carried out to predict fish movement. Therefore, no detailed discussions of the flow results are made in this report. Instead, predicted flow patterns in the notch area presented in graphical forms. They are presented for documentation purpose.

5.3.1 Original Notch Option

The original notch option is the EIR/EIS Alternative 1 studied in Lai (2017b); it is simulated to reflect the new 2016 flow hydrology.

The terrain and the mesh for the Original Option are displayed in **Figure 31** and **Figure 32**. The approach channel is “intake” type. The gate structure consists of two parts: a primary gate having an invert elevation of 14 ft NAVD88 and two secondary gates with 18 ft NAVD88 invert. Note that this same gate is used for all notch options presented below.

The flow through the gate is an additional boundary condition and it is obtained using a rating curve provided from DWR. The rating curve computes the flow discharge through the notch given the stage upstream of the gate; it is shown in **Figure 33**. The design maximum flow through the gate structure is about 6,000 cfs; it occurs at an upstream stage of 27.844 ft.

The predicted flow patterns and velocities are displayed in **Figure 34** for all six flow scenarios. A visual inspection shows that a larger percentage of flow areas in the Sacramento River is entrained through the notch with increasing flow rate through the gate, which should lead to a higher fish entrainment rate. The flow patterns are also different at different notch flows which may impact the fish movement behaviors. ELAM modeling will take these flow pattern changes into account and the impact on fish movement is predicted.

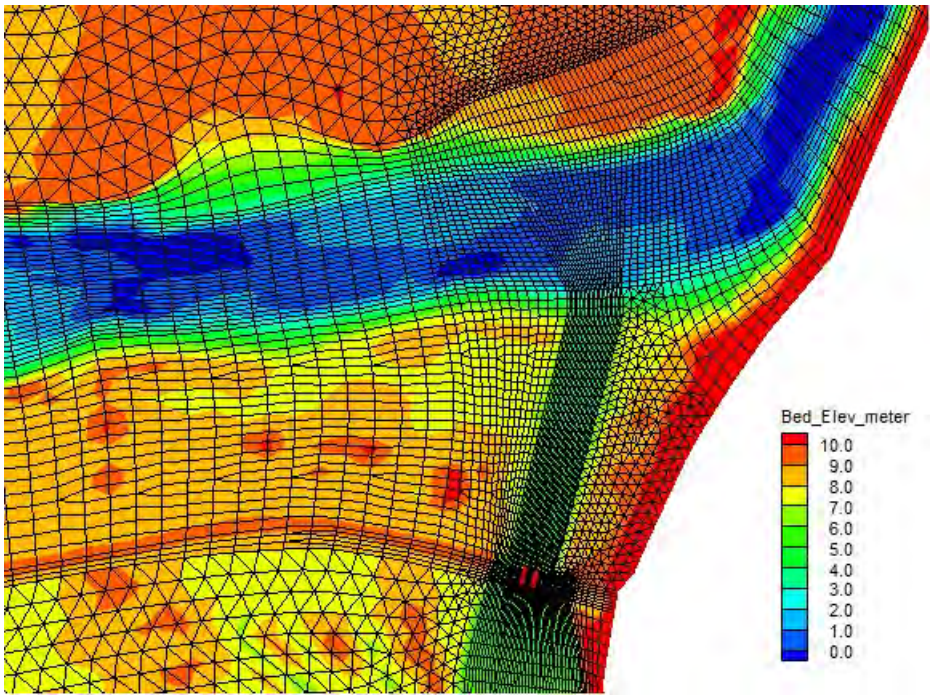


Figure 31. Option Original: planar view of the terrain and mesh in the notch area.

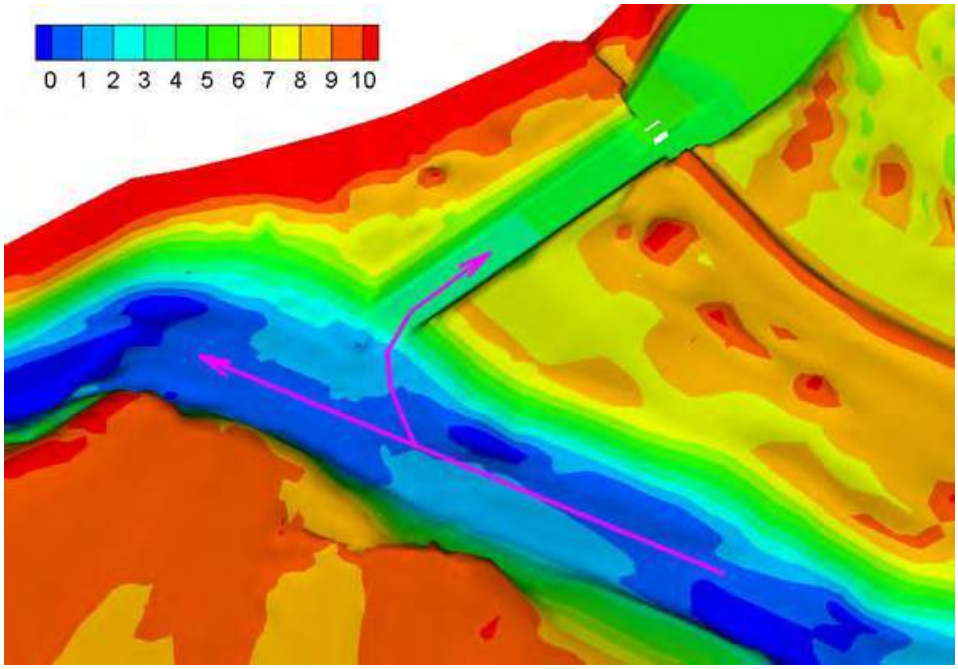


Figure 32. Option Original: terrain 3D view in the notch area.

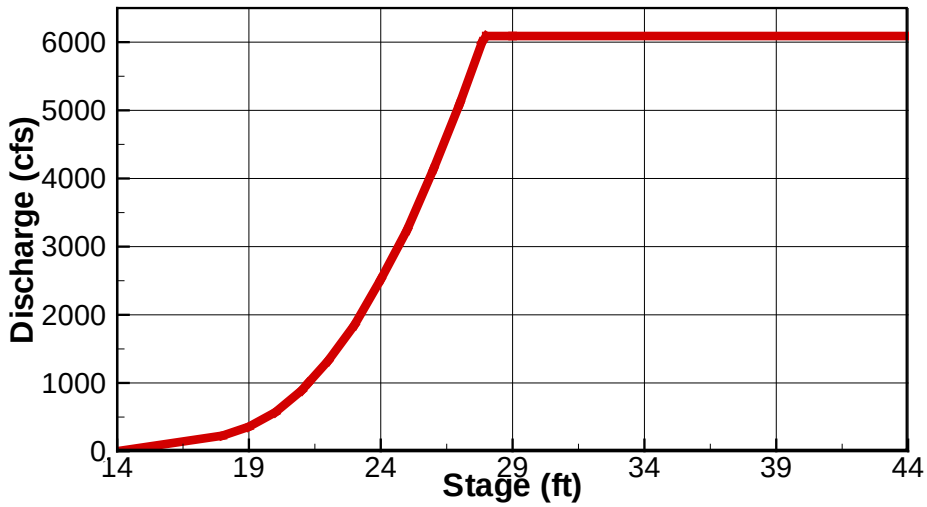
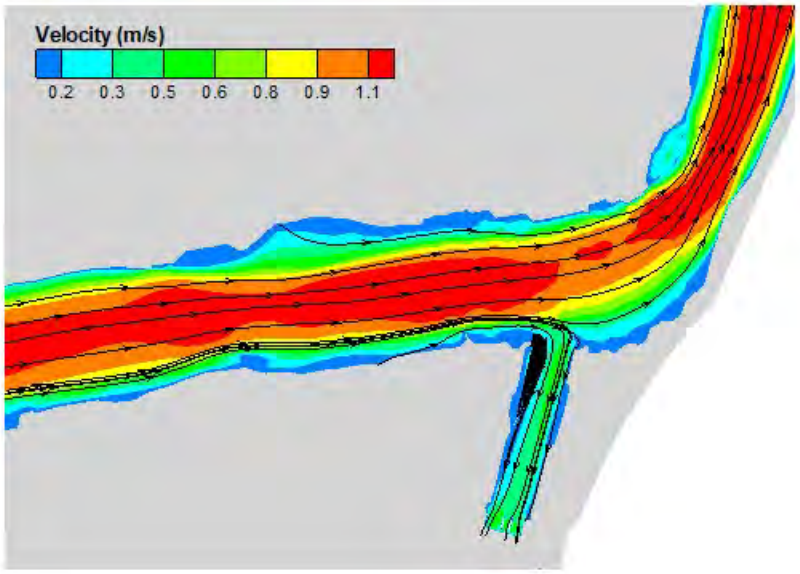
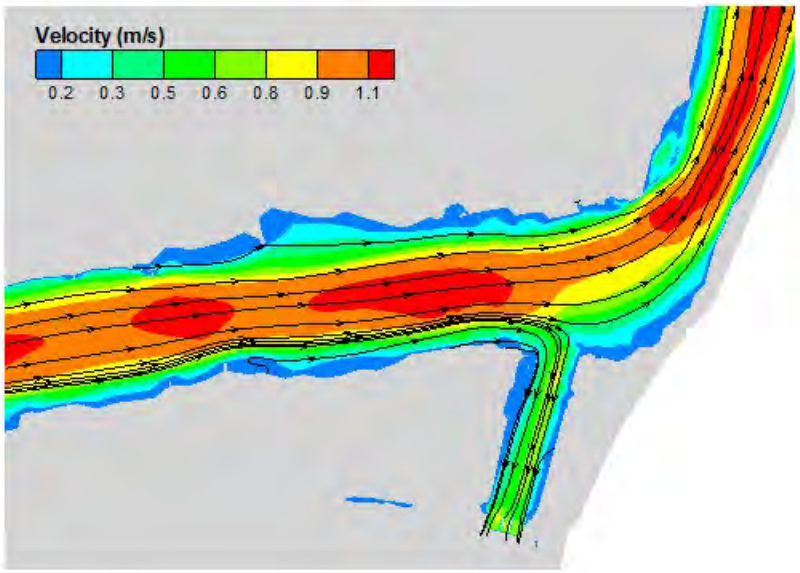


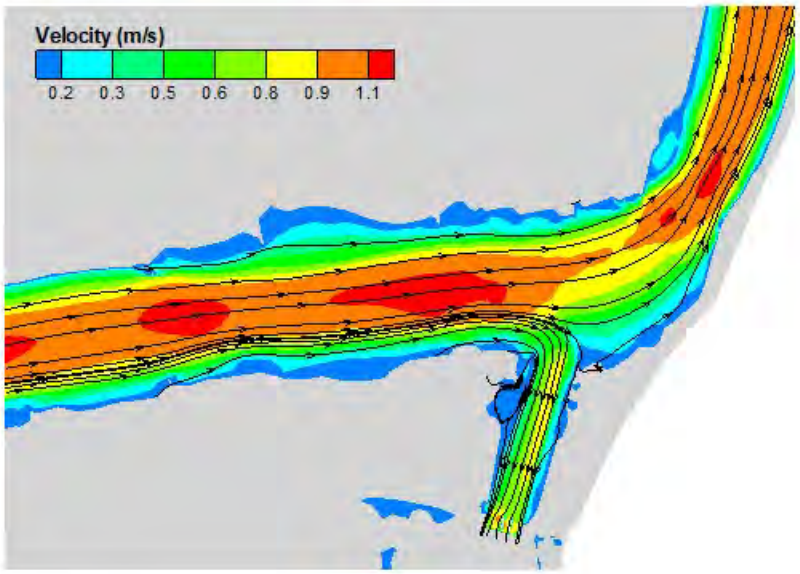
Figure 33. Rating curve used for the flow through the notch/gate.



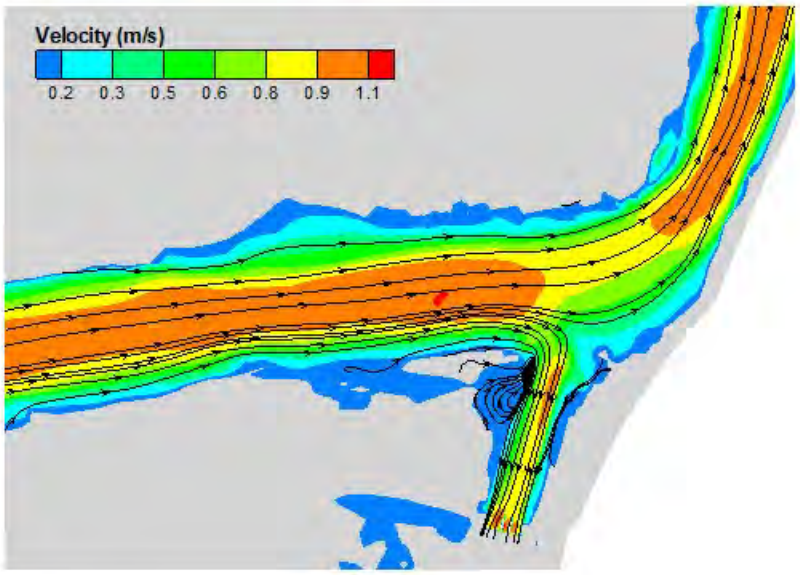
(a) Flow scenario 1



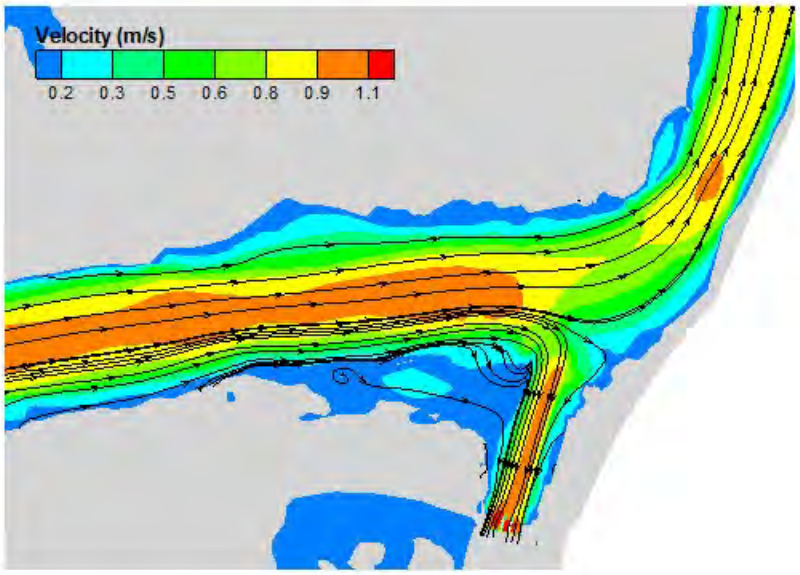
(b) Flow scenario 2



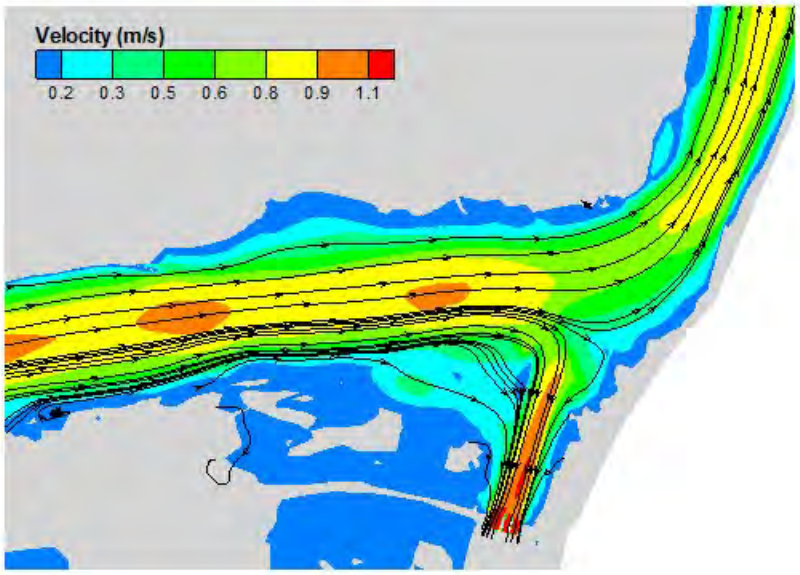
(c) Flow scenario 3



(d) Flow scenario 4



(e) Flow scenario 5



(f) Flow scenario 6

Figure 34. Predicted flow velocity and pattern near the notch for the Original option.

5.3.2 Notch Options 1 and 1B

The terrain and the mesh for Options 1 and 1B are displayed in **Figure 35** and **Figure 36**. The predicted flow patterns and velocities are displayed in **Figure 37** for all six flow scenarios.

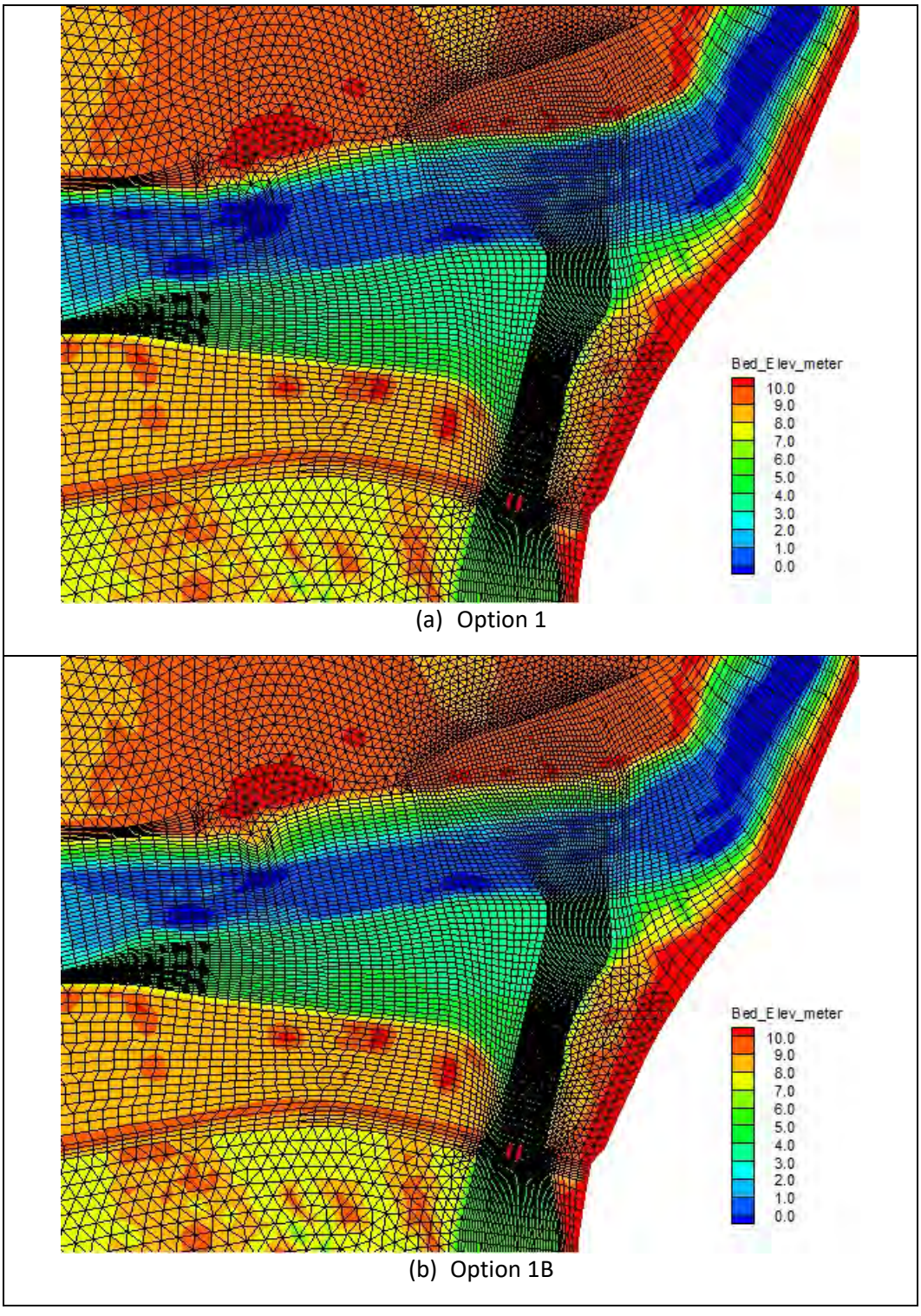


Figure 35. Options 1 and 1B: planar views of the terrain and mesh in the notch area.

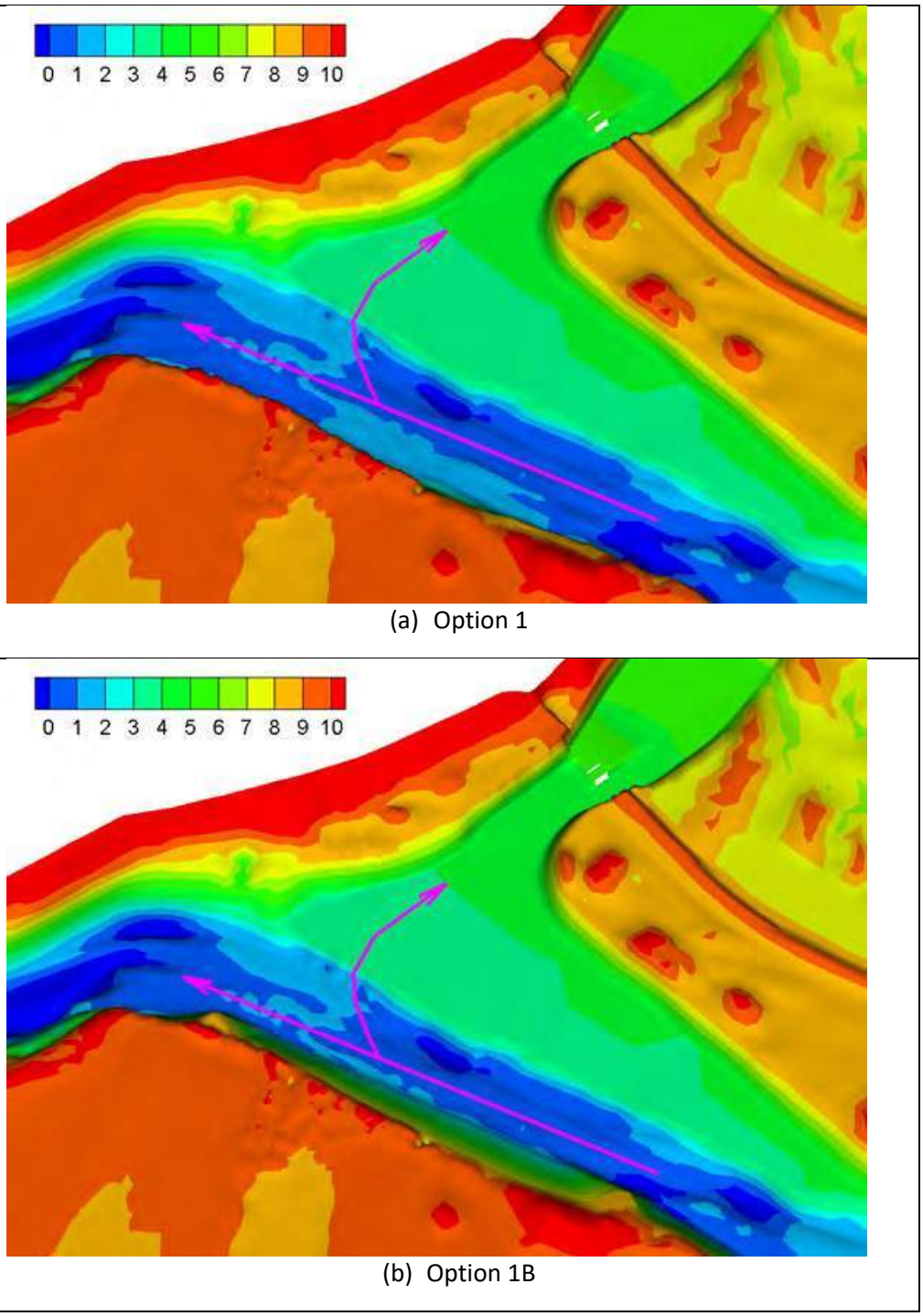
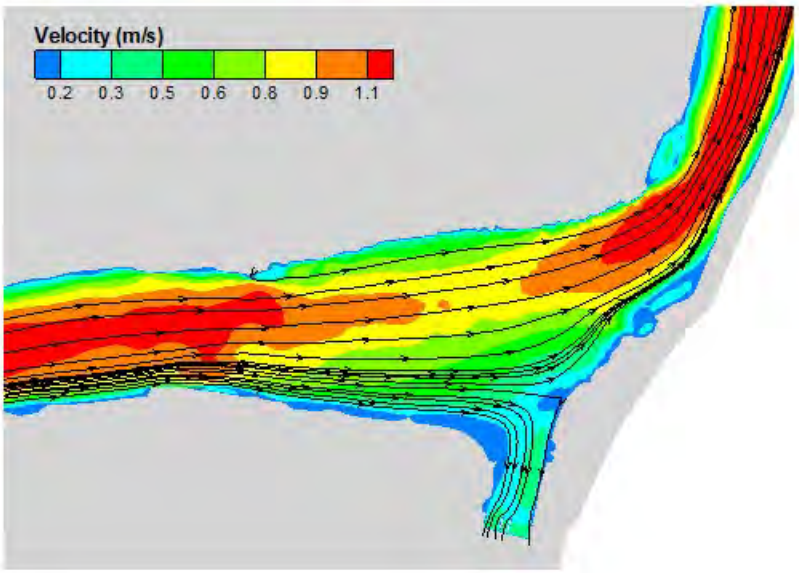
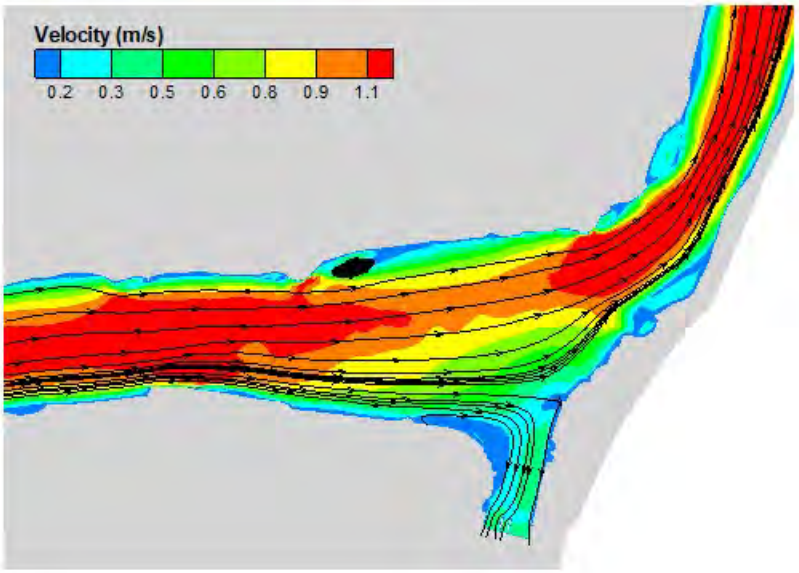


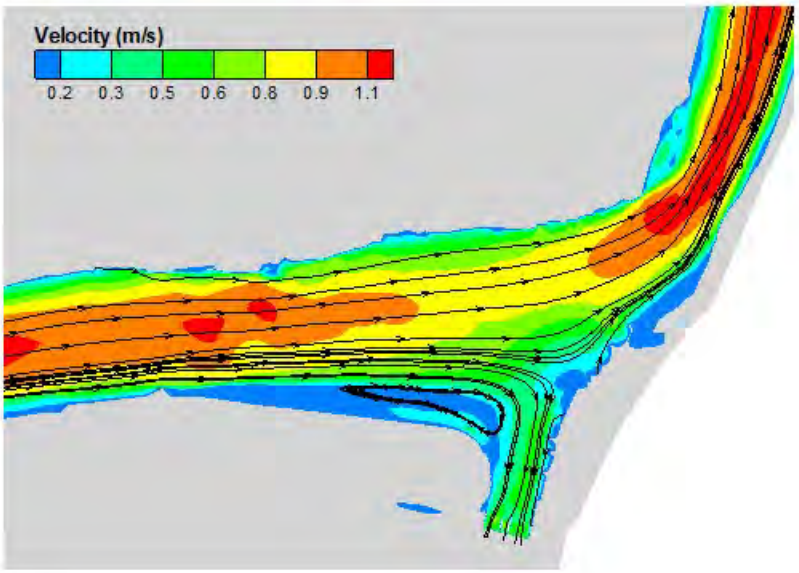
Figure 36. Option 1 and 1B: 3D views of the terrain in the notch area.



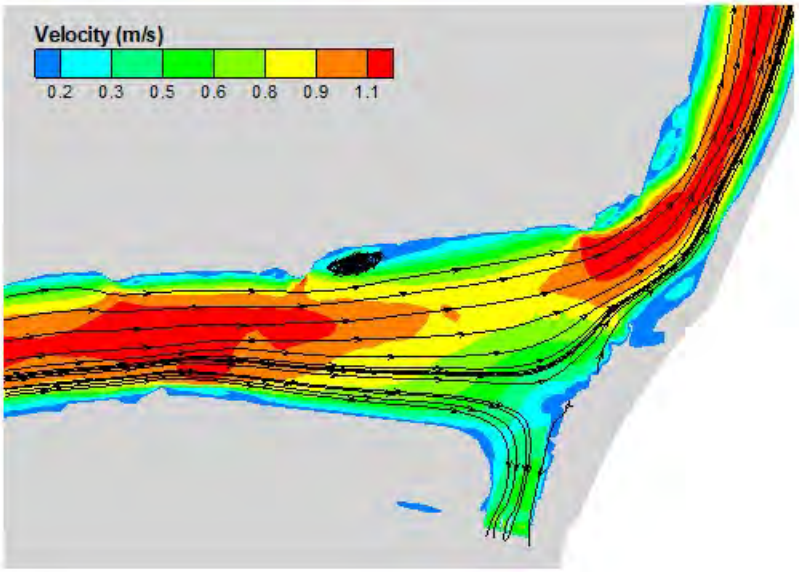
(a) Option 1 and Flow scenario 1



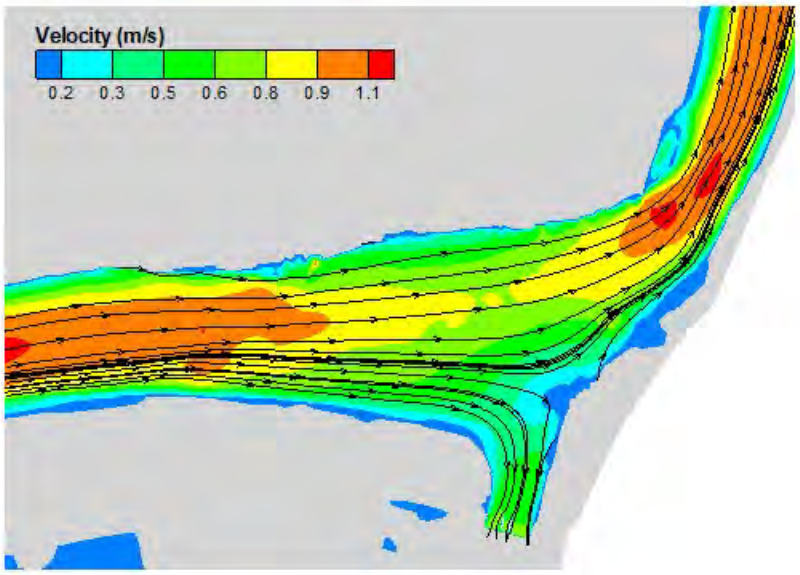
(b) Option 1B and Flow scenario 1



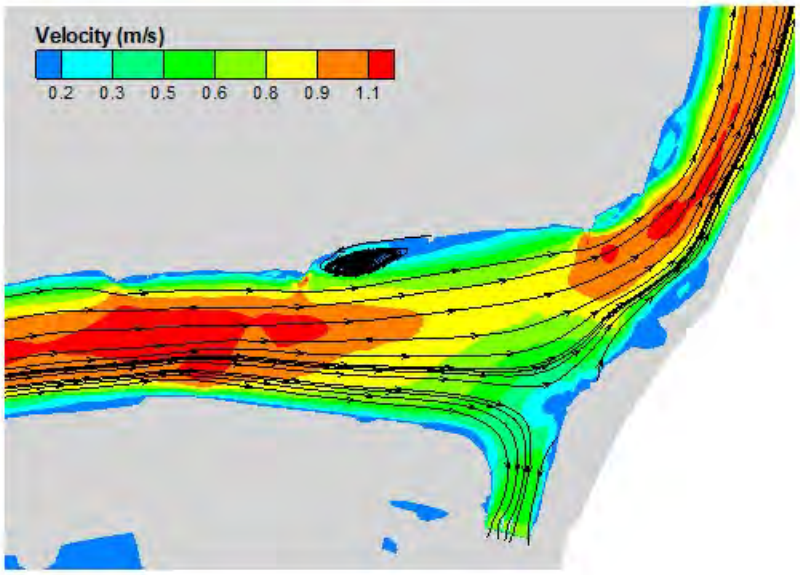
(c) Option 1 and Flow scenario 2



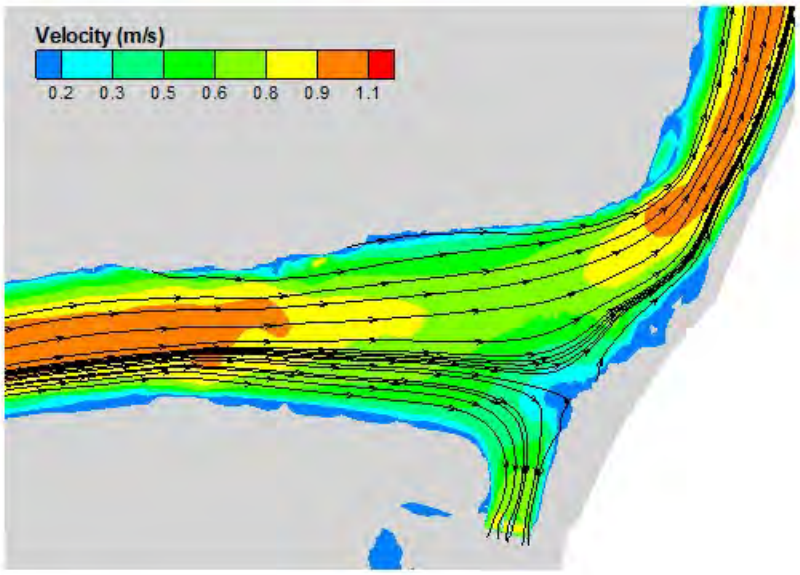
(d) Option 1B and Flow scenario 2



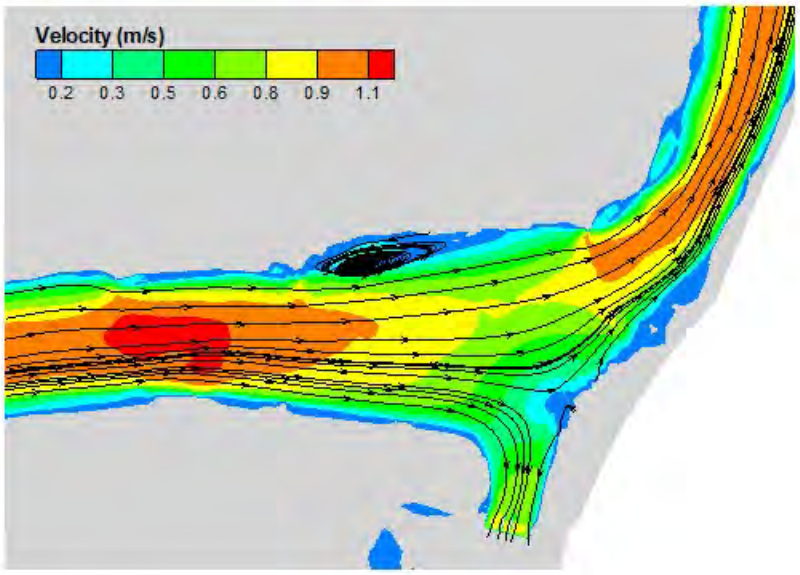
(e) Option 1 and Flow scenario 3



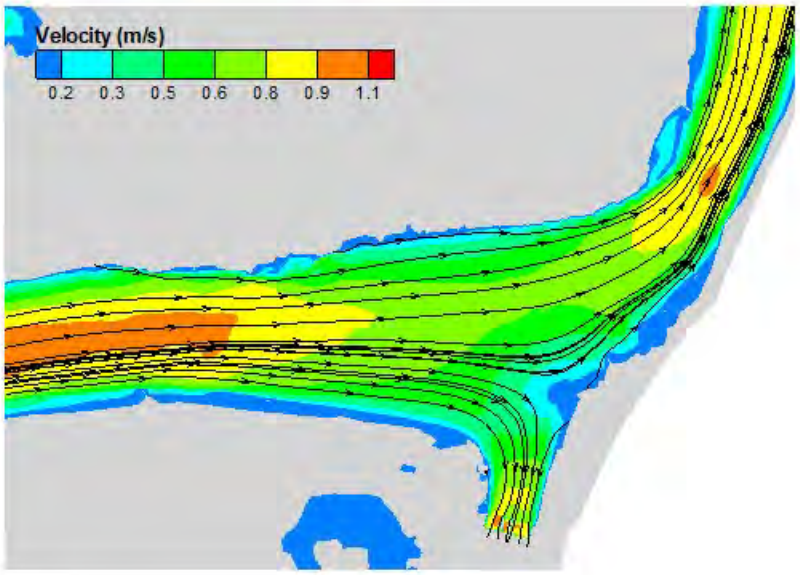
(f) Option 1B and Flow scenario 3



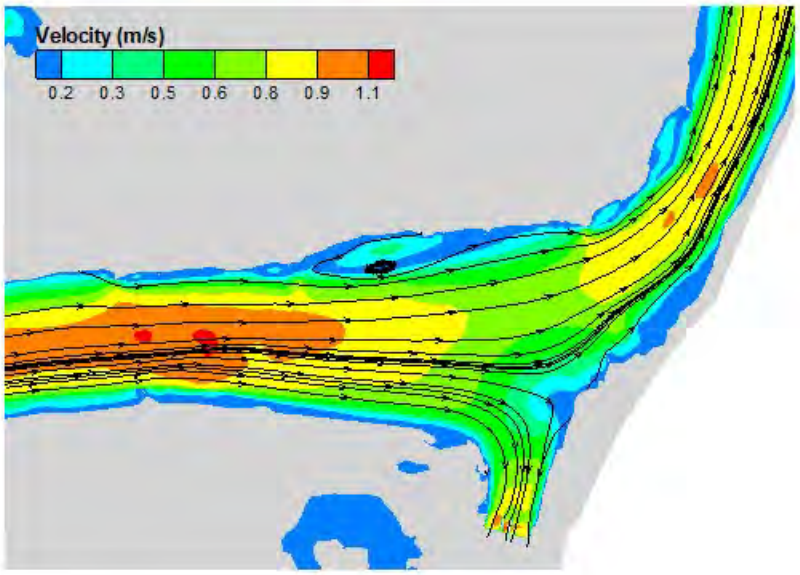
(g) Option 1 and Flow scenario 4



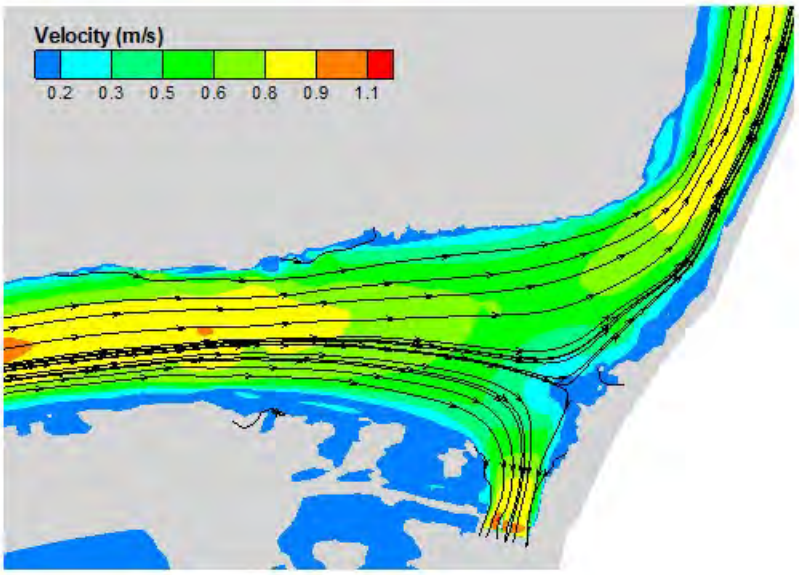
(h) Option 1B and Flow scenario 4



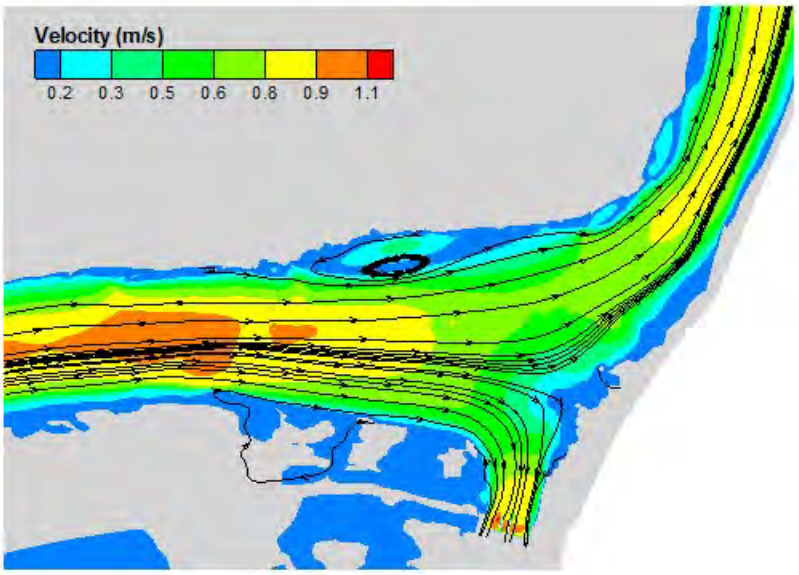
(i) Option 1 and Flow scenario 5



(j) Option 1B and Flow scenario 5



(k) Option 1 and Flow scenario 6

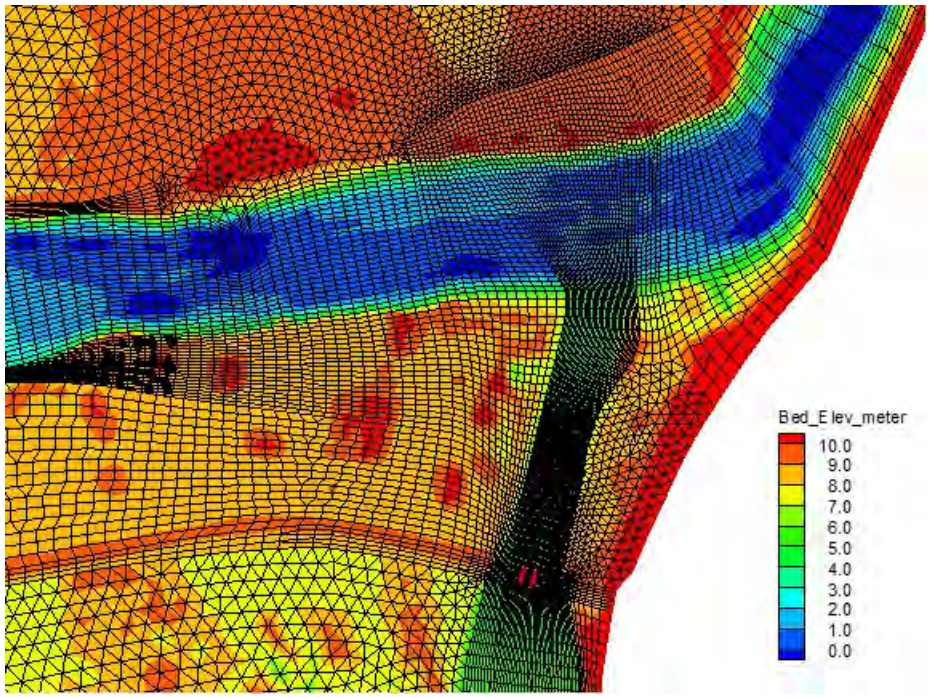


(l) Option 1B and Flow scenario 6

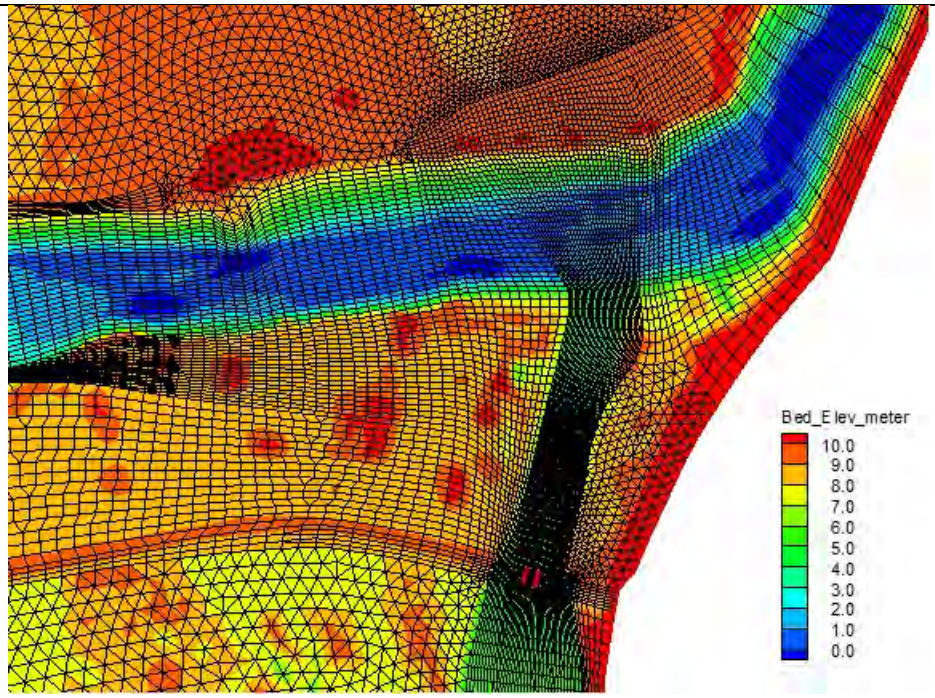
Figure 37. Predicted flow velocity and pattern near the notch for Options 1 and 1B.

5.3.3 Notch Options 2 and 2B

The terrain and the mesh for Options 2 and 2B are displayed in **Figure 38** and **Figure 39**. The predicted flow patterns and velocities are displayed in **Figure 40** for all six flow scenarios.

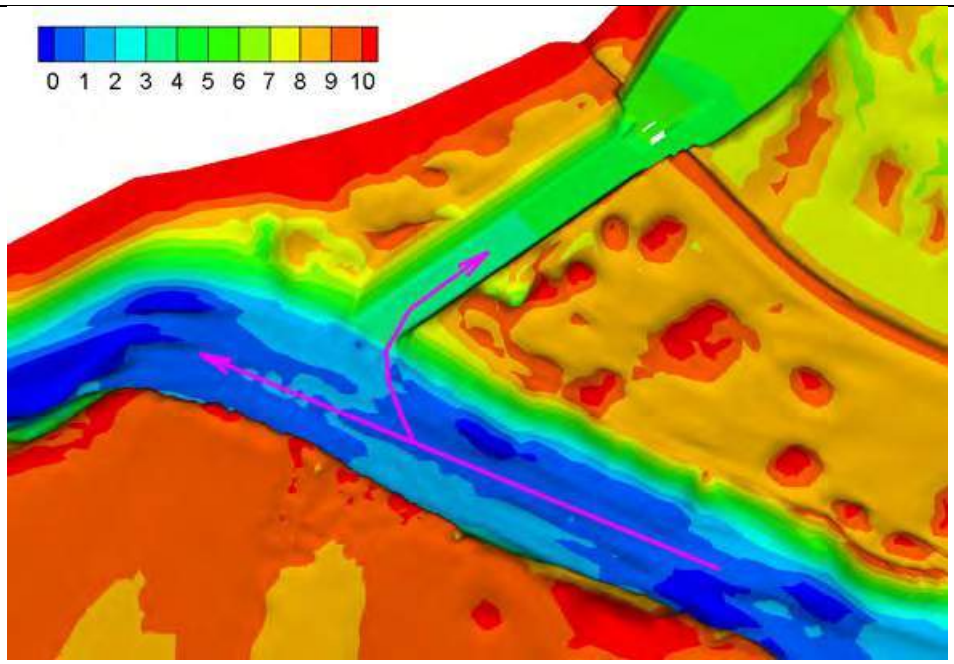


(a) Option 2

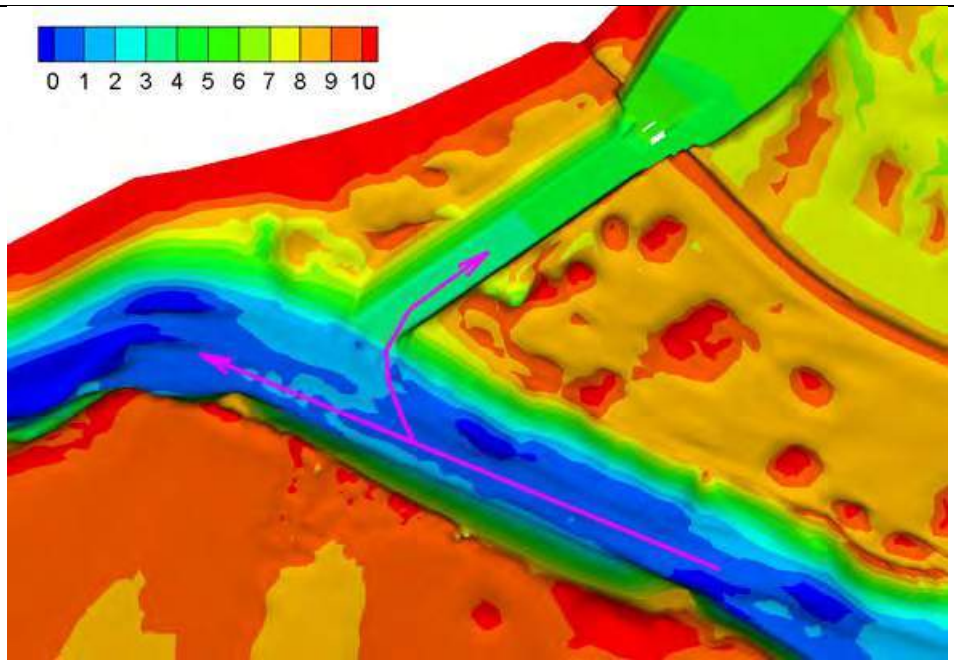


(b) Option 2B

Figure 38. Options 2 and 2B: planar views of the terrain and mesh in the notch area.

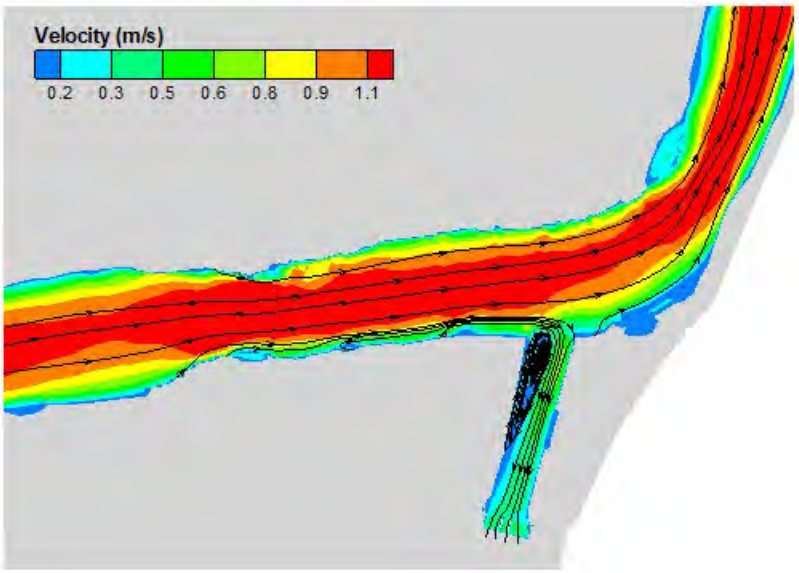


(a) Option 2

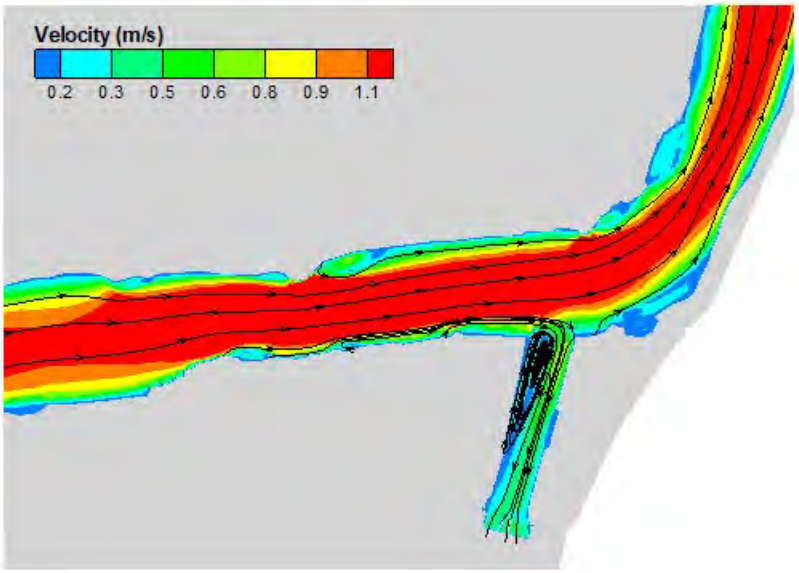


(b) Option 2B

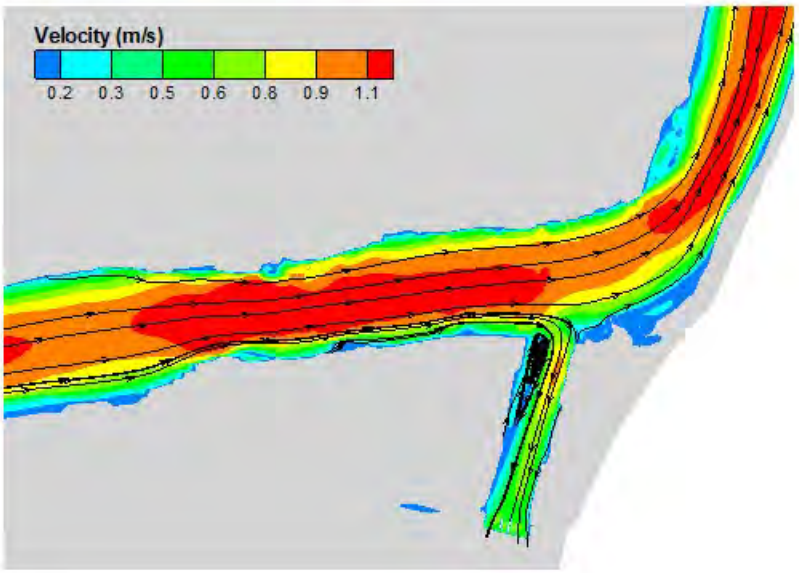
Figure 39. Options 2 and 2B: 3D views of terrain in the notch area.



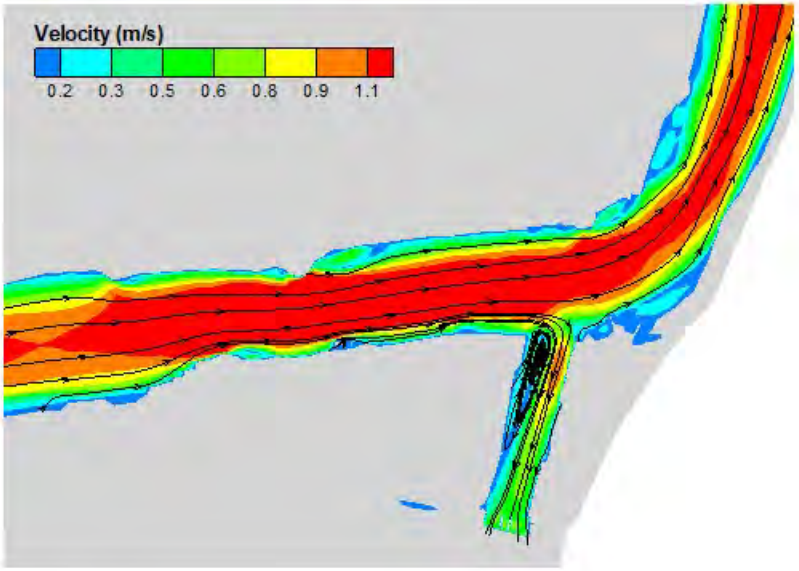
(a) Option 2 and Flow scenario 1



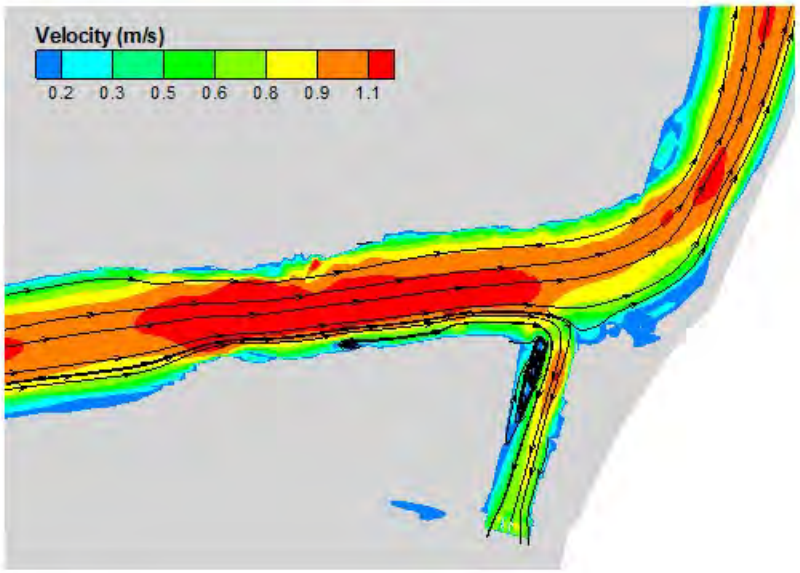
(b) Option 2B and Flow scenario 1



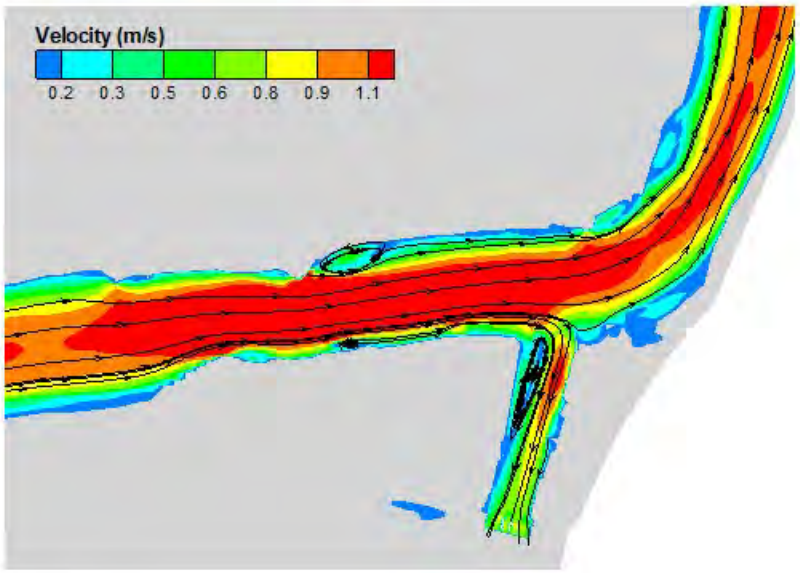
(c) Option 2 and Flow scenario 2



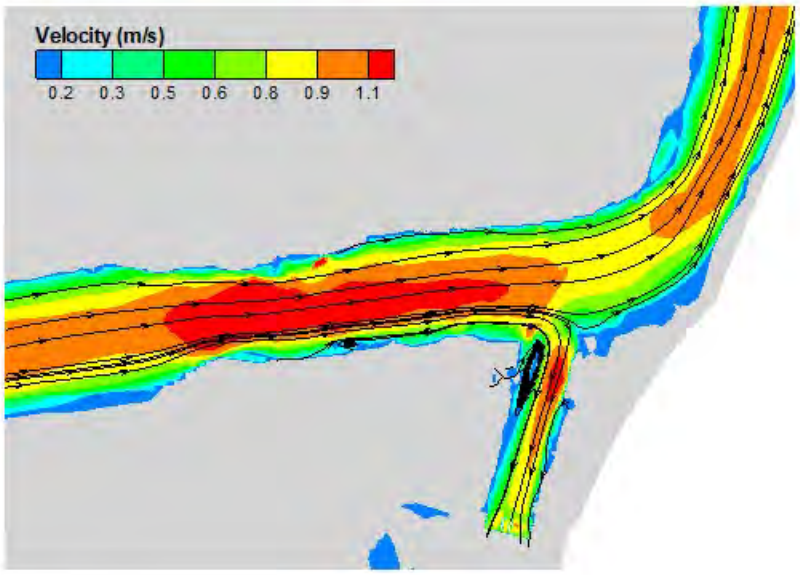
(d) Option 2B and Flow scenario 2



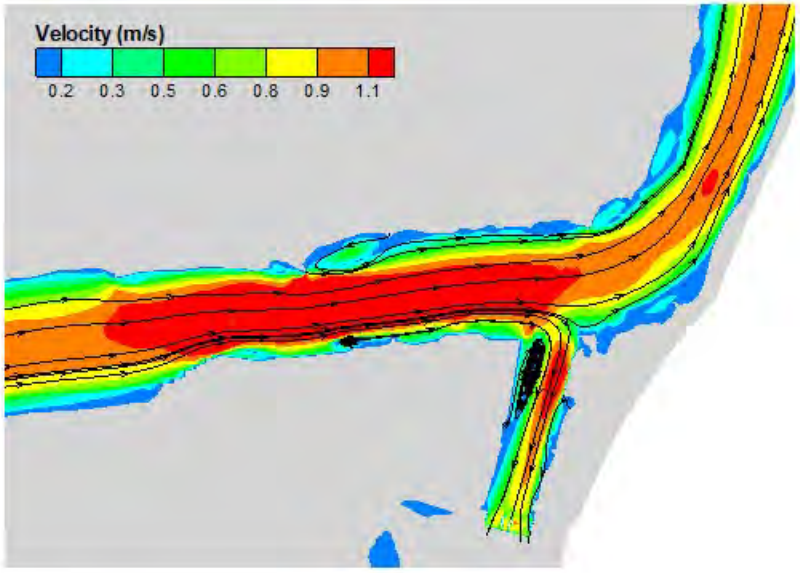
(e) Option 2 and Flow scenario 3



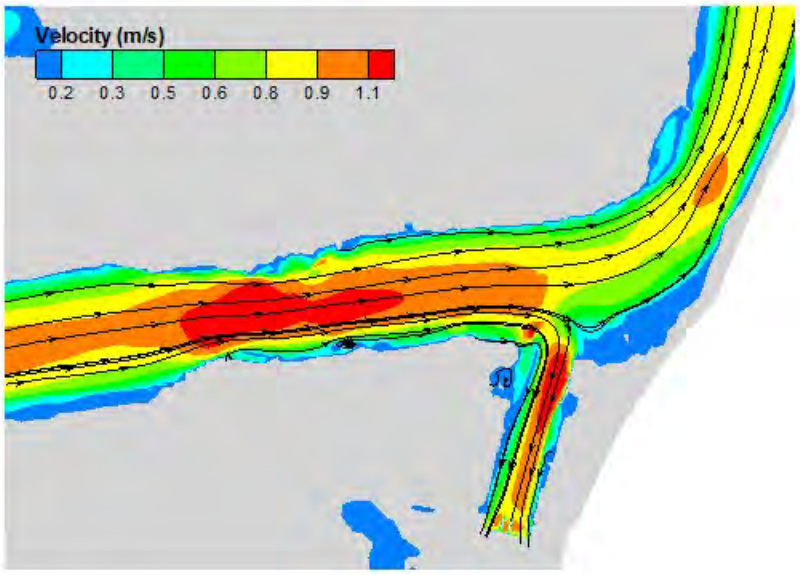
(f) Option 2B and Flow scenario 3



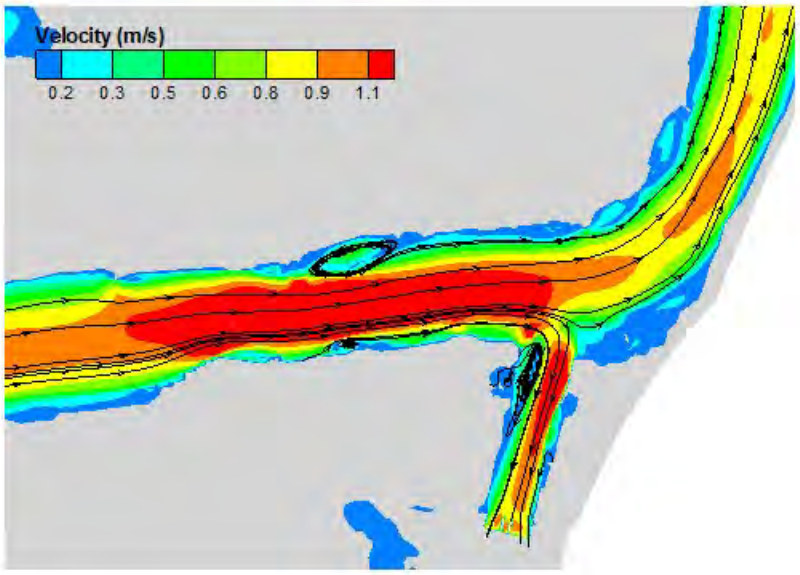
(g) Option 2 and Flow scenario 4



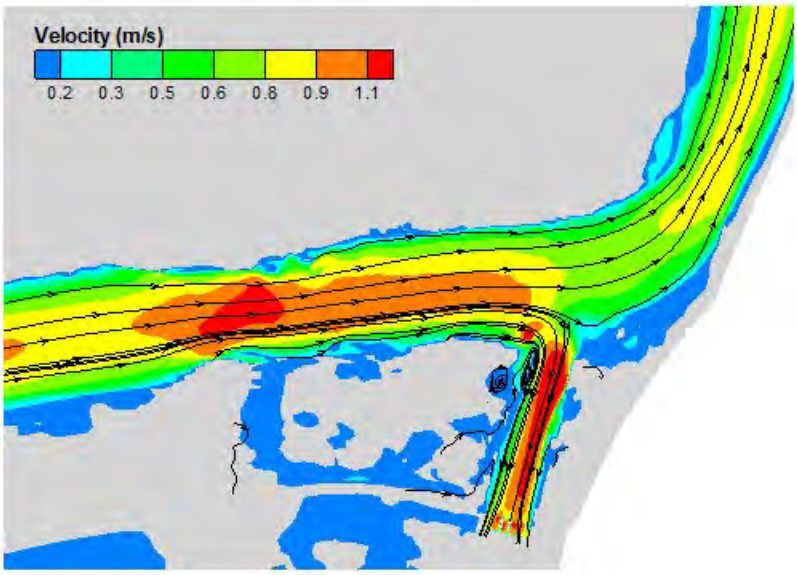
(h) Option 2B and Flow scenario 4



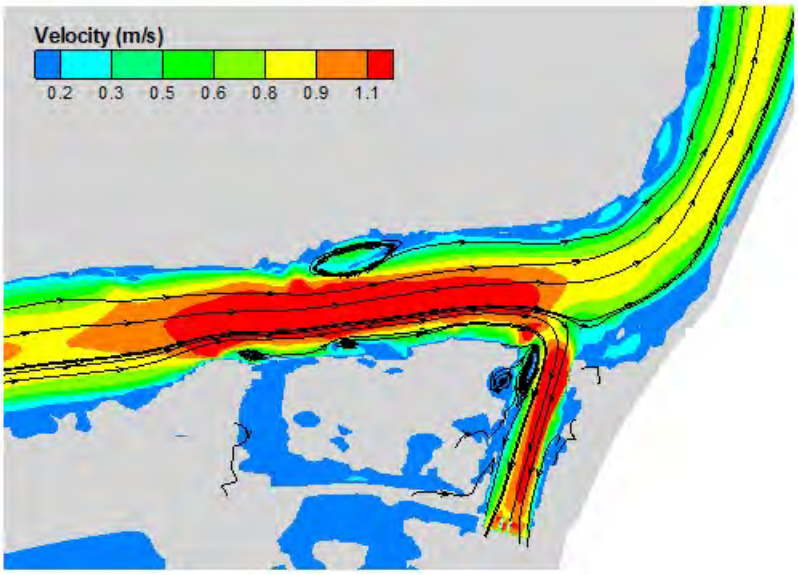
(i) Option 2 and Flow scenario 5



(j) Option 2B and Flow scenario 5



(k) Option 2 and Flow scenario 6



(l) Option 2B and Flow scenario 6

Figure 40. Predicted flow velocity and pattern near the notch for Options 2 and 2B.

5.3.4 Notch Options 3 and 3B

The terrain and the mesh for Options 1 and 1B are displayed in **Figure 41** and **Figure 42**. The predicted flow patterns and velocities are displayed in **Figure 43** for all six flow scenarios.

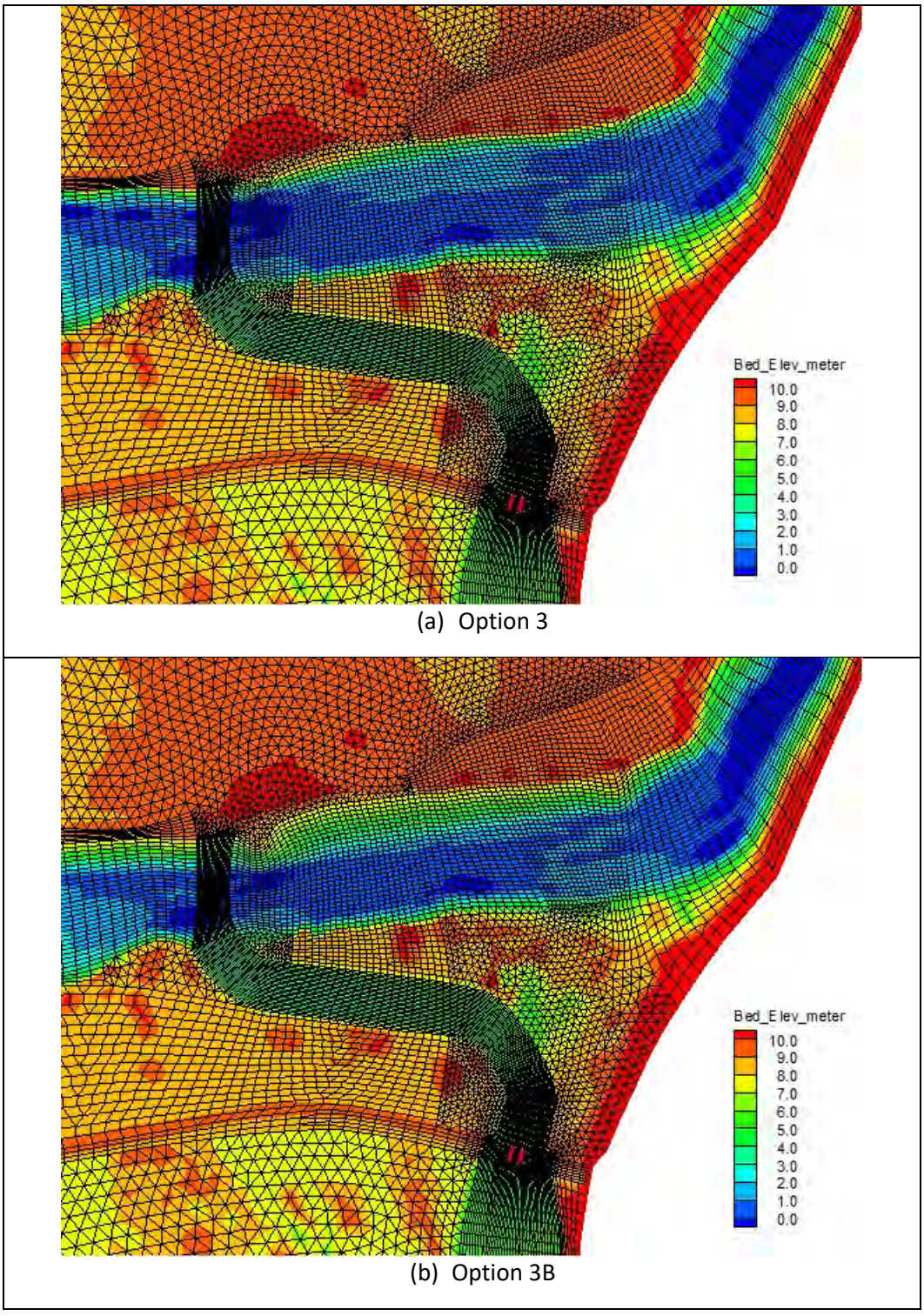
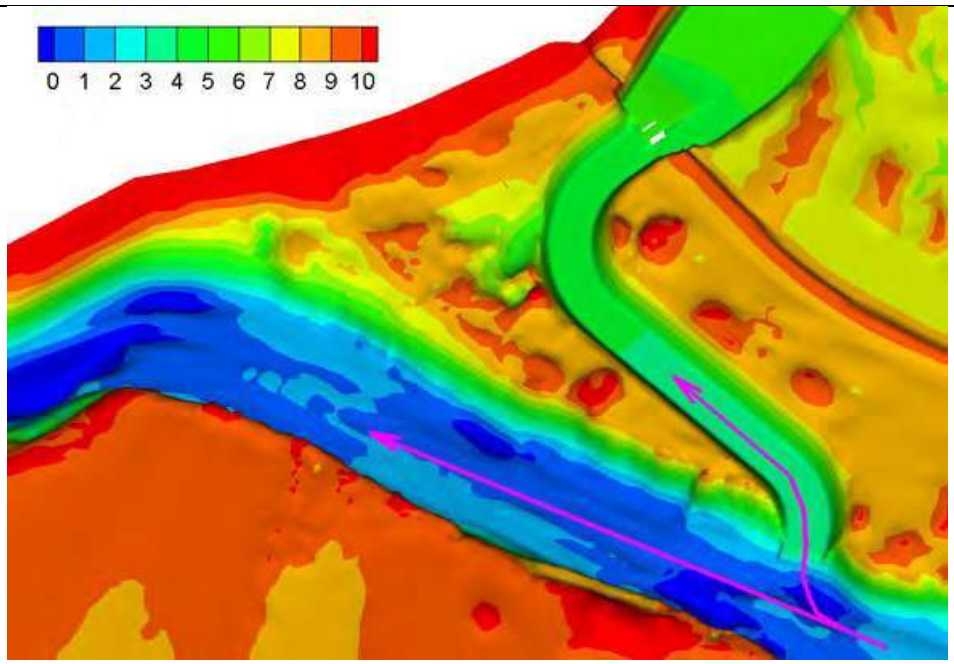
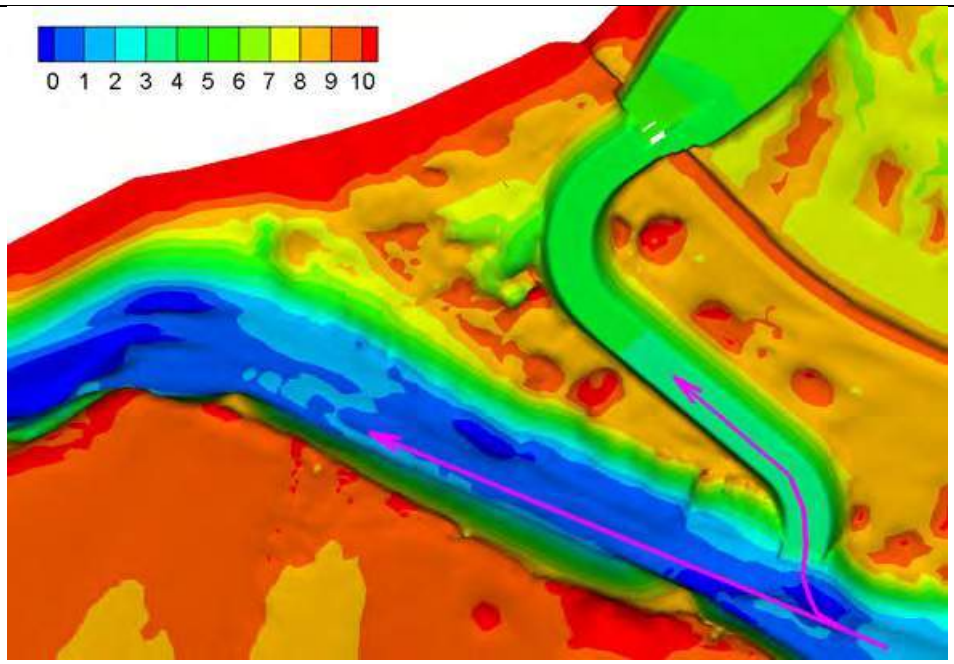


Figure 41. Options 3 and 3B: planar views of the terrain and mesh in the notch area.

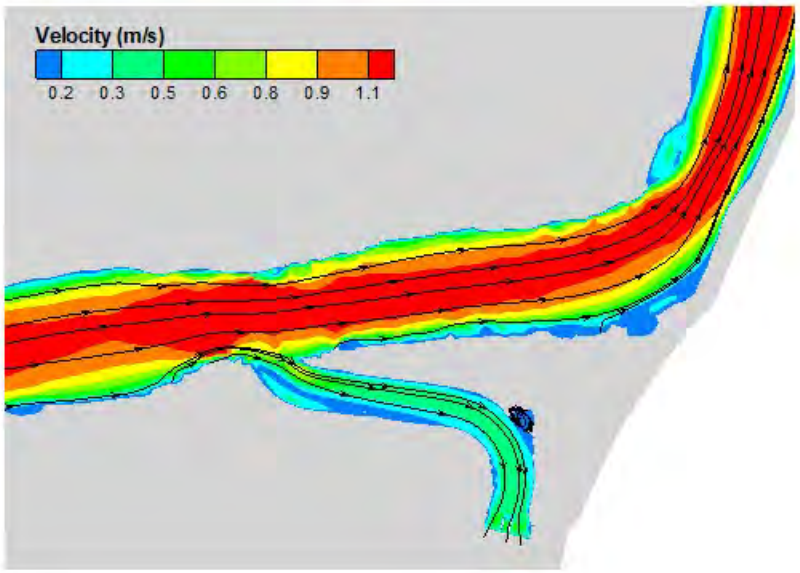


(a) Option 3

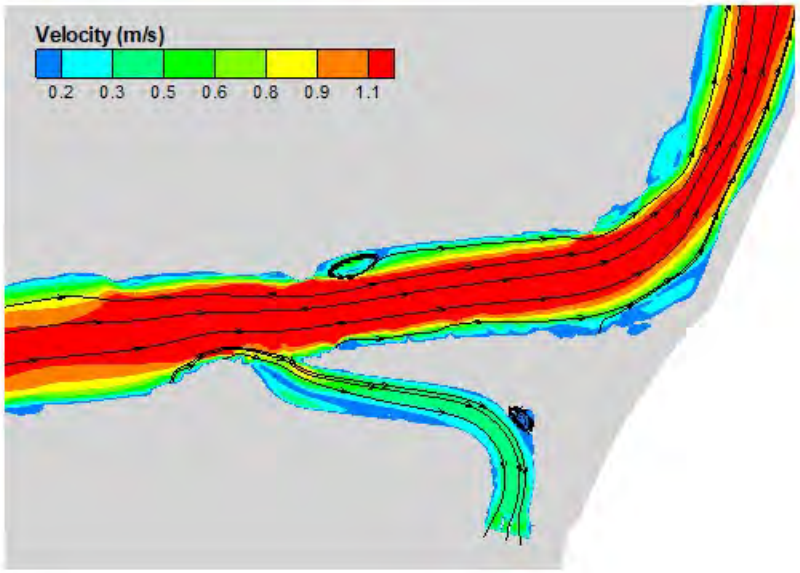


(b) Option 3B

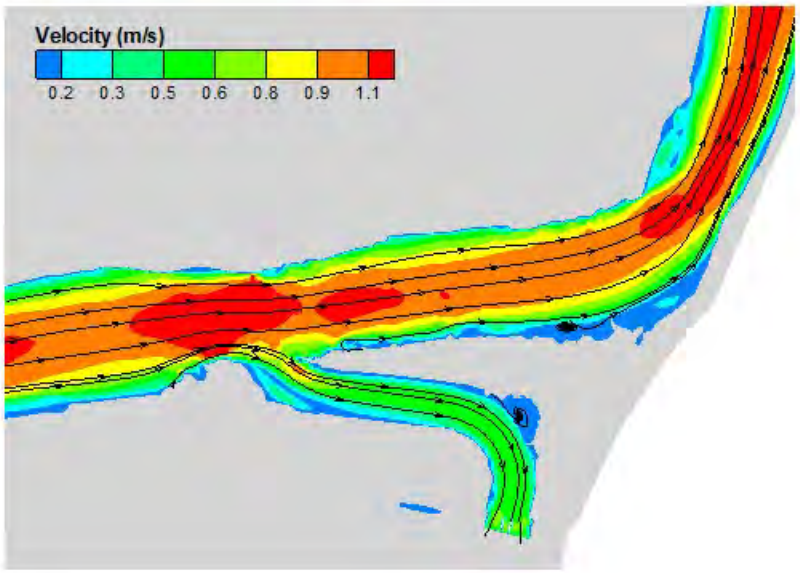
Figure 42. Options 3 and 3B: 3D views of terrain in the notch area.



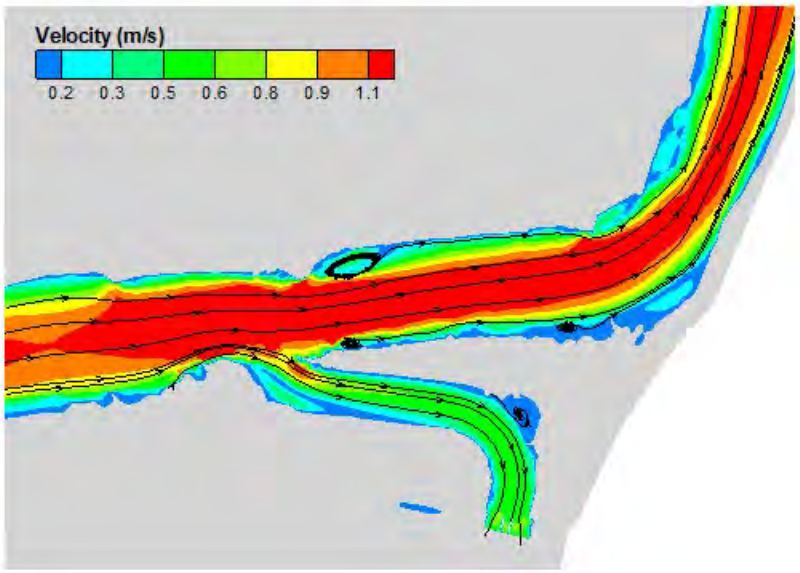
(a) Option 3 and Flow scenario 1



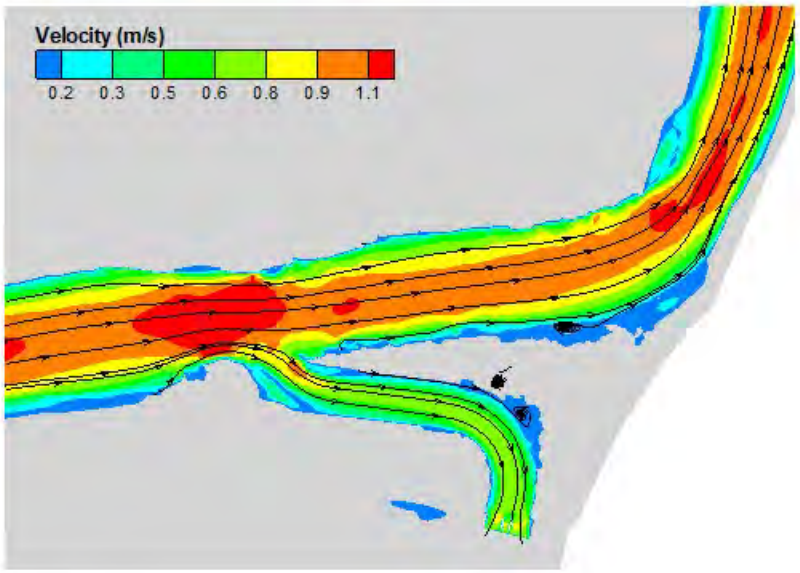
(b) Option 3B and Flow scenario 1



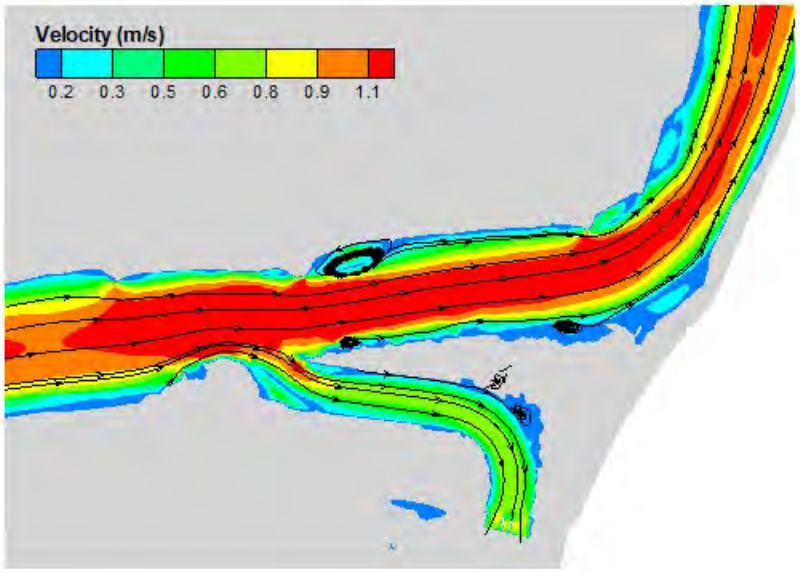
(c) Option 3 and Flow scenario 2



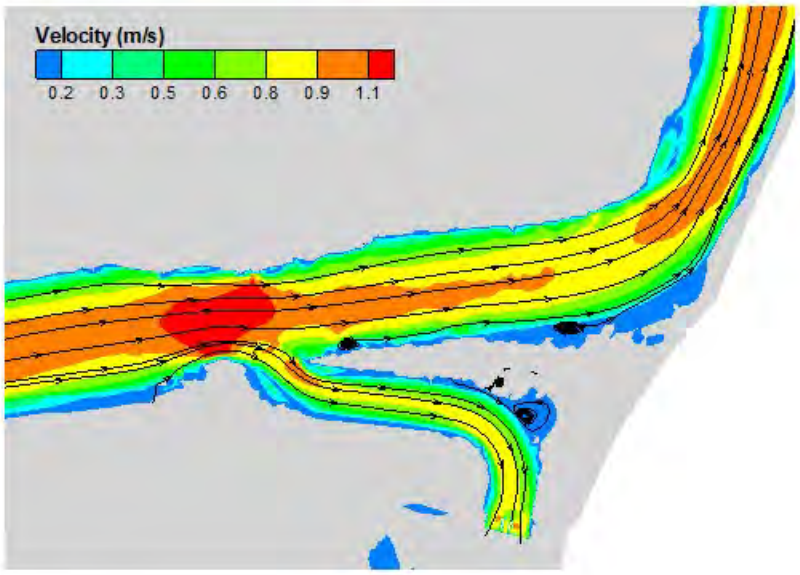
(d) Option 3B and Flow scenario 2



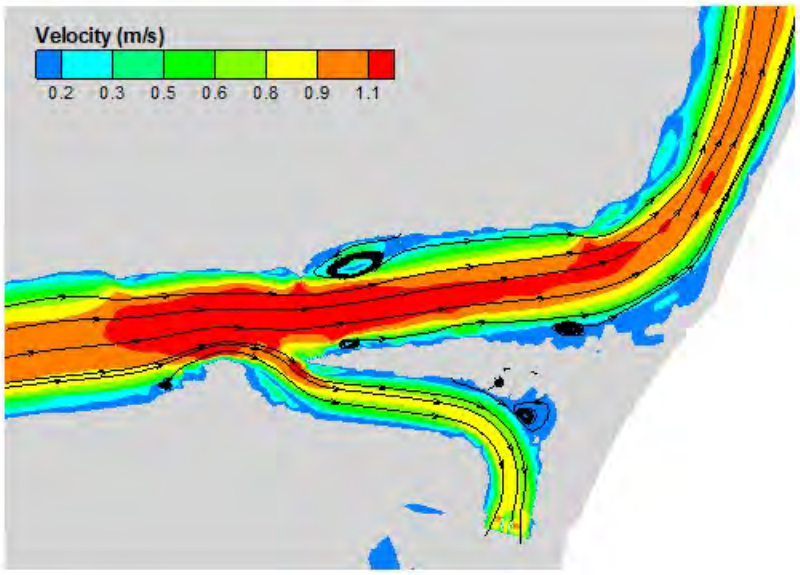
(e) Option 3 and Flow scenario 3



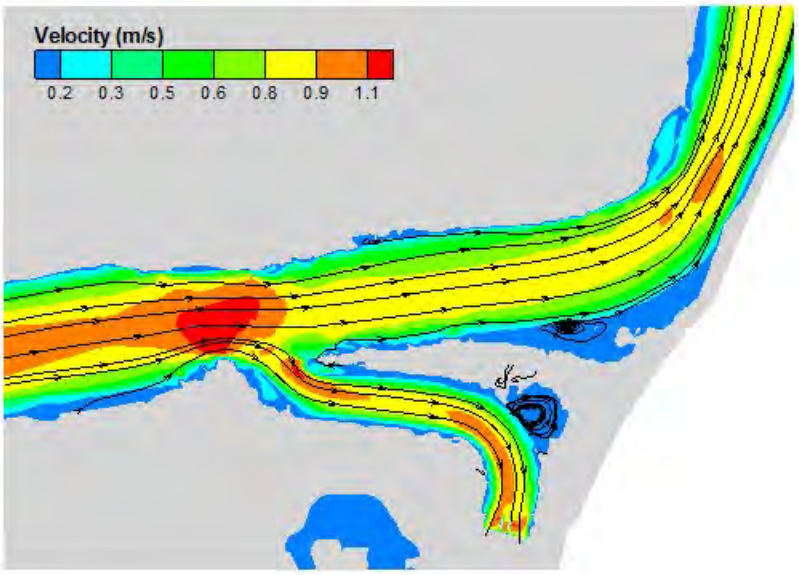
(f) Option 3B and Flow scenario 3



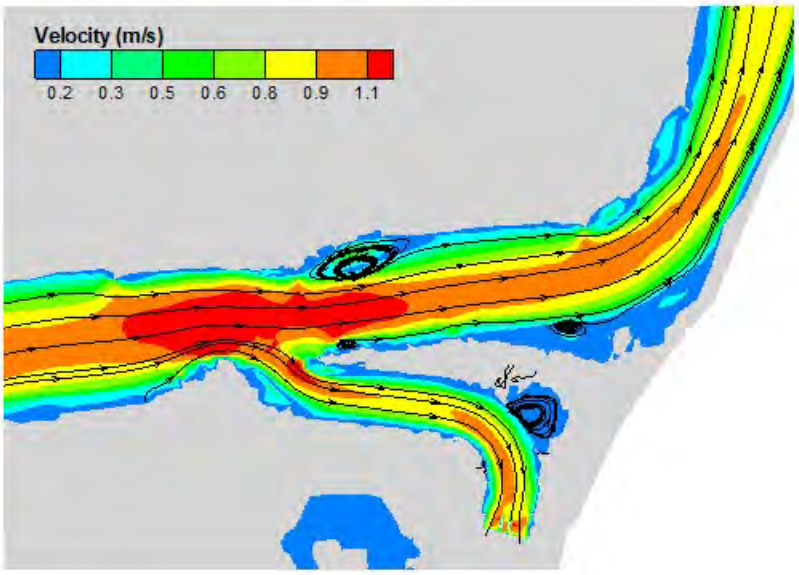
(g) Option 3 and Flow scenario 4



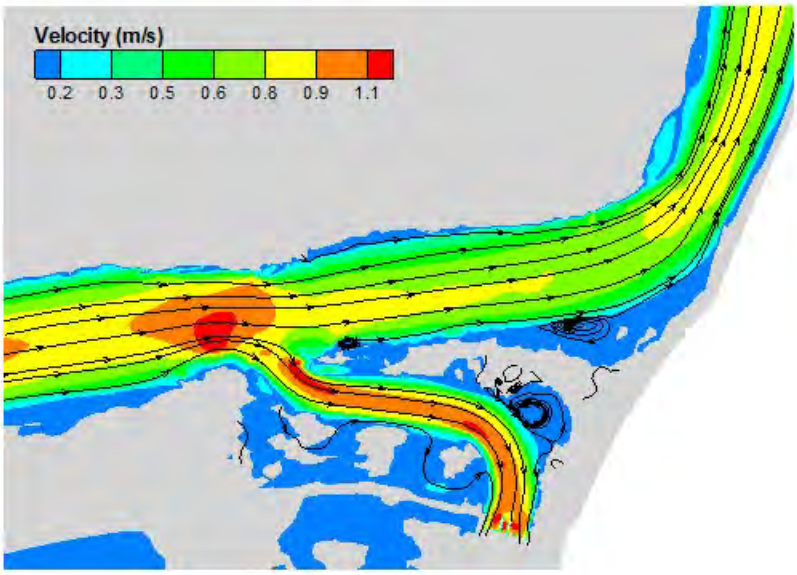
(h) Option 3B and Flow scenario 4



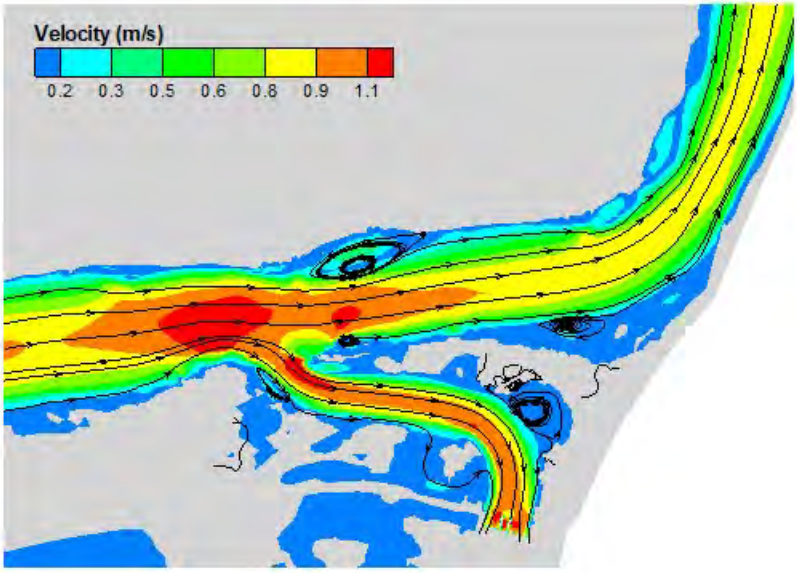
(i) Option 3 and Flow scenario 5



(j) Option 3B and Flow scenario 5



(k) Option 3 and Flow scenario 6

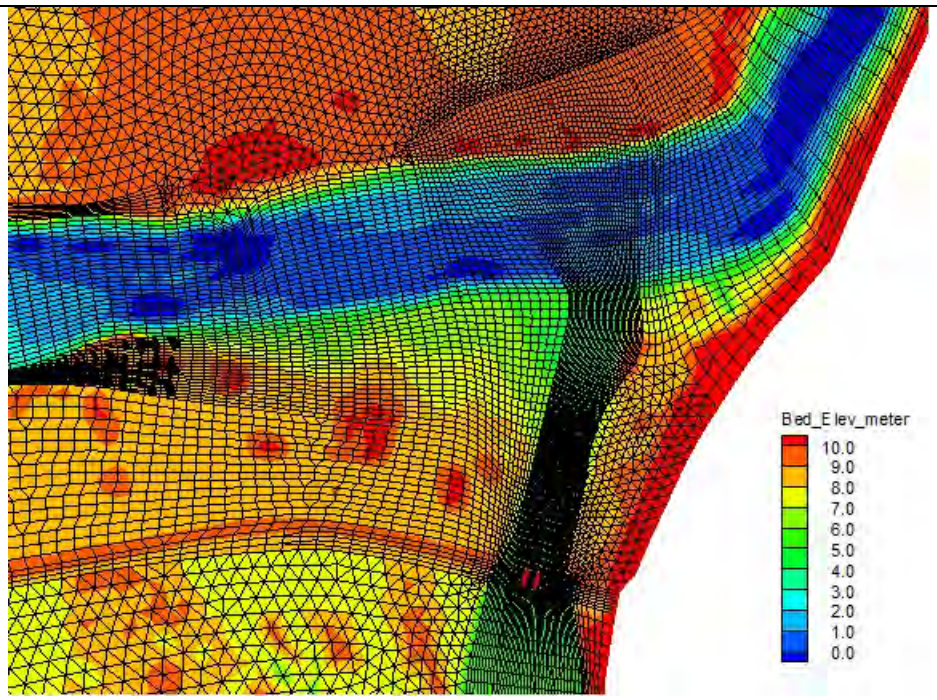


(l) Option 3B and Flow scenario 6

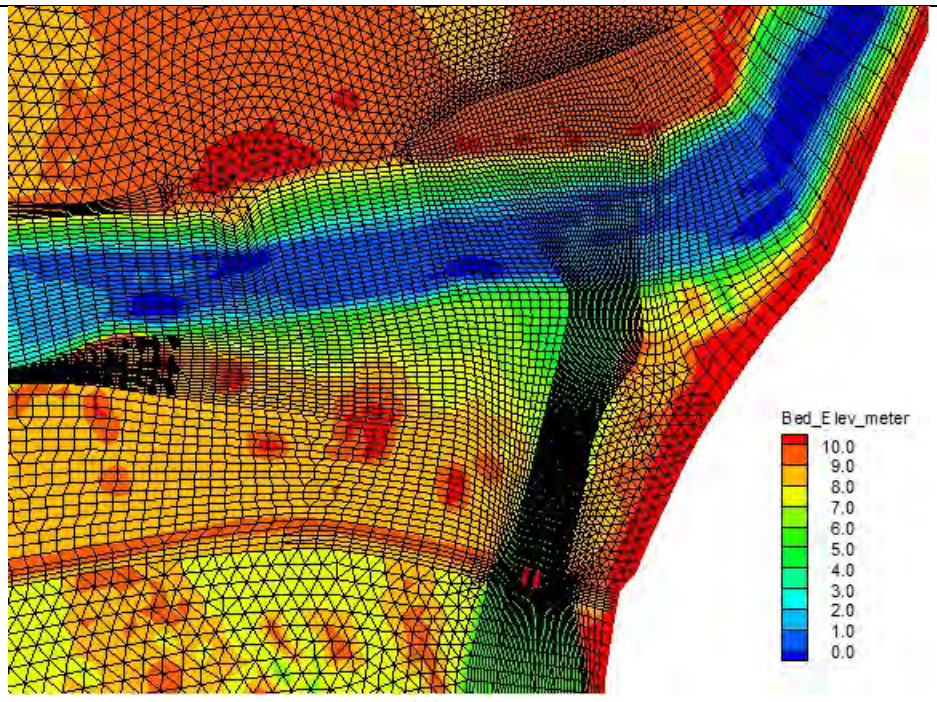
Figure 43. Predicted flow velocity and pattern near the notch for Options 3 and 3B.

5.3.5 Notch Options 4 and 4B

The terrain and the mesh for Options 1 and 1B are displayed in **Figure 44** and **Figure 45**. The predicted flow patterns and velocities are displayed in **Figure 46** for all six flow scenarios.

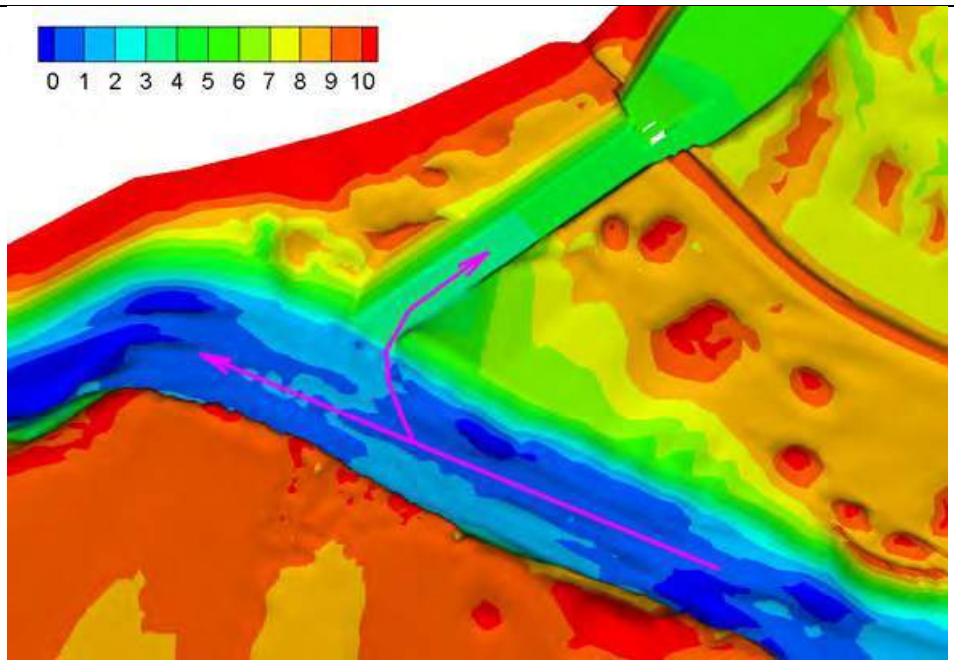


(a) Option 4

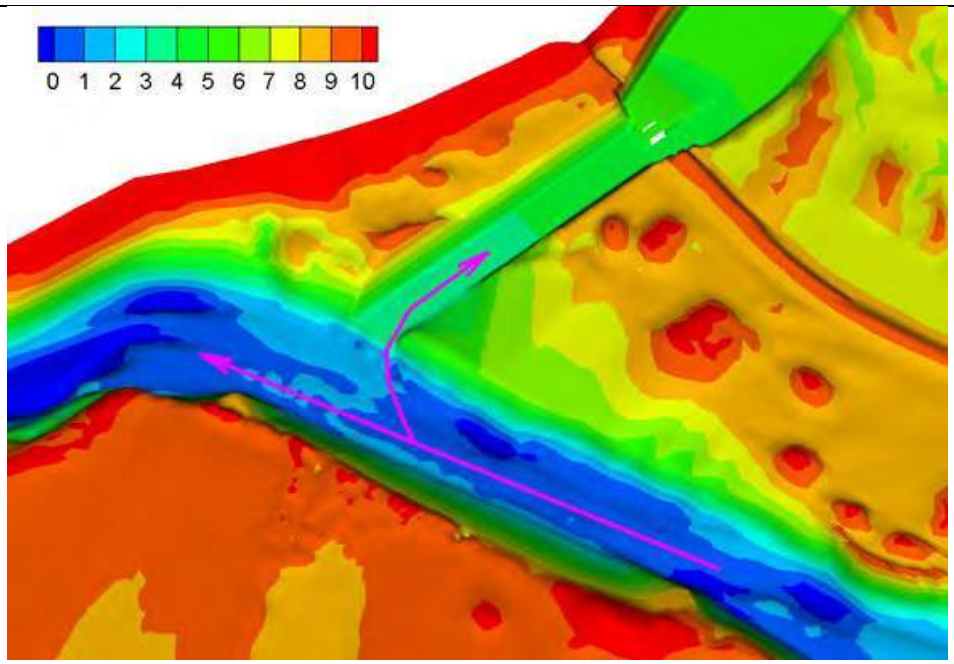


(b) Option 4B

Figure 44. Options 4 and 4B: planar views of the terrain and mesh in the notch area.

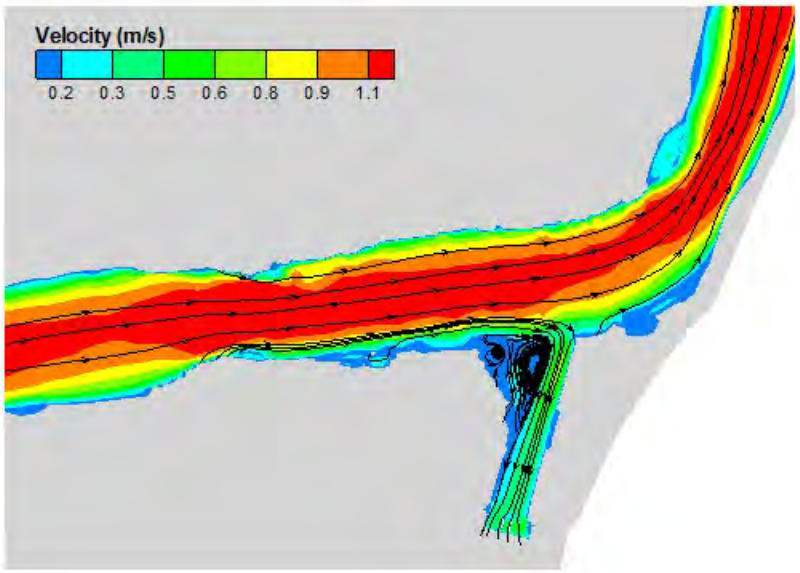


(a) Option 4

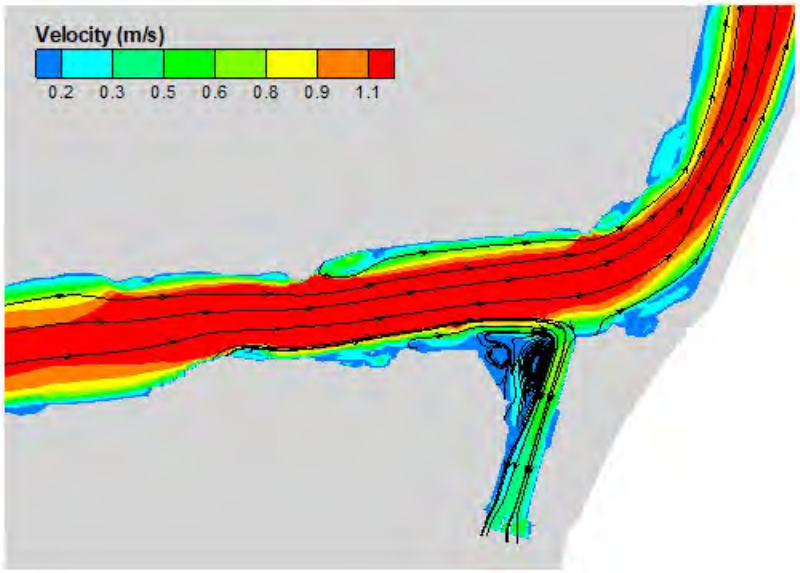


(b) Option 4B

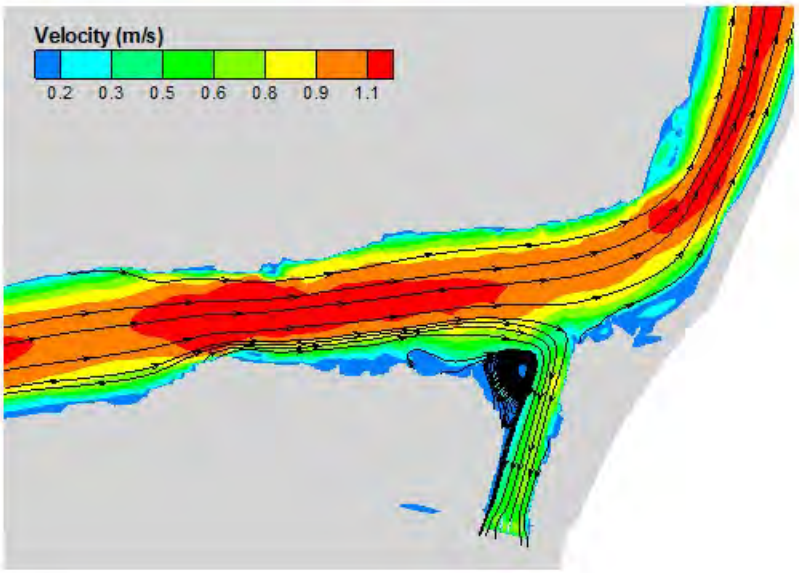
Figure 45. Options 4 and 4B: 3D views of terrain in the notch area.



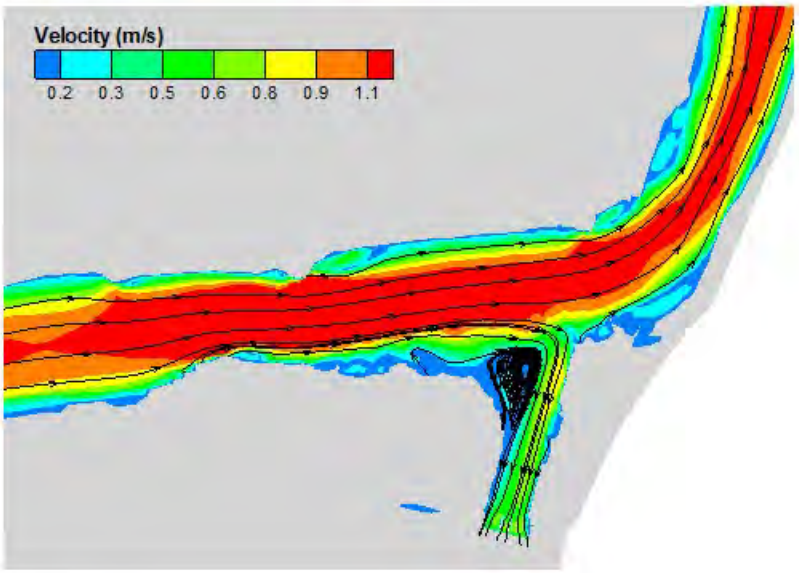
(a) Option 4 and Flow scenario 1



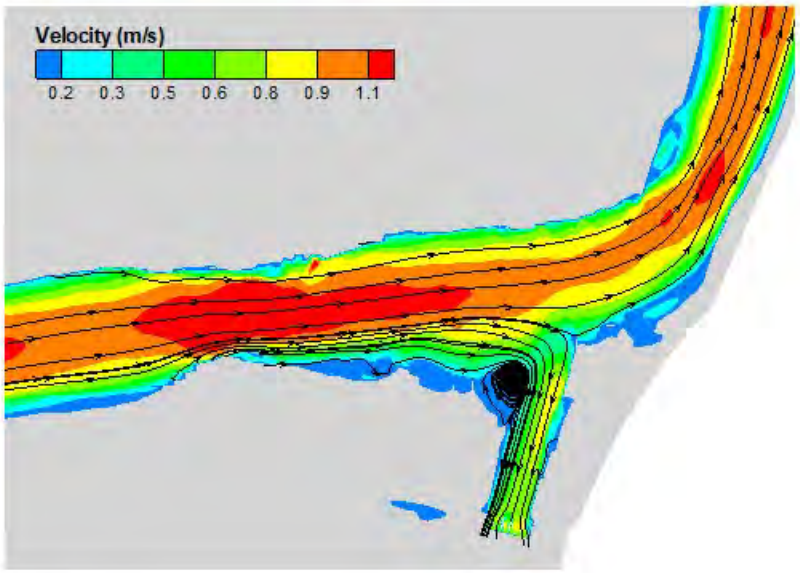
(b) Option 4B and Flow scenario 1



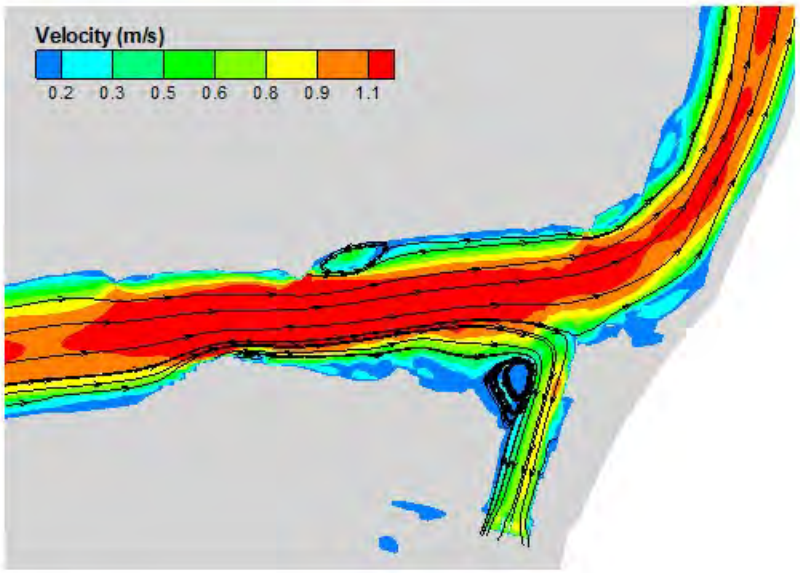
(c) Option 4 and Flow scenario 2



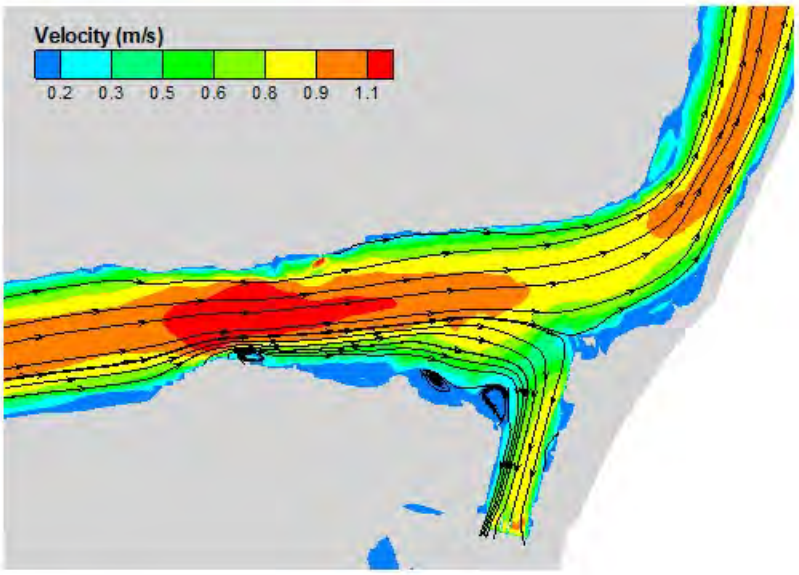
(d) Option 4B and Flow scenario 2



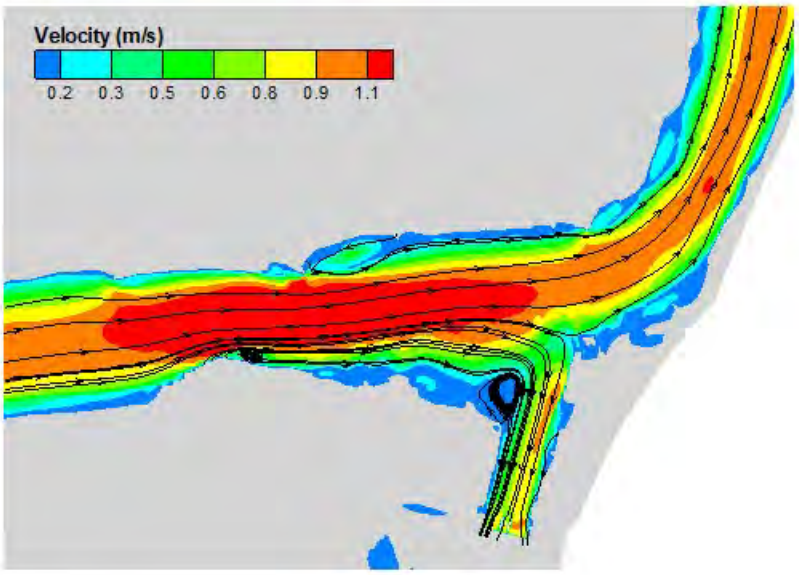
(e) Option 4 and Flow scenario 3



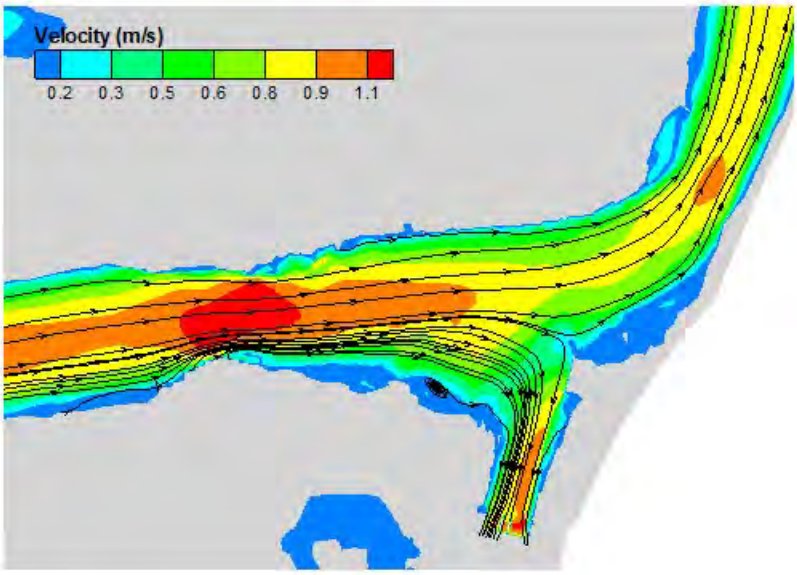
(f) Option 4B and Flow scenario 3



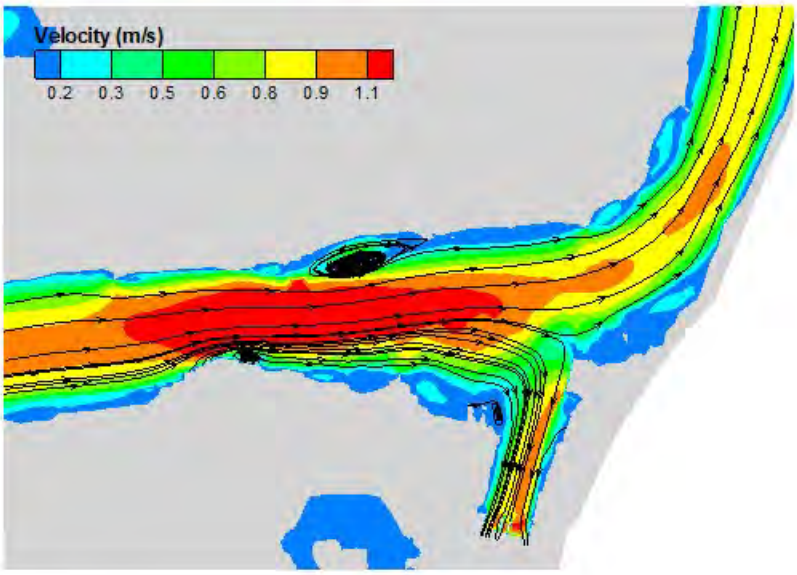
(g) Option 4 and Flow scenario 4



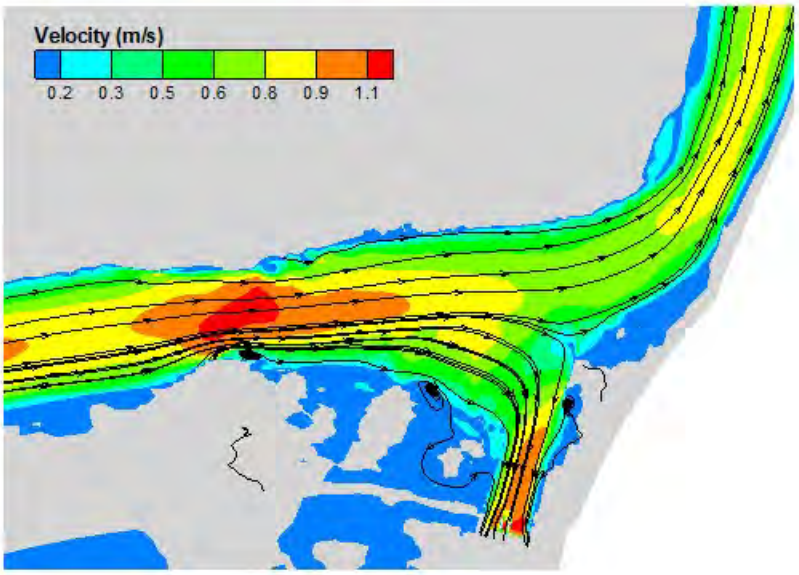
(h) Option 4B and Flow scenario 4



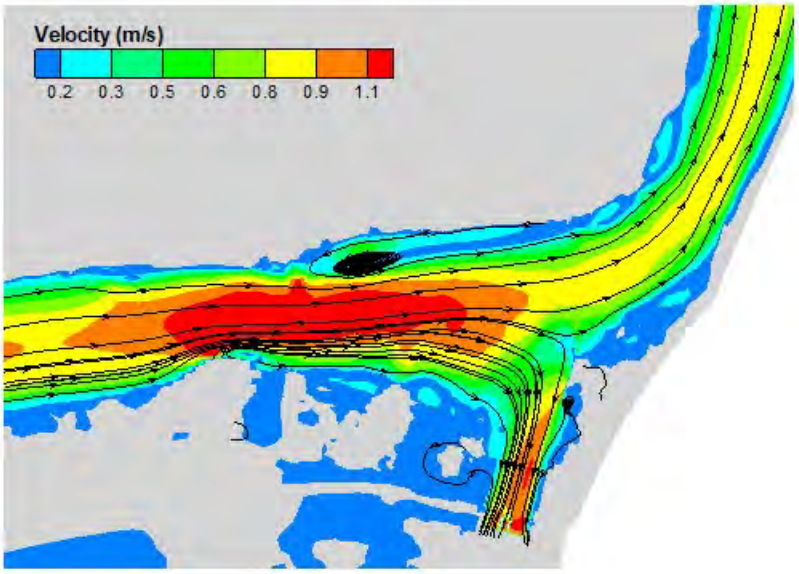
(i) Option 4 and Flow scenario 5



(j) Option 4B and Flow scenario 5



(k) Option 4 and Flow scenario 6



(l) Option 4B and Flow scenario 6

Figure 46. Predicted flow velocity and pattern near the notch for Options 4 and 4B.

6 References

Campbell, C. and Cheshier, N. (2019). Water Years 2015 and 2016 Boundary Conditions - Yolo Bypass Design and Support. Technical Memorandum, CBEC Eco Engineering.

Greimann, B.P., Lai, Y.G., and Huang, J. (2008). "Two-Dimensional Total Sediment Load Model Equations," J. Hydraulic Engineering, ASCE, vol.134(8), 1142-1146.

Hammack, E. A., Threadgill, T. L., Smith, D. L., & Sanborn, S. (2013). Calibration of a Two-Dimensional Hydraulic Model of the Sacramento River Using a Refined, Small Domain Mesh – Data Report. Vicksburg, MS.

Harmel, R. D. and Smith, P. K. (2007). Consideration of measurement uncertainty in the evaluation of goodness-of-fit in hydrologic and water quality modeling. Journal of Hydrology, 337(3-4), 326–336.

Lai, Y.G., Weber, L.J., Patel, V.C. (2003). "A non-hydrostatic three-dimensional method for hydraulic flow simulation - part I: formulation and verification," ASCE Journal Hydraulic Engineering, 129(3), 196-205.

Lai, Y.G. (2008). SRH-2D Theory and User's Manual version 2.0, Technical Service Center, Bureau of Reclamation, Denver, CO.

Lai, Y.G. (2010). Two-Dimensional Depth-Averaged Flow Modeling with an Unstructured Hybrid Mesh. J. Hydraul. Eng., ASCE, 136(1): 12-23.

Lai, Y.G., and Greimann, B.P. (2010). Predicting contraction scour with a two-dimensional depth-averaged model. J. Hydraulic Research, IAHR, 48(3): 383-387.

Lai, Y.G., Greimann, B.P., and Wu, K. (2011). Soft bedrock erosion modeling with a two-dimensional depth-averaged model," J. Hydraul. Eng., ASCE, 137(8): 804-814.

Lai, Y.G. (2015). "2D and 3D Flow Modeling along Fremont Weir Section of the Sacramento River in Support of Fish Tracking." Technical Report No. SRH-2015-33, Technical Service Center, U.S. Bureau of Reclamation.

Lai, Y.G. (2017a). "SRH-2D Modeling of Fremont Weir Notch Configurations in Support of Fish Movement Simulation." Technical Report No. SRH-2017-19, Technical Service Center, U.S. Bureau of Reclamation.

Lai, Y.G. (2017b). "Additional SRH-2D Flow Modeling of Fremont Weir Notch Configurations." Technical Report No. SRH-2017-31, Technical Service Center, U.S. Bureau of Reclamation.

Legates, D. R. and McCabe Jr., G. (1999). Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation, 35(1), 233–241.

Stumpner, P. Blake, A. and Burau, J. (2018). Hydrology and Hydrodynamics on the Sacramento River near the Fremont Weir: Implications for Juvenile

Salmon Entrainment Estimates. Project Report, U.S. Geological Survey, West Sacramento, CA.

EIS/EIR Alternative 1 Entrainment Optimization

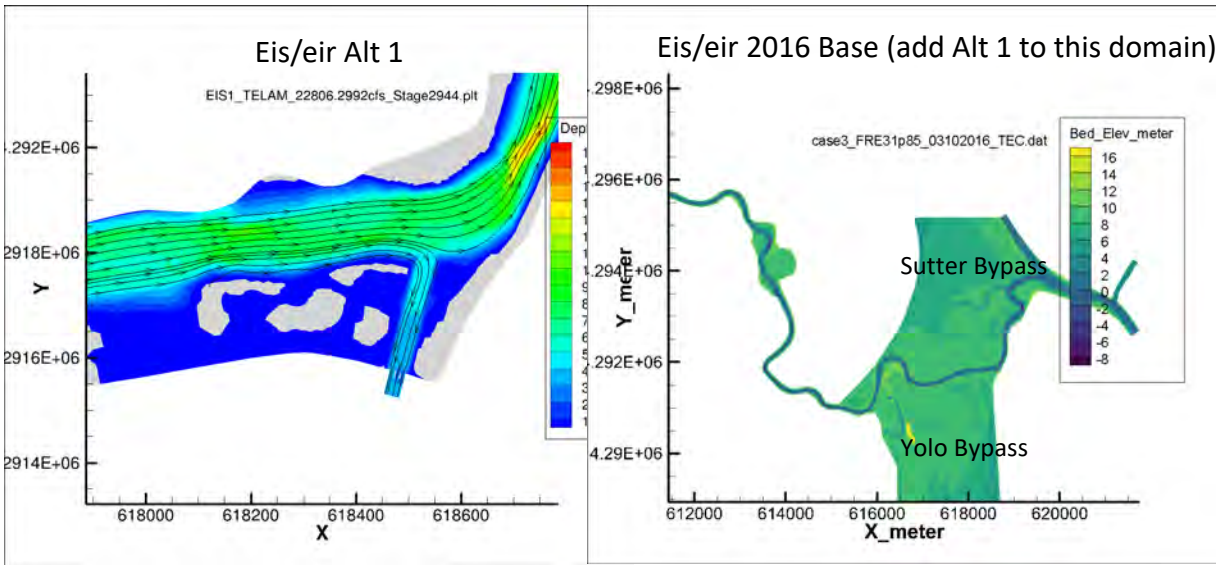
This scope focuses on optimizing EIS/EIR Alt 1. Eight new optimization geometries will be developed and run for 4 different stage/flow combinations.

Reference: CBEC Technical Memorandum "Water Years 2015 and 2016 Boundary Conditions" from Chris Campbell and Nathan Cheshier dated January 23, 2019" for all boundary conditions used.

We are using WY2016 because 1) it matches with the 2016 fish data at Fremont Weir and 2) the Peer Review asked that we include Sutter and Yolo Bypass inflows and outflows in the simulation for 2016.

Task:

1. Develop Eis/eir Alt 1 2dm file for 2016 boundary conditions that include the Sutter and Yolo Bypass flows.



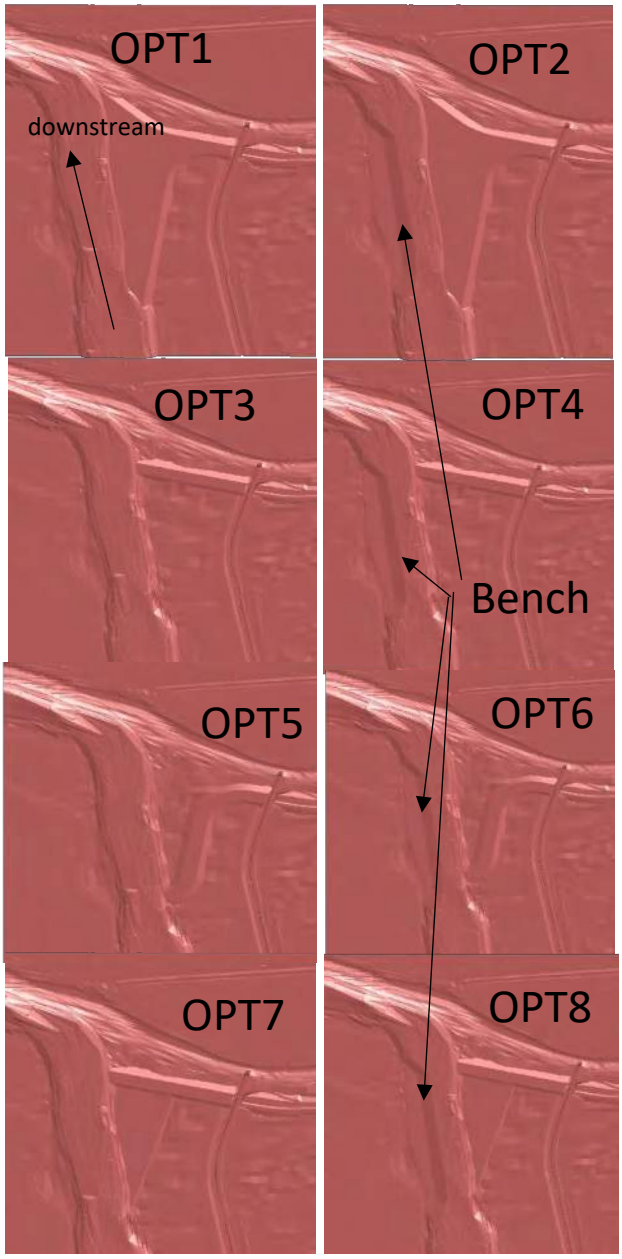
2. Model EIS/EIR Alt 1 using 2016 hydro. Suggestions to match 2015 estimates are
    a. Nominal stage = 21; 1_15_2016_1400_21p02
    b. Nominal stage = 24; 1_16_2016_2100_24p27
    c. Nominal stage = 26; 1_18_2016_1600_26p17
    d. Nominal stage = 28; 1_19_2016_0700_28p07

3. Model fish entrainment using new output from Task 2 and the original calibration used in 2015. and compare to 2015 results.
    a. Additional steps to consider after comparison with 2015 entrainment estimates are understood for all 2016 optimization runs are:
        i. Consider adding smaller fish to the results.
        ii. Consider adding some minor behaviors to capture rearing behaviors as opposed to migration based behaviors.

4. Develop new 2dm files for proposed optimizations using case 1-4 from Task 2 (A total of eight optimizations are proposed, equaling 8 new 2dm files) x 4 stages = test matrix of 32 runs
    a. OPT1 – Flair
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        iv. Nominal stage = 28; 1_19_2016_0700_28p07
    b. OPT2 – Flair with bench
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        iv. Nominal stage = 28; 1_19_2016_0700_28p07
    c. OPT3 -
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        iv. Nominal stage = 28; 1_19_2016_0700_28p07
    d. OPT4 with bench
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        Nominal stage = 28; 1_19_2016_0700_28p07
    e. OPT5 –new alignment
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        (iv) Nominal stage = 28; 1_19_2016_0700_28p07
    f. OPT6 –new alignment with bench
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        (iv) Nominal stage = 28; 1_19_2016_0700_28p07
    g. OPT7 –floodplain cut
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        (iv) Nominal stage = 28; 1_19_2016_0700_28p07
    h. OPT8 –floodplain cut with bench
        i. Nominal stage = 21; 1_15_2016_1400_21p02
        ii. Nominal stage = 24; 1_16_2016_2100_24p27
        iii. Nominal stage = 26; 1_18_2016_1600_26p17
        (iv) Nominal stage = 28; 1_19_2016_0700_28p07

All coordinates will be UTM Zone 10 in meters, vertical datum NAVD88 in meters.

A PowerPoint and Tech memo will be delivered as part of the project.



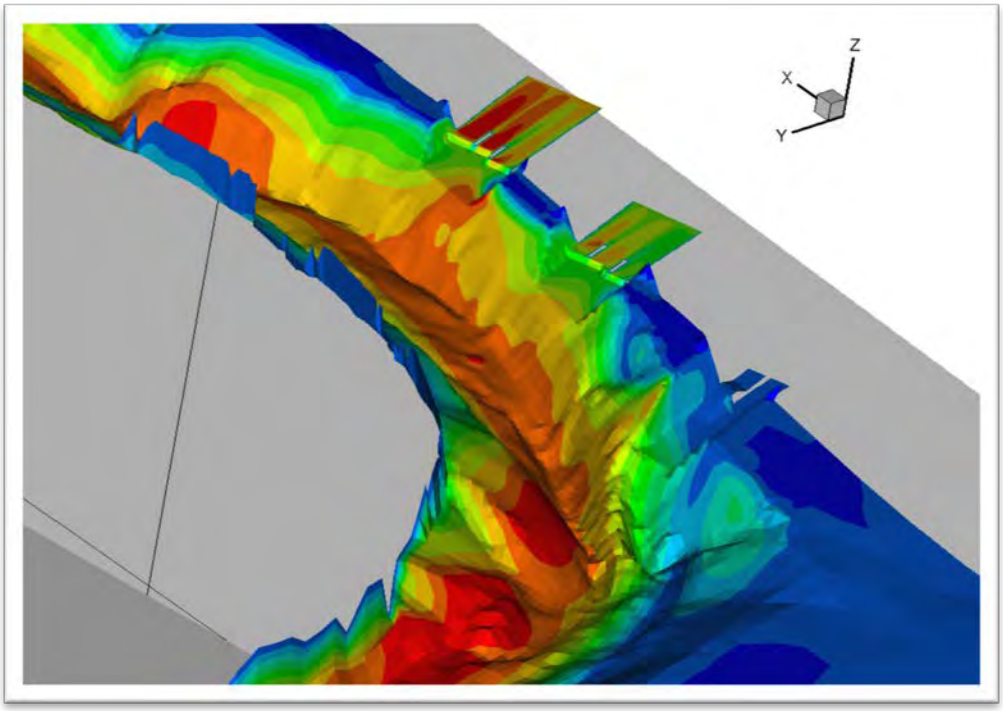
Schematics of proposed optimizations for EIS/EIR Alternative 1

RECLAMATION

Managing Water in the West

Technical Report No. SRH-2017-31

Additional SRH-2D Flow Modeling of Fremont Weir Notch Configurations



U.S. Department of the Interior
Bureau of Reclamation

September 2017

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Figure: Model predicted flow velocity distribution on day 24 for EIR/EIS Alternative 5

Technical Report No. SRH-2017-31

Additional SRH-2D Flow Modeling of Fremont Weir Notch Configurations

Prepared by

_____ _____

Yong G. Lai, Ph.D., Hydraulic Engineer **Date**
Sedimentation and River Hydraulics Group
Technical Service Center
Denver, Colorado

Peer Reviewed by:

_____ _____

Rajat Saha, Ph.D., P.E., CFM **Date**
Water Resources Division of Environmental Sciences
Department of Water Resources
West Sacramento, California

U.S. Department of the Interior
Bureau of Reclamation **September, 2017**

Table of Contents

Page

Summary **1**
1. Background **2**
2. New Notch Configurations and Their Representations by the Model **3**
2.1 General Description 3
2.2 Key Parameters 4
2.3 Notch Representation in the Model 5
2.4 Boundary Conditions 15
3. SRH-2D Model Results **20**
3.1 Configurations 13 and 13b (Central 6K Intake with the Original BC) 20
3.2 Configuration 14 (East 6K Intake with the Original BC) 27
3.3 Configuration 15 (Central Multi-Gate Intake with the Original BC) 31
3.4 Configuration 16 (West 3K Intake with the Original BC) 39
3.5 EIR/EIS Alternative 1 (East 6K Intake with the USGS BC) 43
3.6 EIR/EIS Alternative 2 (Central 6K Intake with the USGS BC) 47
3.7 EIR/EIS Alternative 3 (West 6K Intake with the USGS BC) 51
3.8 EIR/EIS Alternative 4 (West 3K Intake with the USGS BC) 55
3.9 EIR/EIS Alternative 5 (Central Multi-Gate Intake with the USGS BC) 59
4.10 EIR/EIS Alternative 6 (West 12K Intake with the USGS BC) 66
4. References **71**

Index of Figures

Page

Figure 1. Three locations of all notch configurations/alternatives 4
Figure 2. Model domain used for modeling the Sacramento River along the Fremont Weir 6
Figure 3. Configurations 13 and 3b and EIR/EIS Alternative 2: location, terrain/geometry and mesh features (main gate invert is 14.8 ft; elevated gate invert is 18.8 ft) 8
Figure 4. Configuration 14 and EIR/EIS Alternative 1: location, terrain/geometry and mesh features (main gate invert is 14 ft; elevated gate invert is 18 ft) 10
Figure 5. Configuration 15 and EIR/EIS Alternative 5: location, terrain/geometry and mesh features (see Table 1and Table 2for gate invert elevation)..... 11
Figure 6. Configuration 16 and EIR/EIS Alternative 3 and 4: location, terrain/geometry and mesh features (main gate invert is 16.1 ft; elevated gate invert is 20.1 ft) 13
Figure 7. EIR/EIS Alternative 6: location, terrain/geometry and mesh features .. 14
Figure 8. Flow discharges at Knights Landing and Feather River for the period of December 1, 2014 to January 5, 2015..... 16
Figure 9. Stage at Verona Station for the period of December 1, 2014 to January 5, 2015..... 16
Figure 10. Sutter Bypass on Jan 3, 2003 showing overland flow distributed along the entire width of the Sutter Bypass but Fremont Weir is not overtopped..... 18
Figure 11. Flow discharges at Knights Landing, Feather River and Karnak using the USGS rating curve for the period of December 1, 2014 to January 5, 2015 .. 19
Figure 12. Rating curve used for Configurations 13 and 13b..... 21
Figure 13. Time history of predicted discharge through the gate and stage upstream of the gate for Configurations 13 and 13b..... 23
Figure 14. Terrain comparison in the notch area between Configurations 13 and 13b..... 24
Figure 15. Predicted flow velocity and flow pattern near the notch for Configurations 13 and 13b at Day 6 25
Figure 16. Predicted flow velocity and flow pattern near the notch for Configurations 13 and 13b at Day 18 26
Figure 17. Rating curve used for Configuration 14 27
Figure 18. Time history of predicted discharge through the gate and stage upstream of the gate for Configuration 14 (East 6K Intake) 28
Figure 19. Predicted flow velocity and flow pattern near the notch of Configuration 14 at Day 6..... 29
Figure 20. Predicted flow velocity and flow pattern near the notch of Configuration 14 at Day 18..... 30
Figure 21. Location and gate invert of four gates on the river right (Yolo Bypass side) for Configuration 15..... 32

Figure 22. The rating curves used at four gates of Configuration 15 (Red=Gate A; blue=Gate B; Black=Gate C; Green=Gate D) 32
Figure 23. Time history of predicted discharge through Gate A and the stage upstream of Gate A for Configurations 15 (Central Multi-Gate Intake) 33
Figure 24. Time history of predicted discharge through Gate B and stage upstream of Gate B for Configurations 15 (Central Multi-Gate Intake) 34
Figure 25. Time history of predicted discharge through Gate C and stage upstream of Gate C for Configurations 15 (Central Multi-Gate Intake) 35
Figure 26. Time history of predicted discharge through Gate D and stage upstream of Gate D for Configurations 15 (Central Muli-Gate Intake) 36
Figure 27. Predicted flow velocity and flow pattern near the notch of Configuration 15 at Day 6..... 37
Figure 28. Predicted flow velocity and flow pattern near the notch of Configuration 15 at Day 18..... 38
Figure 29. Rating curve used for Configuration 16 (West 3K Intake) 39
Figure 30. Time history of predicted discharge through the gate and stage upstream of the gate for Configuration 16 (West 3K Intake) 40
Figure 31. Predicted flow velocity and flow pattern near the notch of Configuration 16 at Day 6..... 41
Figure 32. Predicted flow velocity and flow pattern near the notch of Configuration 3 at Day 18..... 42
Figure 33. Rating curve used for EIR/EIS Alternative 1 (East 6K Intake)..... 43
Figure 34. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 1 (East 6K Intake) 44
Figure 35. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 1 at Day 6 45
Figure 36. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 1 at Day 18 46
Figure 37. Rating curve used for EIR/EIS Alternative 2 (Central 6K Intake)..... 47
Figure 38. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 2 (Central 6K Intake) 48
Figure 39. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 2 at Day 6 49
Figure 40. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 2 at Day 18 50
Figure 41. Rating curve used for EIR/EIS Alternative 3 (West 6K Intake) 51
Figure 42. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 3(West 6K Intake) 52
Figure 43. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 3 at Day 6 53
Figure 44. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 3 at Day 18 54
Figure 45. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 4 (West 3K Intake) 56
Figure 46. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 4 at Day 6 57

Figure 47. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 4 at Day 18 58
Figure 48. Time history of predicted discharge and stage at Gate A for EIR/EIS Alternative 5 (Central Multi-Gate Intake) 60
Figure 49. Time history of predicted discharge and stage at Gate B for EIR/EIS Alternative 5 (Central Multi-Gate Intake) 61
Figure 50. Time history of predicted discharge and stage at Gate C for EIR/EIS Alternative 5 (Central Multi-Gate Intake) 62
Figure 51. Time history of predicted discharge and stage at Gate D for EIR/EIS Alternative 5 (Central Muli-Gate Intake) 63
Figure 52. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 5 at Day 6 64
Figure 53. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 5 at Day 18 65
Figure 54. The mesh and bed elevation of the notch structure for EIR/EIS Alternative 6 67
Figure 55. Rating curve used for EIR/EIS Alternative 6 (West 12K Intake) 67
Figure 56. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 6 (West 12K Intake) 68
Figure 57. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 6 at Day 6 69
Figure 58. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 6 at Day 18 70

Index of Tables

Page

Table 1. Key parameters of batch 1 configurations: 13 through 16 5
Table 2. Key parameters of batch 2 alternatives: EIR/EIS 1 through 6 5
Table 3. Comparisons of Discharges at the Fremont Gauge Station using the Lai (2017) approach and with the USGS rating curve 17

Summary

This report serves as an Amendment to the previous 2017 modeling report titled "SRH-2D Modeling of Fremont Weir Notch Configurations in Support of Fish Movement Simulation." The 2017 report is referenced as Lai (2017).

In the 2017 report, SRH-2D modeling was carried out for flow hydrodynamics along the Fremont Weir section of the Sacramento River, California. The flow model was described and validated using the 2015 survey data under the existing conditions. The validated flow model was then used to simulate future scenarios with 12 proposed notch configurations. Flow modeling was generated to support the Eulerian Lagrangian Agent Method (ELAM) modeling of fish movement within the river and through the Yolo Bypass Fremont Weir so that the effectiveness of different notch configurations may be assessed. ELAM modeling was used to assist the Fremont Weir notch design to achieve the desired fish migration through the Yolo Bypass.

After the completion of the 2017 work, more notch configurations and EIR/EIS Alternatives were proposed and are simulated. Specifically, 4 additional configurations and 6 EIR/EIS Alternatives are simulated with SRH-2D. This report documents these additional modeling runs.

1. Background

This report serves as an Amendment to the previous 2017 modeling report titled "SRH-2D Modeling of Fremont Weir Notch Configurations in Support of Fish Movement Simulation" and referenced as Lai (2017). In this study, additional Fremont Weir notch configurations and EIR/EIS Alternatives, with modified notch geometry and/or flow conditions, are simulated. The additional model runs are determined based on the initial results obtained in the 2017 study. Herein, we document the new model results carried out after the 2017 report. For the SRH-2D model itself, as well as its calibration and validation, refer to two previous reports (Lai, 2015; 2017).

The 2017 report documented the work performed as part of a larger effort related to the Yolo Bypass EIR/EIS study for fish survival. The California Department of Water Resources (DWR) and the Bureau of Reclamation (Reclamation) have been working together on the Yolo Bypass Salmonid Habitat Restoration and Fish Passage project (YBSHRFP), which is working to implement actions in the 2009 National Marine Fisheries Service (NMFS) Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (2009 NMFS BO). A list of key contents in the 2017 report are as follows:

- A general description of the SRH-2D flow model
- Specific details of the SRH-2D model developed to simulate the Fremont Section of the Sacramento River
- Model validation study using the field data under the 2015 existing conditions
- Model applications to simulate 12 Fremont notch configurations with flows diverted to the Yolo Bypass

The flow modeling study is carried out to predict flow hydrodynamics along Fremont Weir section of the Sacramento River under the future conditions of new notch for flow diversion to Yolo Bypass. Flow hydrodynamic variables are generated to support the Eulerian Lagrangian Agent Method (ELAM) modeling of fish movement within the river and through the Yolo Bypass Fremont Weir. The modeling is used to assess the effectiveness of different notch configurations in increasing fish migration to the Yolo Bypass.

2. New Notch Configurations and Their Representations by the Model

2.1 General Description

Two batches of new scenarios have been simulated since the report by Lai (2017) and they are documented herein. First batch consists of 4 new configurations as an expansion to the previous 12 configurations documented by Lai (2017). For this reason, the same terminology is used to label these four configurations to be consistent with the 2017 report; they are labeled as Configuration 13 through 16. The second batch consists of 6 new scenarios which were developed by DWR and Reclamation after examining the findings of the 2015 and 2017 ELAM modeling study results along with several other studies. The six are designated as the "refined" EIR/EIS Alternatives and labeled as EIR/EIS Alternative 1 through 6.

There are, however, correspondence between the new EIR/EIS alternatives and the previous configurations in terms of the notch geometry and river terrains, though the flow conditions may be slightly modified. The list of correspondence between the two batches is as follows:

- EIR/EIS Alternative 1 = Configuration 14
- EIR/EIS Alternative 2 = Configuration 13
- EIR/EIS Alternative 3 = Configuration 2
- EIR/EIS Alternative 4 = Configuration 16
- EIR/EIS Alternative 5 = Configuration 15
- EIR/EIS Alternative 6 = Configuration 11

All scenarios place the notch at different locations along the Fremont Weir section of the Sacramento River. Three primary locations adopted are: west, central, and east portion of the Fremont Weir as shown in Figure 1.

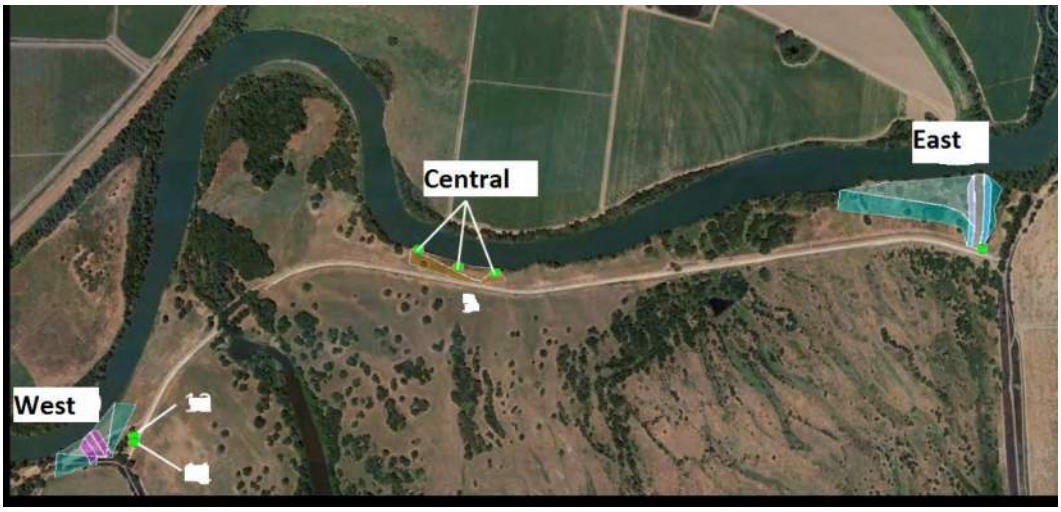


Figure 1. Three locations of all notch configurations/alternatives

Each new notch scenario includes a floodplain inundation channel at a unique location on the Sacramento River to existing waterways within the Yolo Bypass with grading north of Fremont Weir to attract juvenile salmonids. Different grading configurations north of Fremont Weir are analyzed using SRH-2D flow hydrodynamic model and ELAM modeling of fish behaviors along with different flows. Previous modeling efforts by DWR concluded 6,000 cfs to be the preferred flow amount used for floodplain inundation in coordination with other programs such as Cal Waterfix. To maintain up to about 6,000 cfs entering the Yolo Bypass at Fremont Weir there will be a control structure with components including inlet transition, gates, head works structure, access structure (pedestrian, vehicle), and outlet transition. Additional features are one or more fish passage facilities at Fremont Weir and stranding reduction actions with the Yolo Bypass.

2.2 Key Parameters

Key parameters of the first batch of four new configurations are listed in Table **1** and the second batch of six EIR/EIS alternatives are in Table **2**. Each scenario is different in terms of location, approach channel, flow rating curve through the notch, notch invert elevations, and width. These differences are translated into the 2D simulation of the flow field which, in turn, translates into simulated fish movement.

Some of the notch configurations have complexities with multiple gates being opened or closed at different river stages (e.g., EIR/EIS Alternative 5). In addition, an extra configuration, Configuration 13b, is added, to assess the influence of local bathymetry changes to the flow hydrodynamics. The terrain features and flow rating characteristics of each configuration/alternative are presented later in this report.

Table 1. Key parameters of batch 1 configurations: 13 through 16

Configuration ID	Project Key Features	Main Channel – Gate 1 Invert (ft)	Elevated Channel Gates 2&3 Invert (ft)	Max Flow (cfs)
13	Central 6K Intake	14.8	18.8	6,000
13b	Central 6K Intake modified	14.8	18.8	6,000
14	East 6K Intake	14	18	6,000
15	Central Multi-Gate	14(A); 17(B)	20(C); 23(D)	3,400
16	West 3K Intake	16.1	20.1	3,000

Table 2. Key parameters of batch 2 alternatives: EIR/EIS 1 through 6

EIR/EIS Alternative ID	Project Key Features	Main Channel – Gate 1 Invert (ft)	Elevated Channel Gates 2&3 Invert (ft)	Max Flow (cfs)
1	East 6K Intake	14	18	6,000
2	Central 6K Intake	14.8	18.8	6,000
3	West 6K Intake	16.1	20.1	6,000
4	West 3K Intake	16.1	20.1	3,000
5	Central Multi-Gates Intake	14(A); 17(B)	20(C); 23(D)	3,400
6	West 12K Intake	16.1	n/a	12,000

2.3 Notch Representation in the Model

SRH-2D flow simulation is carried out to obtain flow hydrodynamics in the 18-km Sacramento River reach along the Fremont Weir. These results are used by ELAM model to simulate fish movement behaviors so that the entrainment efficiency of different notch scenarios may be compared and evaluated. Refer to Lai (2017) for some details of the SRH-2D model.

Each notch scenario was designed in a CAD system by DWR; the placement of the notch into the river and merging of the notch geometry with the river terrain were carried out by USACE. Once delivered to Reclamation, the merged terrain and geometry were “placed” into the existing-condition SRH-2D model developed and reported by Lai (2017). A new and final composite terrain was developed at Reclamation for each notch scenario and used to generate a mesh for simulation with SRH-2D.

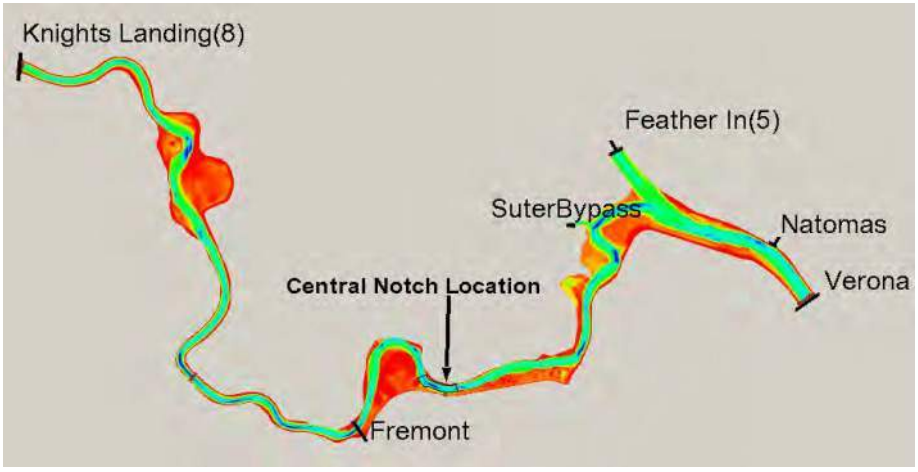
The 18-kilimeter model domain is shown in Figure **2**. It consists of 5 open boundaries: Knights Landing (upstream), Verona Station (downstream), Feather River confluence, California Slough at Karnak, and Natomas Cut. A 2D mesh is generated for each notch scenario due to differences in notch location and geometry. Mesh differences, however, lie primarily in the notch area. These meshes consist of about 32,000 to 45,000 mesh cells – very fine meshes for the applications. The river bathymetry used for the modeling is based on the 2015 survey data as discussed in Chapter 3 of Lai (2017); but terrain in the neighborhood of each notch scenario is specific to each case.



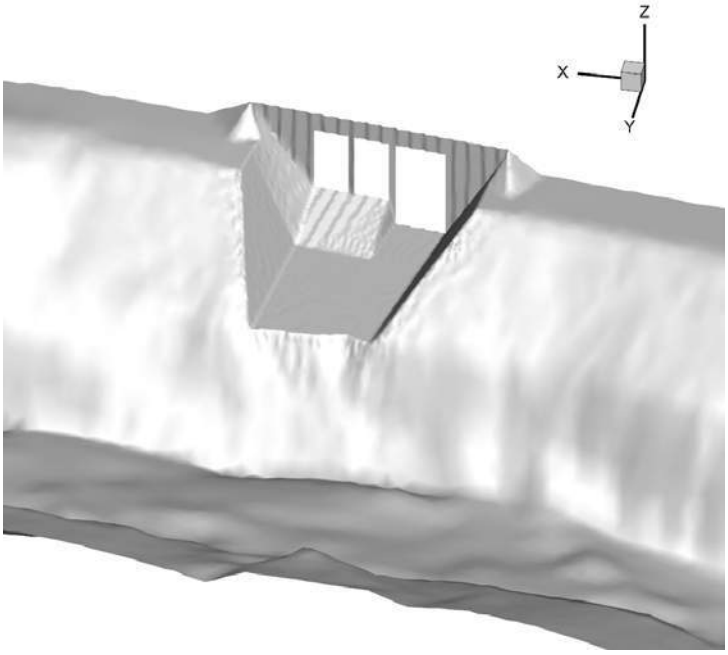
Figure 2. Model domain used for modeling the Sacramento River along the Fremont Weir

The notch location, notch geometry, 2D mesh, and terrain near the notch area of each scenario are presented below. Mostly plots and figures are used. These plots provide a visual documentation of the additional notch configurations/alternatives simulated in this study.

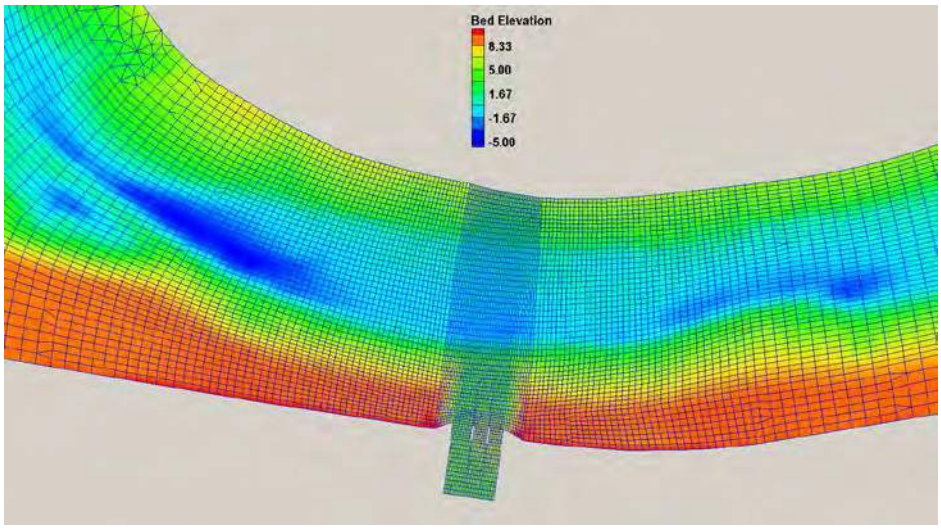
1. Configurations 13 and 13b and EIR/EIS Alternative 2



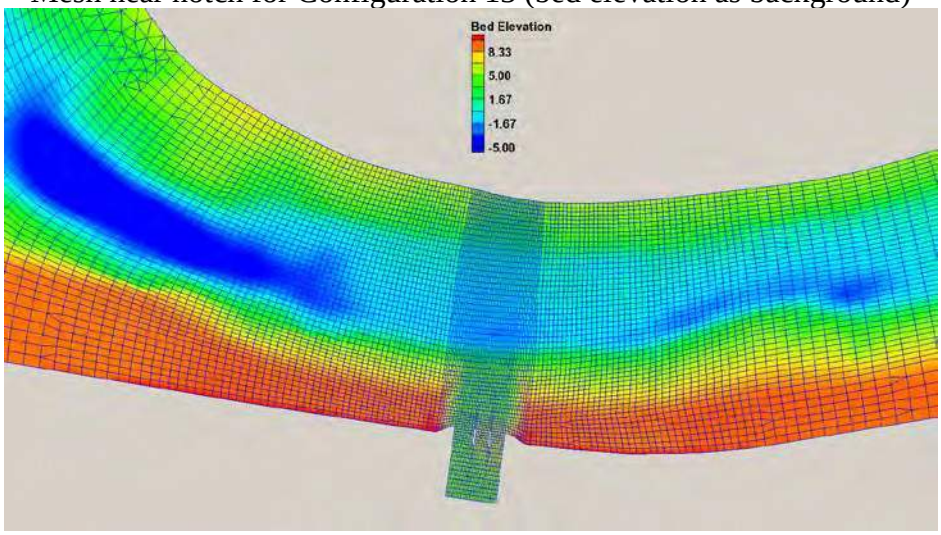
Located at central part of Fremont Weir



Notch geometry based on CAD model(1:5 vertical distortion) (Top is Yolo Bypass side; Bottom is river side)



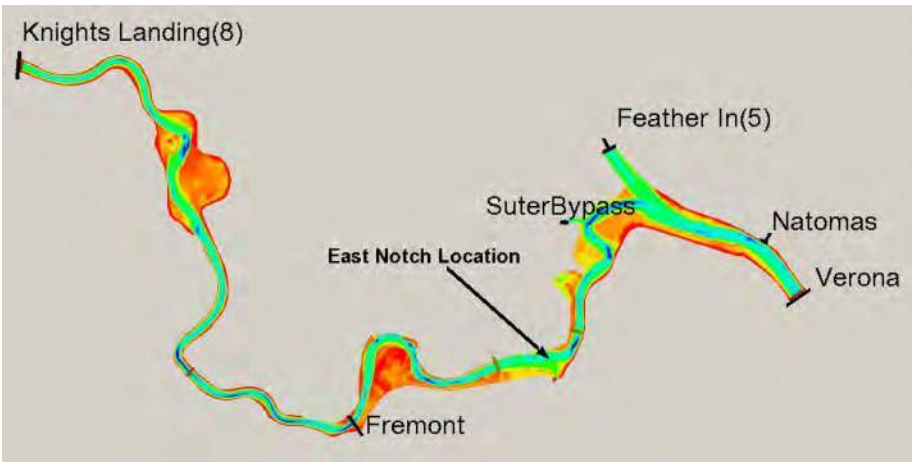
Mesh near notch for Configuration 13 (bed elevation as background)



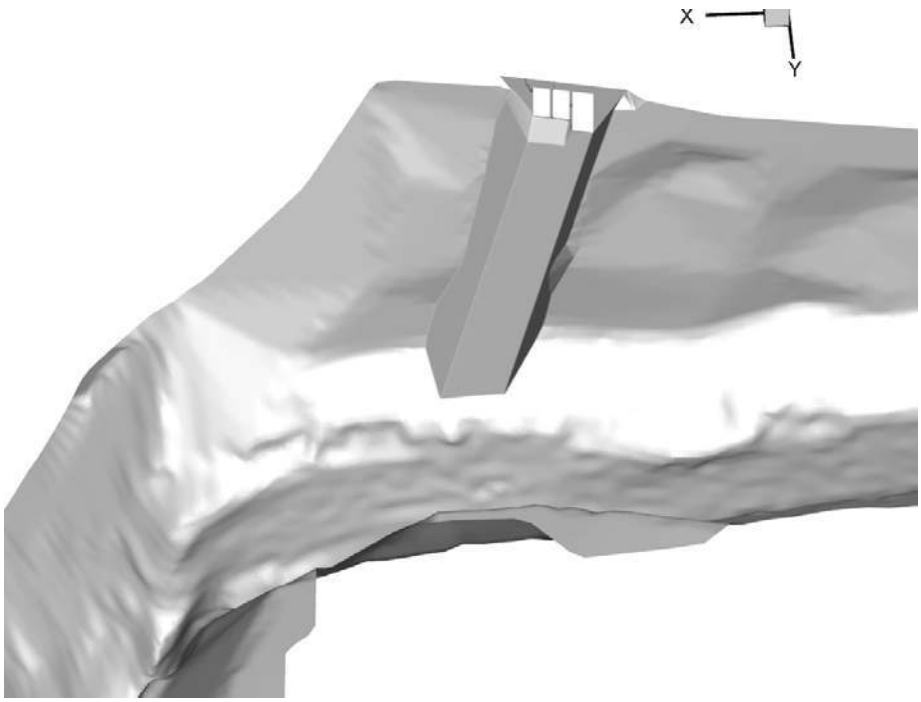
Mesh near notch for Configuration 13b (bed elevation as background)

Figure 3. Configurations 13 and 3b and EIR/EIS Alternative 2: location, terrain/geometry and mesh features (main gate invert is 14.8 ft; elevated gate invert is 18.8 ft)

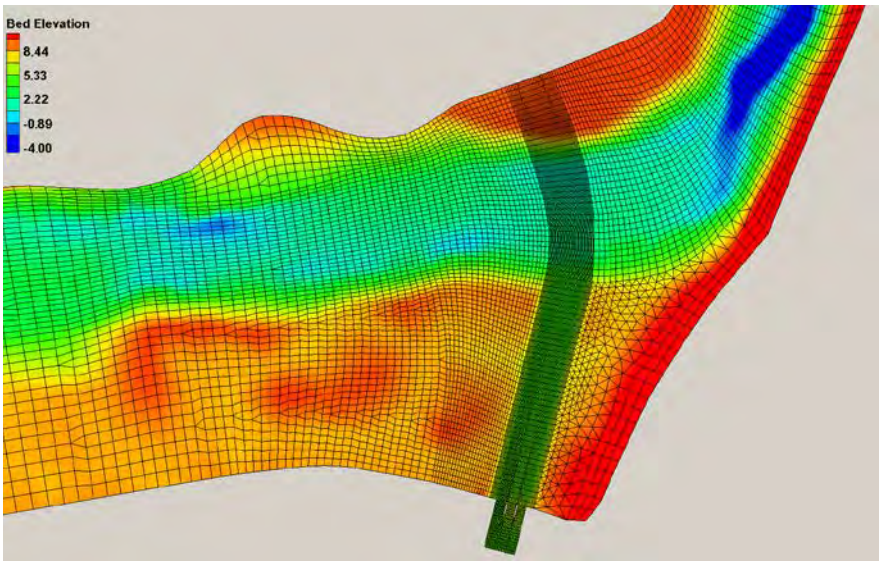
2. Configuration 14 and EIR/EIS Alternative 1



Located at east part of Fremont Weir



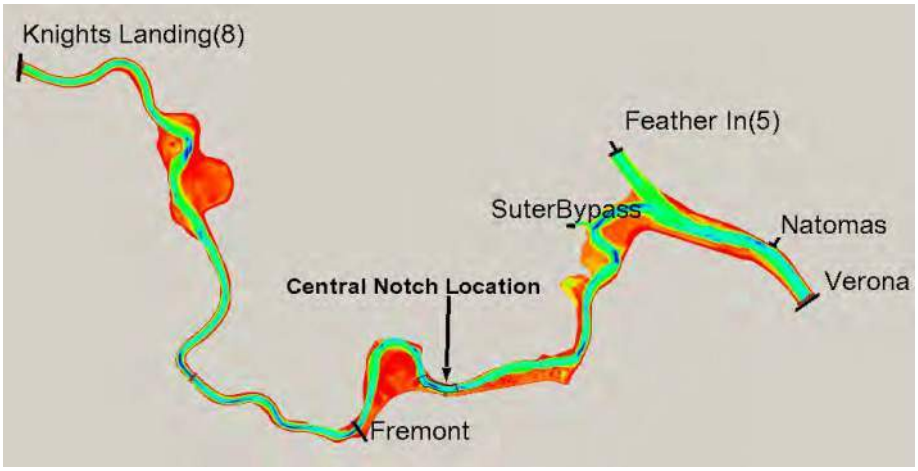
Notch geometry based on CAD model (1:5 vertical distortion)) (Top is Yolo Bypass Side; Bottom is River Side)



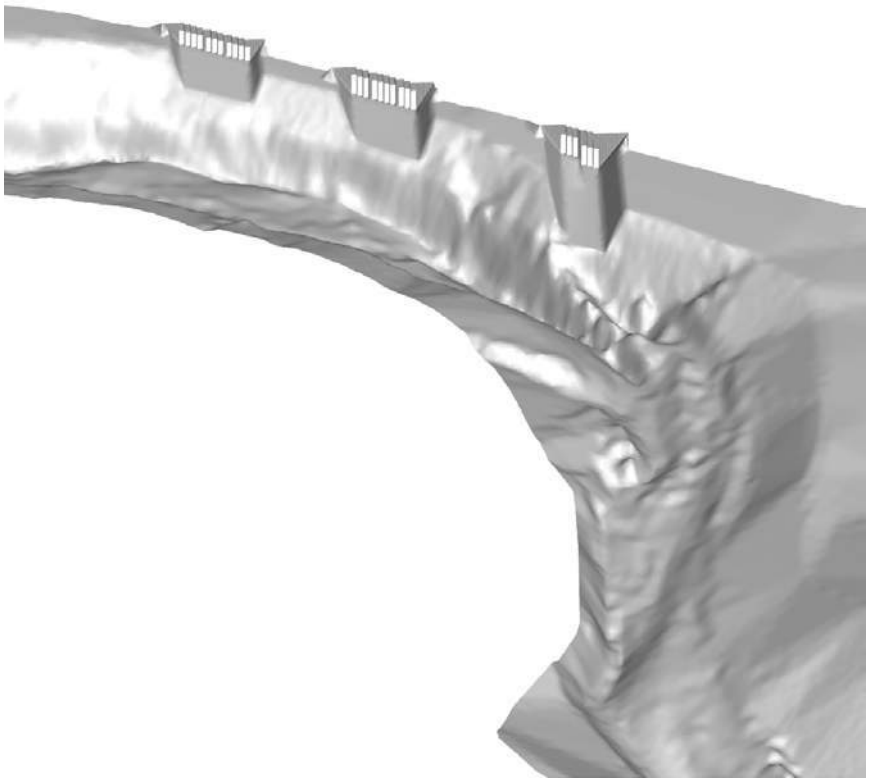
Mesh near notch

Figure 4. Configuration 14 and EIR/EIS Alternative 1: location, terrain/geometry and mesh features (main gate invert is 14 ft; elevated gate invert is 18 ft)

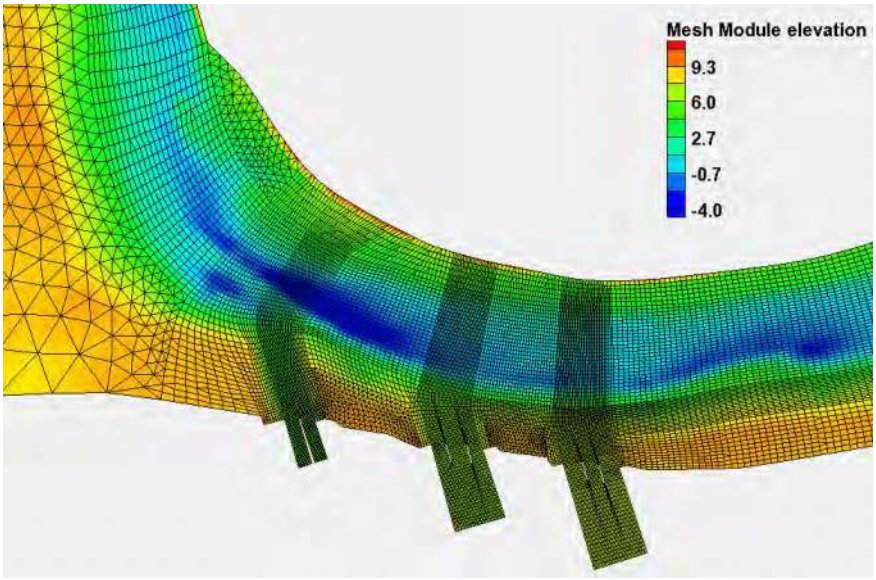
3. Configurations 15 and EIR/EIS Alternative 5



Located at central part of Fremont Weir



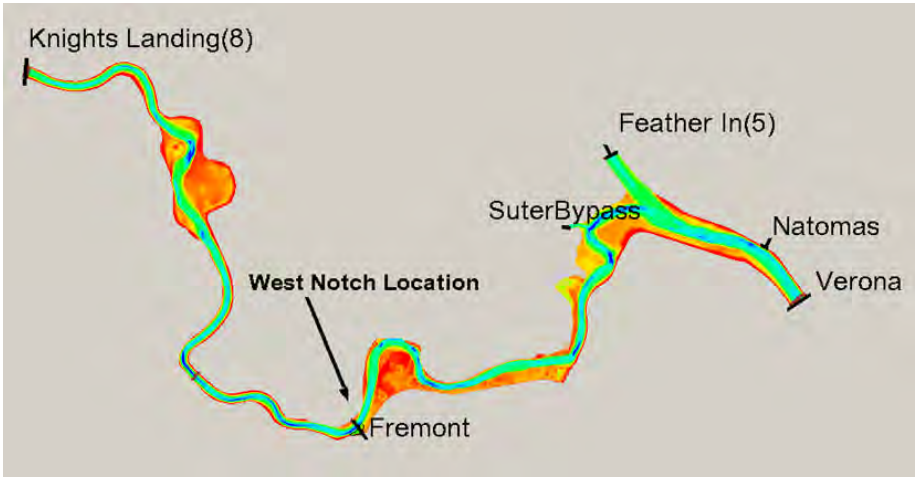
Notch geometry based on CAD model(1:5 vertical distortion) (Top is Yolo Bypass Side; Bottom is River Side)



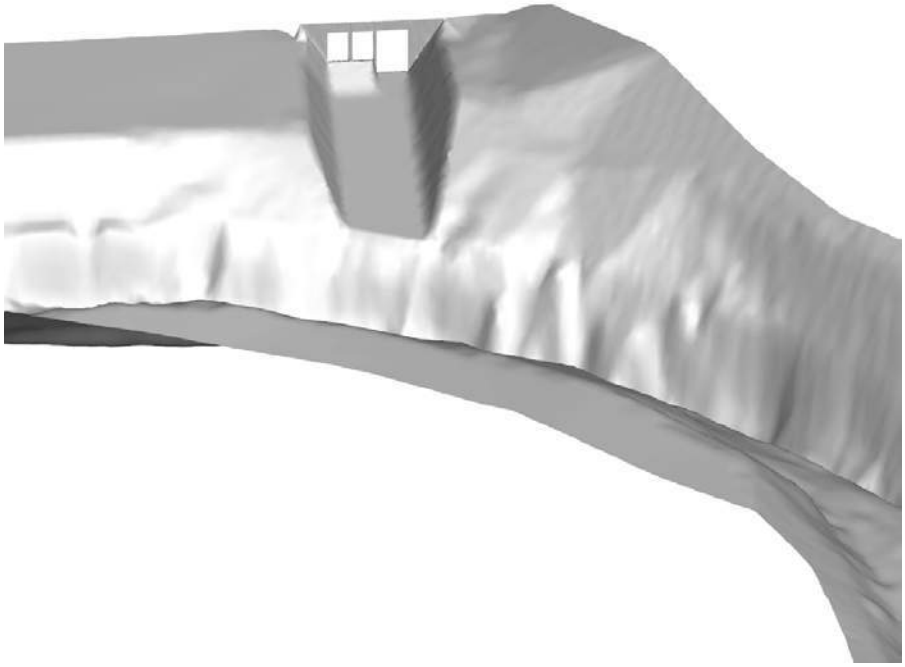
Mesh near notch

Figure 5. Configuration 15 and EIR/EIS Alternative 5: location, terrain/geometry and mesh features (see Table 1and Table 2for gate invert elevation)

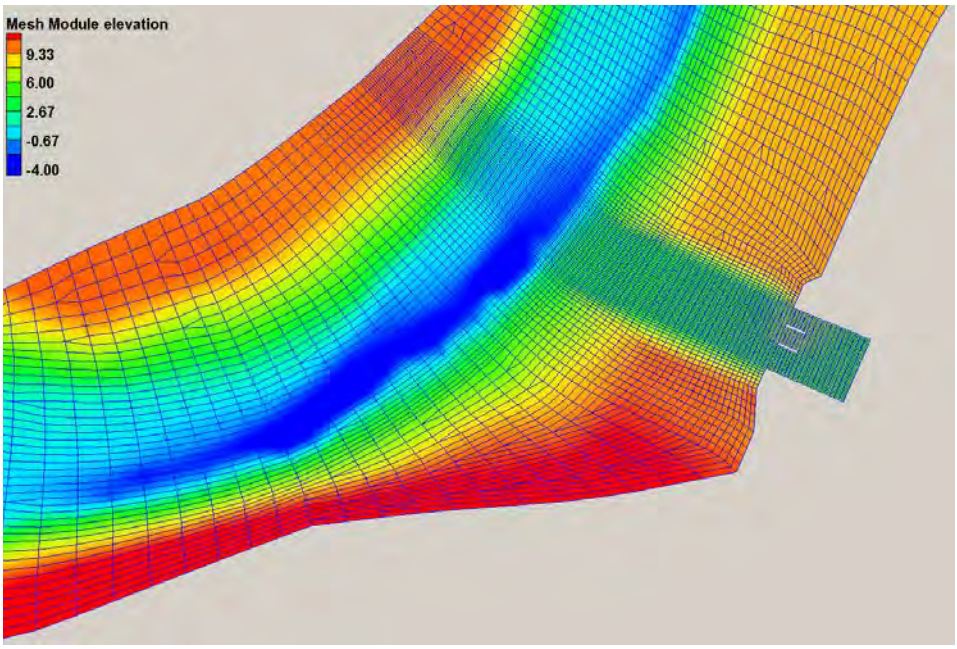
4. Configurations 16 and EIR/EIS Alternative 3 and 4



Located at west part of Fremont Weir



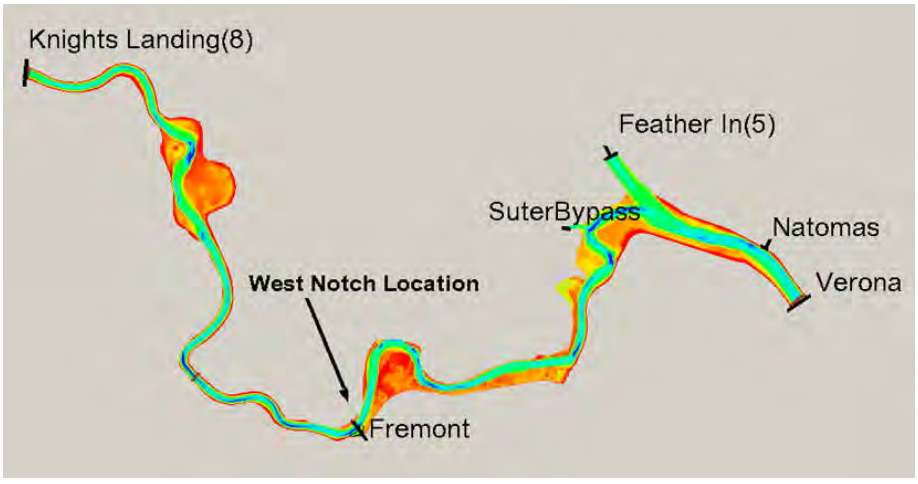
Notch geometry based on CAD model (1:5 vertical distortion) (Top is Yolo Bypass Side; Bottom is River Side)



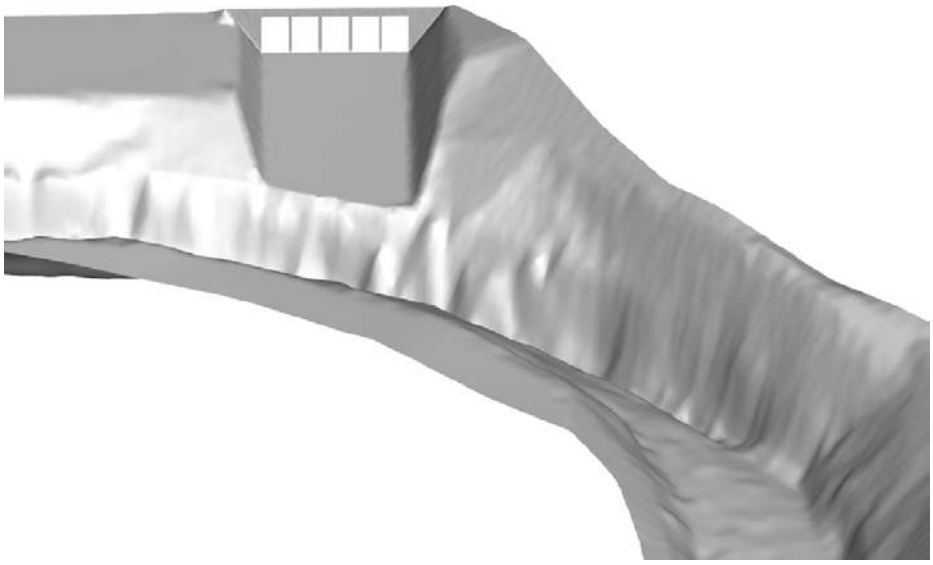
Mesh near notch

Figure 6. Configuration 16 and EIR/EIS Alternative 3 and 4: location, terrain/geometry and mesh features (main gate invert is 16.1 ft; elevated gate invert is 20.1 ft)

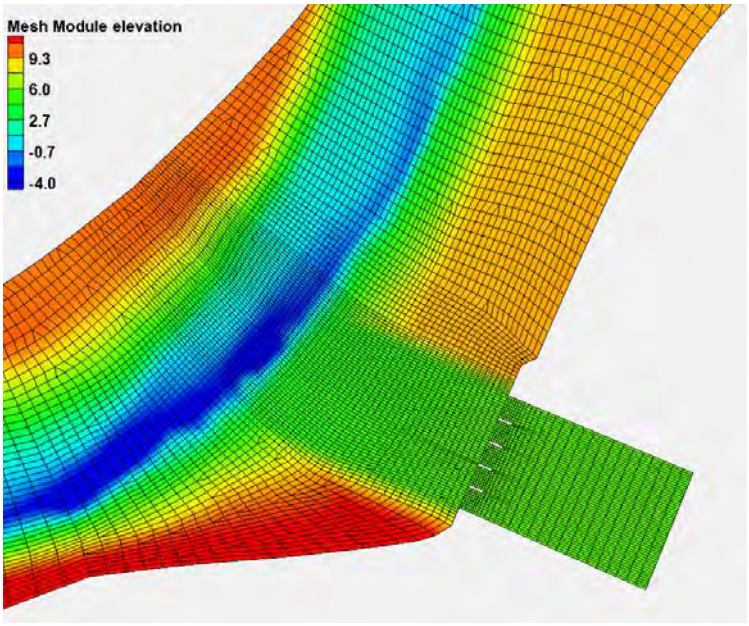
5. EIR/EIS Alternative 6



Located at west part of Fremont Weir



Notch geometry based on CAD model (1:5 vertical distortion) (Top is Yolo Bypass Side; Bottom is River Side)



Mesh near notch

Figure 7. EIR/EIS Alternative 6: location, terrain/geometry and mesh features

2.4 Boundary Conditions

SRH-2D simulation of all configurations/alternatives is performed for the period of December 1, 2014 to January 5, 2015 during which Sacramento River experienced both low and high flows. Flow simulation needs boundary conditions at all open boundaries of the model domain. Refer to Lai (2017) for a detailed discussion on how the flow or stage conditions were developed for the simulation. The boundary conditions used by Lai (2017) are briefly presented below, which is named as the original BC. After the completion of all simulation runs, a different set of boundary conditions were developed using the USGS rating curve which became available to us after the 2017 study. This new USGS rating curved based boundary conditions are also discussed below with some details.

The original BC data set is based on the 2015 gauge data and a large-domain numerical model simulating the 2015 event. This set was used for all 12 previous configurations reported by Lai (2017). The flow hydrograph at the model upstream (Knights Landing) was developed from the Verona Station gauge data and the simulated flow of Feather River into Sacramento ; it is plotted in Figure 8 for the simulation period of Decem,ber 1, 2014 to January 5, 2015. The flow from the Feather River into the Sacramento River was obtained from a much larger SRH-2D model than the current one and is plotted also in the figure. The discharge from the Sutter Bypass via the Sacramento Slough near Karnak, about 800 meters upstream of the Feather River confluence, ranges from 0.1 to 8.43 cfs which was insignificant. The Inflow from the Natomas Cross-cut downstream of the Feather River confluence is also small; a constant of 5.0 cfs is used. Finally, the stage (water elevation) at the Verona Station was available from the gauge and is used as the model downstream boundary condition. Time series changes of the stage at Verona Station are shown in Figure 9. Additional boundary conditions specific to each notch scenario are discussed later when model results are presented. Specifically, the discharges through the gate structures to the Yolo Bypass are needed as the boundary conditions; they are computed from the rating curves developed by DWR for the gates.

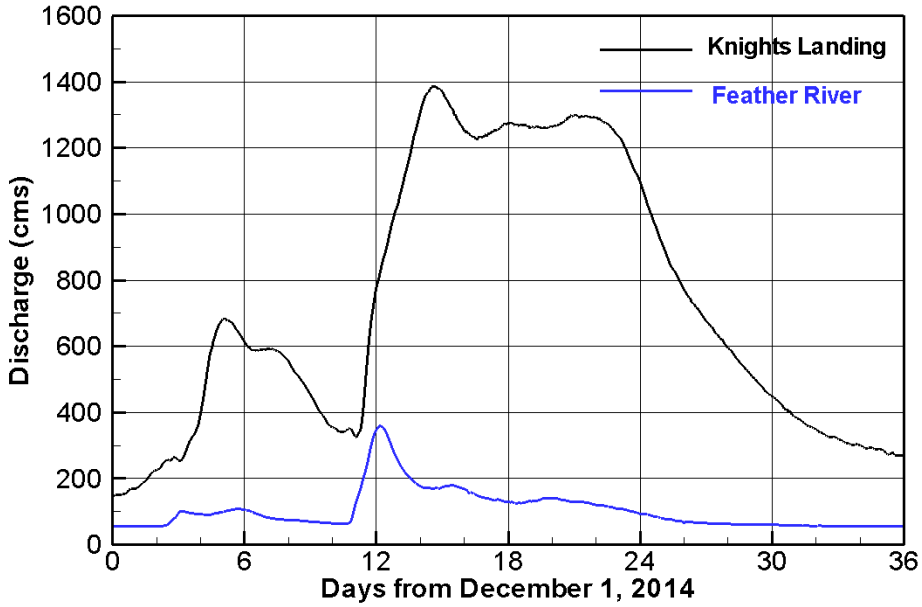


Figure 8. Flow discharges at Knights Landing and Feather River for the period of December 1, 2014 to January 5, 2015

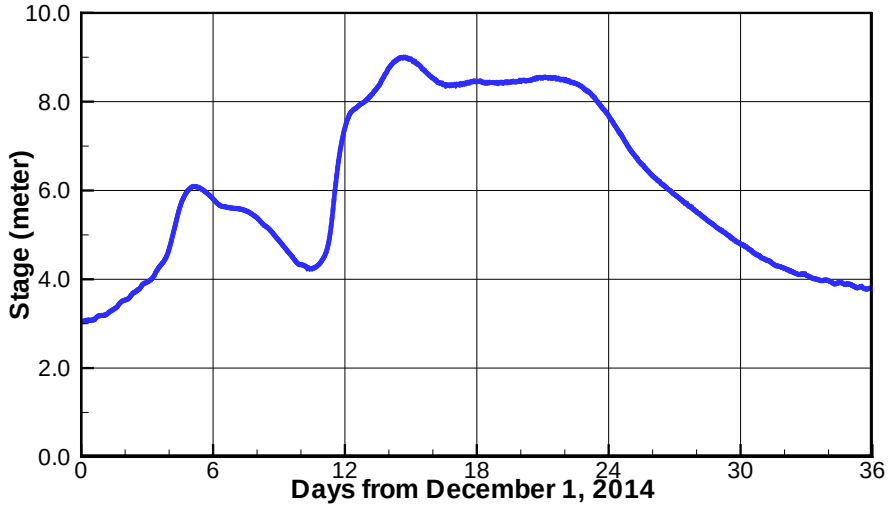


Figure 9. Stage at Verona Station for the period of December 1, 2014 to January 5, 2015

After the 2017 study (Lai, 2017) and completion of Configurations 13 through 16 (reported herein), USGS review comments were brought to our attention. A USGS rating curve was provided to us at the Fremont Weir gauge section of the Sacramento River. The USGS rating curve can be expressed as:

$$Q = 1030.1S - 7522.2$$

where Q is the discharge at the Fremont Weir gauge station in cfs; and S is the stage in feet (NAVD88) at the gauge. A comparison of the USGS rating curve with the boundary condition developed by Lai (2017) suggested that the flow discharge through the Fremont Weir gauge used in Lai (2017) represented probably an extremely high end of the probable flow occurrences. We have decided to simulate the EIR/EIS Alternatives 1 through 6 again using the newly available USGS rating curve. The objective of the new runs is two-folds: (a) The set of new model runs will provide additional results for notch evaluation; and (b) the new runs will partially address the variability issue – that is, how sensitive is the ELAM results to the differing flow conditions.

For comparison purpose, the discharges estimated using the original approach of Lai (2017), specifically for 2015 flow season, and those using the USGS rating curve are tabulated in Table **3**. The first column in the table represents the stages at the Fremont Weir gauge station chosen by DWR as the preferred stages to examine the fish entrainment with ELAM modeling. It is seen that the difference is high for high flows.

Table 3. Comparisons of Discharges at the Fremont Gauge Station using the Lai (2017) approach and with the USGS rating curve

Stage at Fremont Gauge (ft; NAVD88)	Discharge using the Lai (2017) approach (cfs)	Discharge using the USGS rating curve (cfs)
21.79	21888	14925
22.99	24074	16161
24.5	28805	17717.21
27.94	30809	21261
29.44	37635	22806
31.22	45018	24640

If the USGS rating curve is used to determine the flow discharge through the Knight Landing at the upstream boundary of the model, the difference of flows between Verona Station and Knights Landing then has to be made up by flows at the Feature River and Karnak open boundaries or even through other means. At high flows, it is possible that extra flows may be distributed along the Sutter Bypass. Such a scenario is evidenced by the aerial photo taken on January 3, 2003

(see Figure 10). It is possible that part of the difference between the Lai (2017) approach and USGS rating curve is attributed to this unaccounted inflows into the Sacramento River downstream of the Fremont Weir gauge. After discussion among engineers from USACE, Reclamation and DWR, it was decided that the extra water, due to the use of smaller flows through Knights Landing, is added to Karnak and Feather River. Specifically, up to 50 cms is added to Karnak. The rest, if any, is added to the Feather River. This approach enforces that the flow at Knights Landing follows the USGS rating curve; but the total combined flow through Verona Station equals the gauge data. The final flow hydrographs used at Knights Landing, Feather River and Karnak are plotted in Figure 11. This set of boundary conditions are called USGS rating curve BC in this report.



Figure 10. Sutter Bypass on Jan 3, 2003 showing overland flow distributed along the entire width of the Sutter Bypass but Fremont Weir is not overtopped

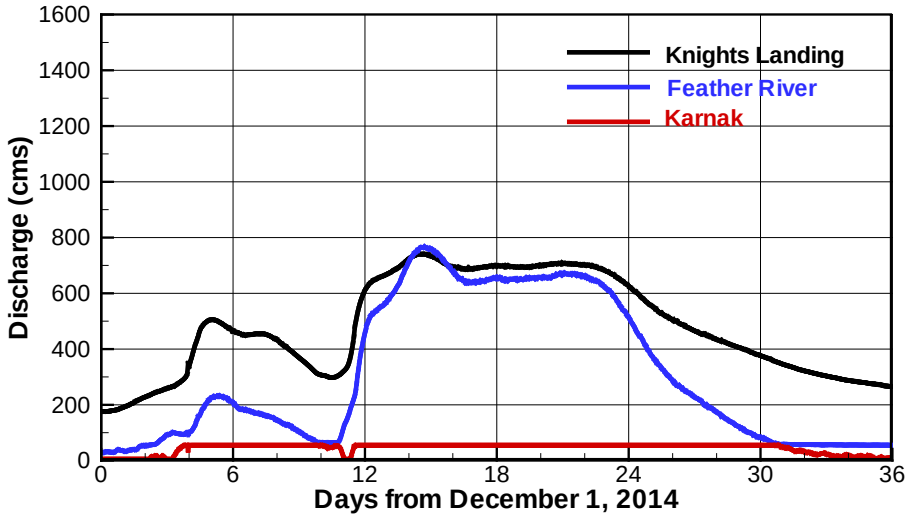


Figure 11. Flow discharges at Knights Landing, Feather River and Karnak using the USGS rating curve for the period of December 1, 2014 to January 5, 2015

3. SRH-2D Model Results

Large amount of hydrodynamic data sets have been generated with the SRH-2D simulation. Results are unsteady and cover more than a month. For each unsteady simulation of a notch scenario, 120 result files in digital form are created and delivered to USACE for ELAM fish migration modeling. Flow result files are numbered consecutively with two consecutively numbered results 6 hours apart (e.g., TEC1.dat is at hour 6, TEC2.dat is at hour 12, etc.). The primary purpose of the hydrodynamic simulation is to predict the flow field under notch scenario so that ELAM modeling may be carried out. Therefore, no detailed discussions of the flow hydrodynamic results are provided in this report. Instead, predicted flows through the notch gate structure are documented in graphical forms. Snapshots of flow patterns in the notch area are presented at two selected times.

3.1 Configurations 13 and 13b (Central 6K Intake with the Original BC)

The location and terrain of Configurations 13 and 13b may be seen in Figure **3**. It is located at the central part of the Fremont Weir. The approach channel is "intake" type and the gate structure consists of one gate with a primary opening and two elevated openings. The primary opening invert is 14.8 ft and the elevated invert is 18.8 ft. The design maximum flow through the gate structure is 6,000 cfs at an upstream stage of 29.348 ft. Note that: (a) Configurations 13 and 13B herein are simulated using the original BC only, and (b) Configuration 13 has the same geometry and terrain as EIR/EIS Alternative 2.

The flow through the gate is computed using the rating curve developed by DWR. The rating curve relates the discharge through the gate to the stage upstream of the gate and is shown in Figure **12**. The same rating curve is used also by Configurations 13b. The model simulated discharge through the gate and the stage upstream of the gate are plotted in Figure **13** for the period of December 1, 2014 to January 5, 2015.

An additional run, Configuration 13b, is carried out which is the same as Configuration 13 except that the river terrain near the gate is modified. Terrain modifications include primarily changes made to the bank and the river bottom near the notch due to the removed remnant rock revetment. Modifications were done by USACE engineers and supplied to Reclamation. A comparison of the terrains in the notch area between Configurations 13 and 13b is shown in Figure **14**. The predicted discharges through the gate and the stage upstream for Configuration 13b are shown in Figure **13**. As far as the flows through the gate are concerned, the differences between the two configurations seem small and negligible.

The predicted flow hydrodynamic results are primarily used for ELAM modeling; so they are not discussed in details. For documentation purpose, only snapshots of the flow patterns at two times are plotted in Figure **15** and Figure **16**.

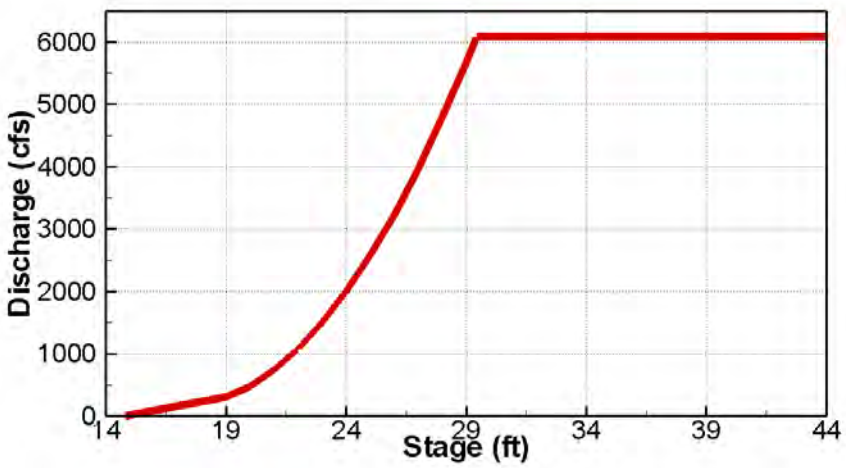
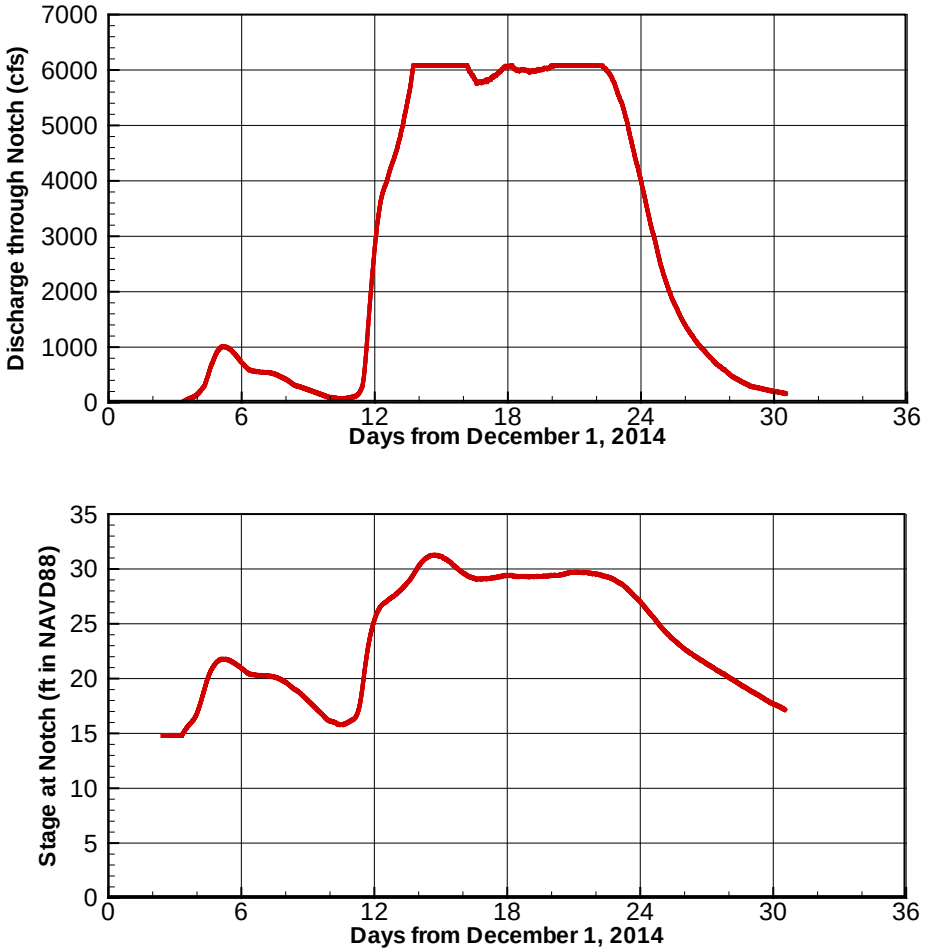
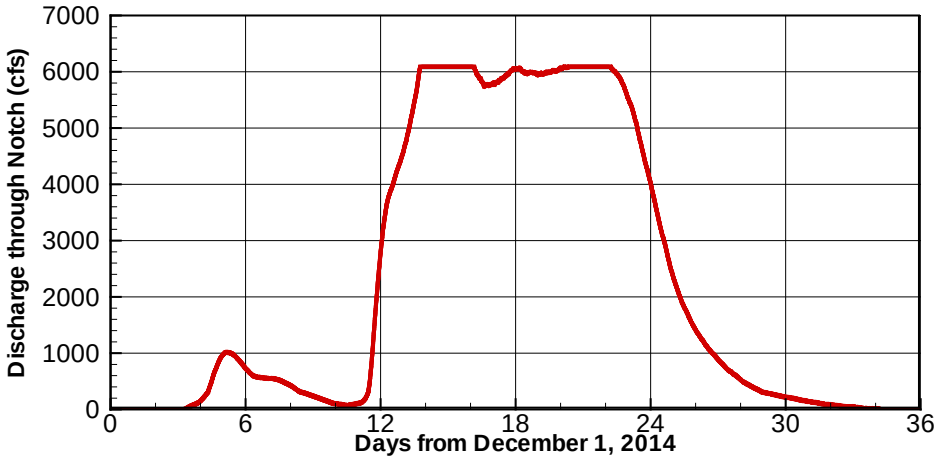
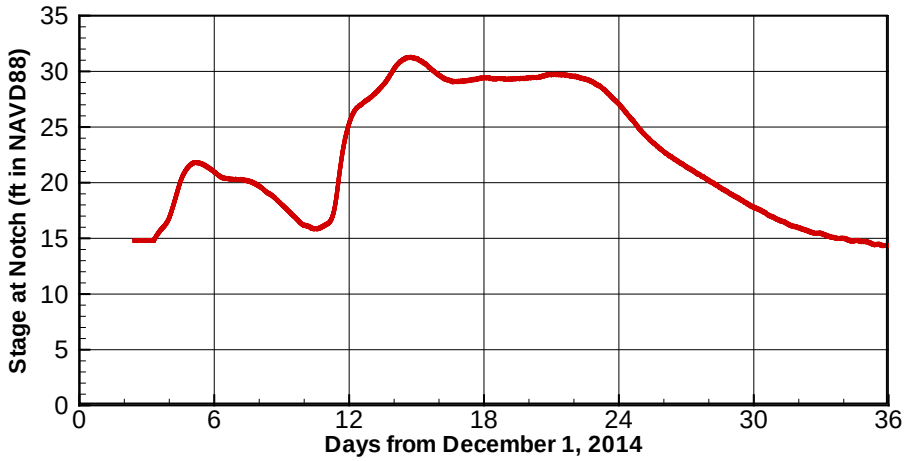


Figure 12. Rating curve used for Configurations 13 and 13b



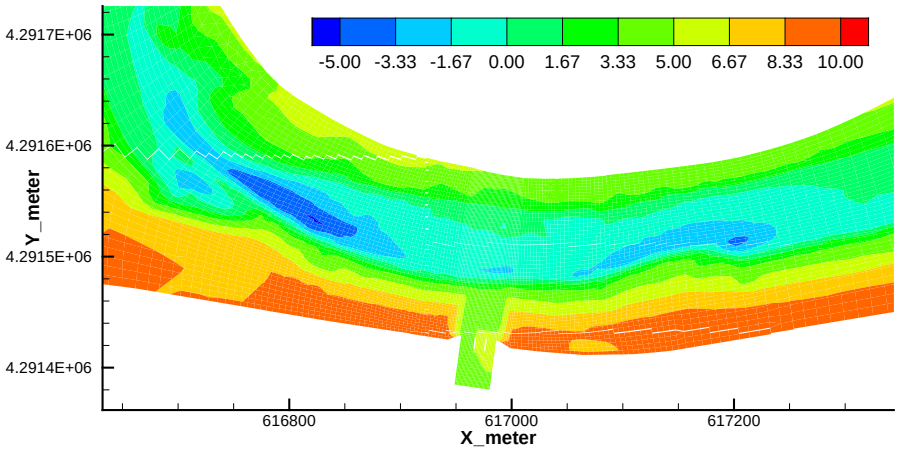
(a) Configuration 13



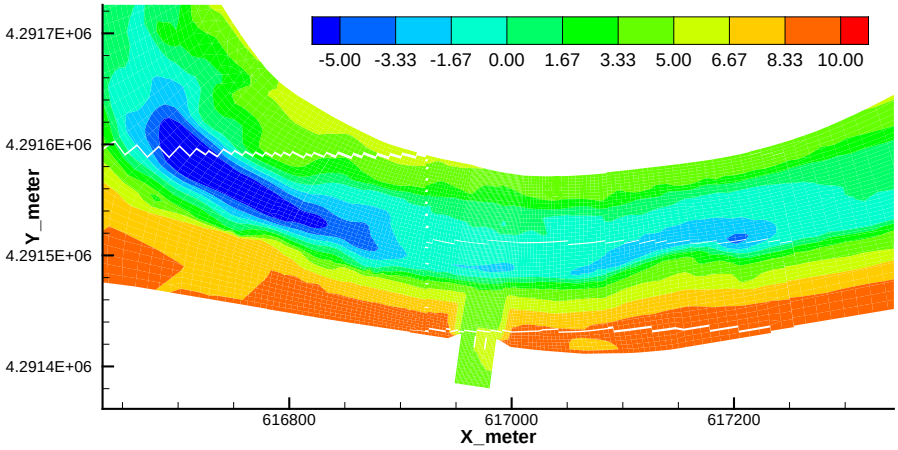


(b) Configuration 13b

Figure 13. Time history of predicted discharge through the gate and stage upstream of the gate for Configurations 13 and 13b

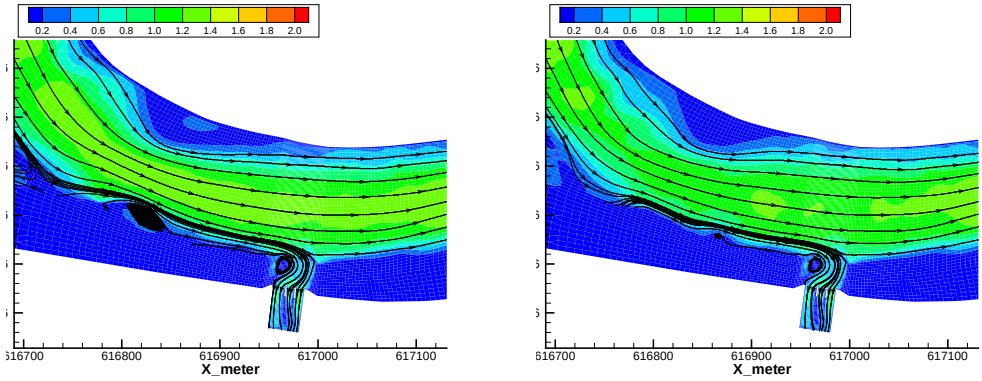


(a) Configuration 13



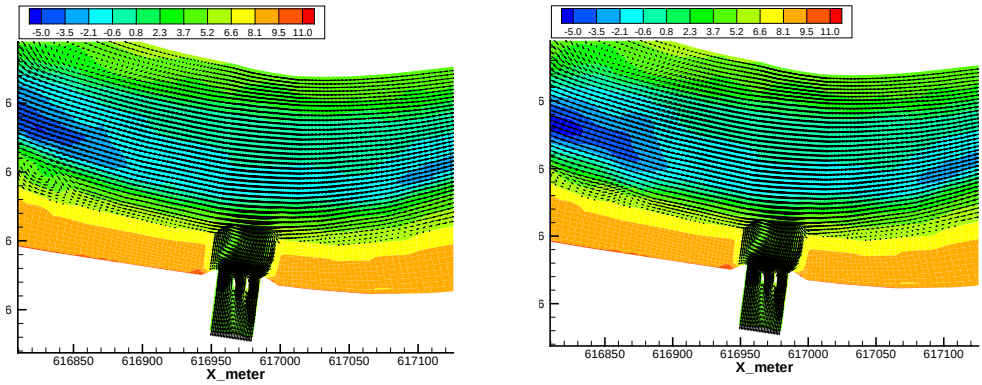
(b) Configuration 13b

Figure 14. Terrain comparison in the notch area between Configurations 13 and 13b



Configuration 13 Configuration 13b

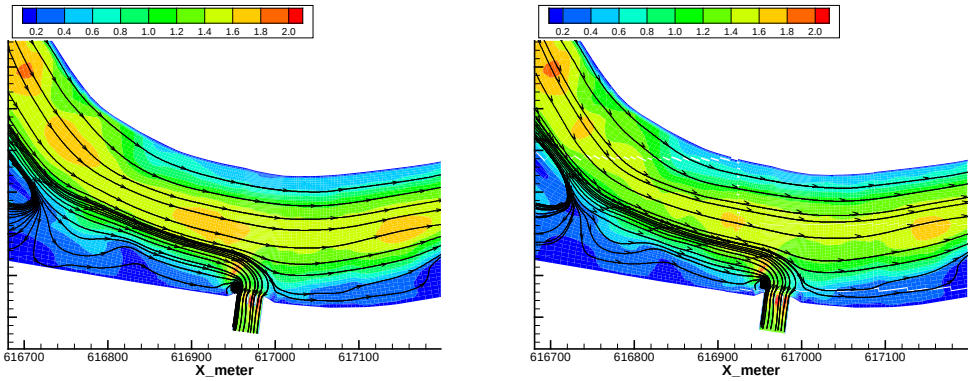
Flow streamlines with velocity magnitude (m/s) as background



Configuration 13 Configuration 13b

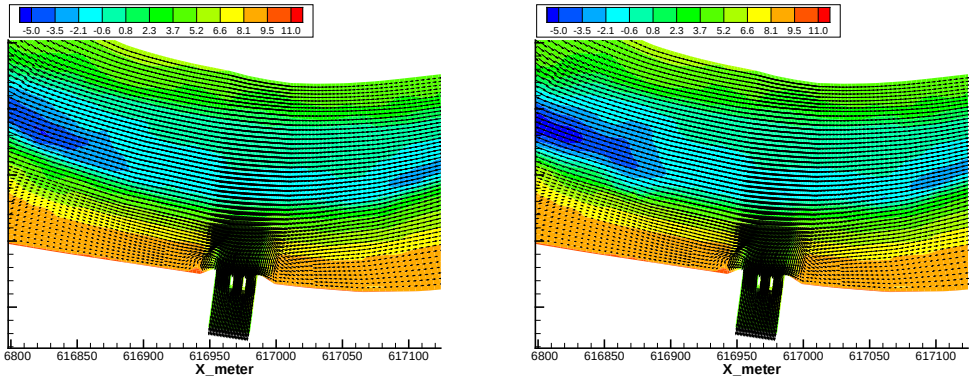
Velocity vector with bed elevation (m) as background

Figure 15. Predicted flow velocity and flow pattern near the notch for Configurations 13 and 13b at Day 6



Configuration 13 Configuration 13b

Flow streamlines with velocity magnitude (m/s) as background



Configuration 13 Configuration 13b

Velocity vector with bed elevation (m) as background

Figure 16. Predicted flow velocity and flow pattern near the notch for Configurations 13 and 13b at Day 18

3.2 Configuration 14 (East 6K Intake with the Original BC)

The location and terrain of Configuration 14 are displayed in Figure **4**. The notch is located at the east part of the Fremont Weir. The approach channel is "intake" type. The gate structure consists of two parts: a primary gate having an invert elevation of 14 ft and two secondary gates with 18 ft invert. The design maximum flow through the gate structure is 6,000 cfs; it occurs at an upstream stage of 27.844 ft. Note that the geometry and terrain of Configuration 14 are the same as EIR/EIS Alternative 1.

The flow through the gate is an additional boundary condition and it is obtained using a rating curve provided from DWR. The rating curve used is shown in Figure **17**.

Simulation from December 1, 2014 to January 5, 2015 is carried out using the original BC. The predicted discharge through the gate and the stage upstream of the gate are shown in Figure **18**. Snapshots of predicted flow patterns at two times are plotted in Figure **19** and Figure **20** for documentation purpose.

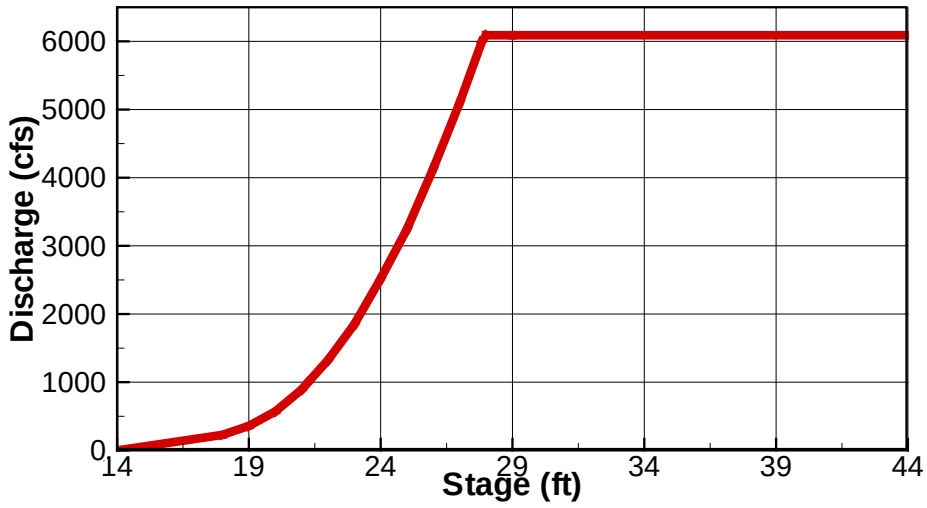


Figure 17. Rating curve used for Configuration 14

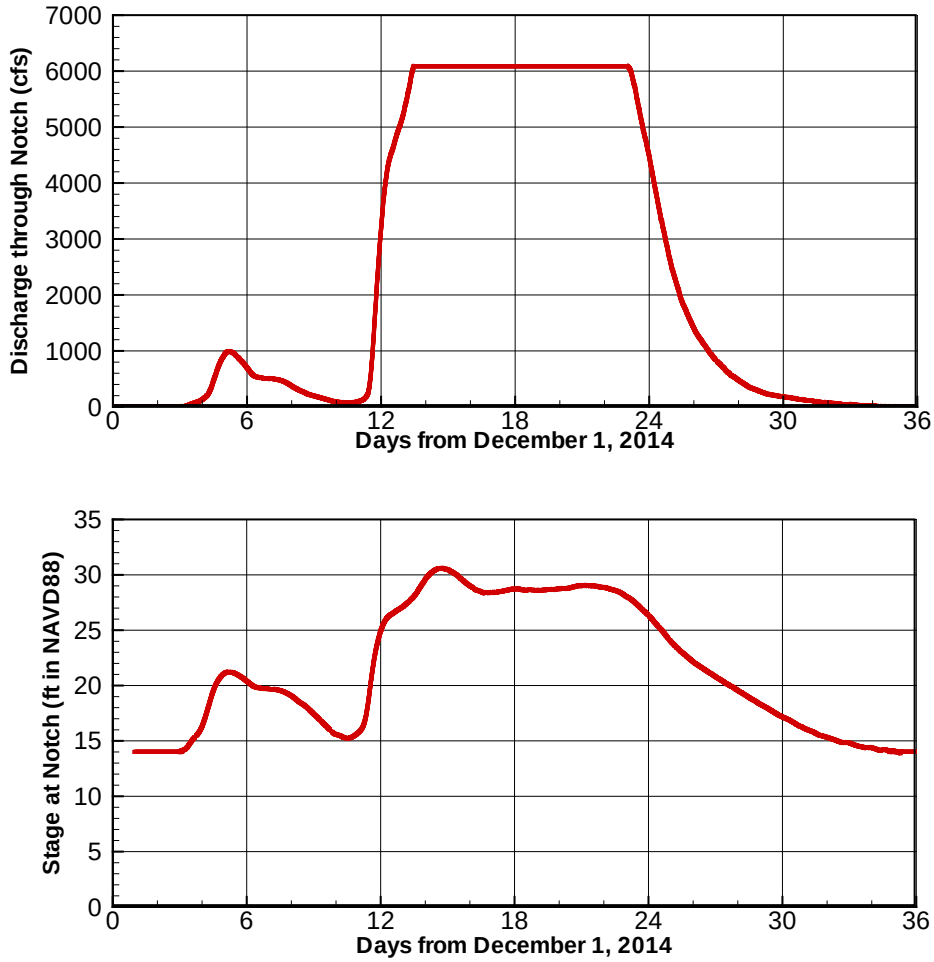
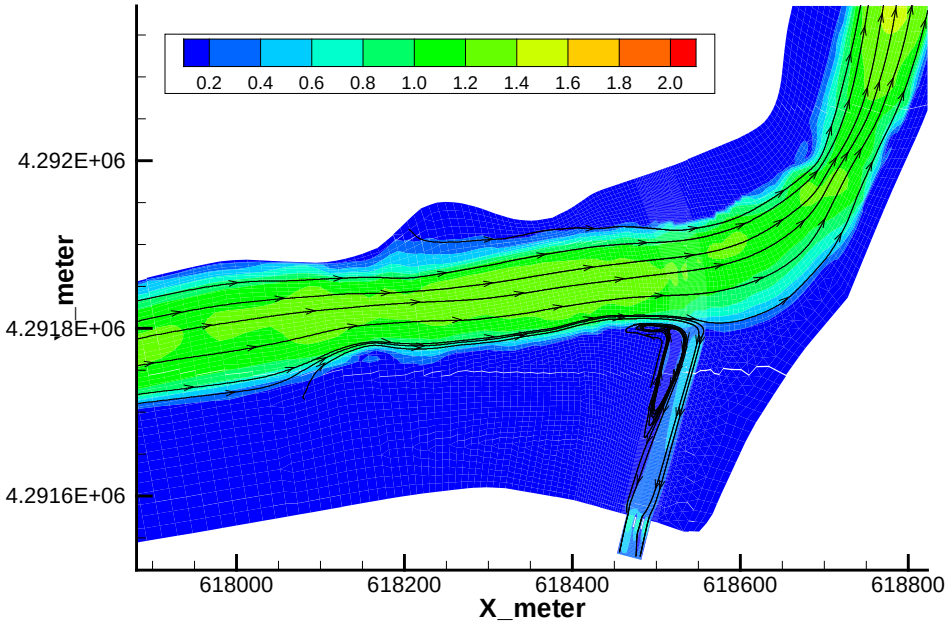
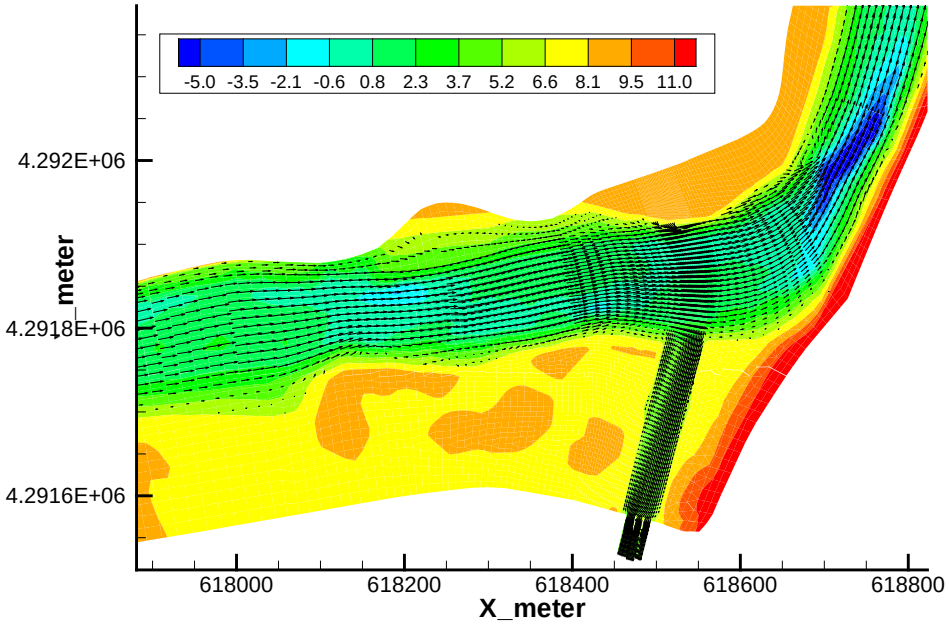


Figure 18. Time history of predicted discharge through the gate and stage upstream of the gate for Configuration 14 (East 6K Intake)

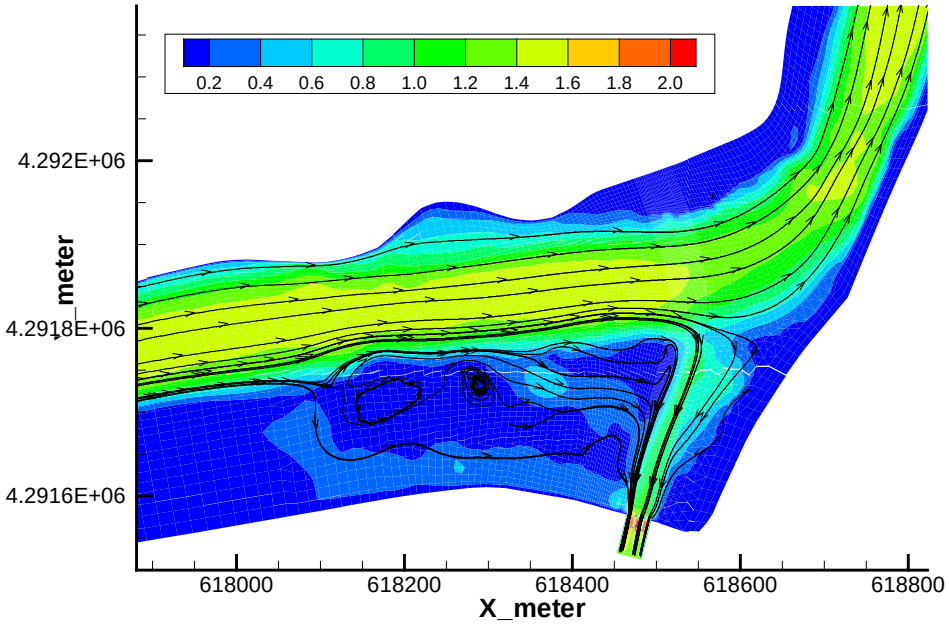


(a) Flow streamlines with velocity magnitude (m/s) as background

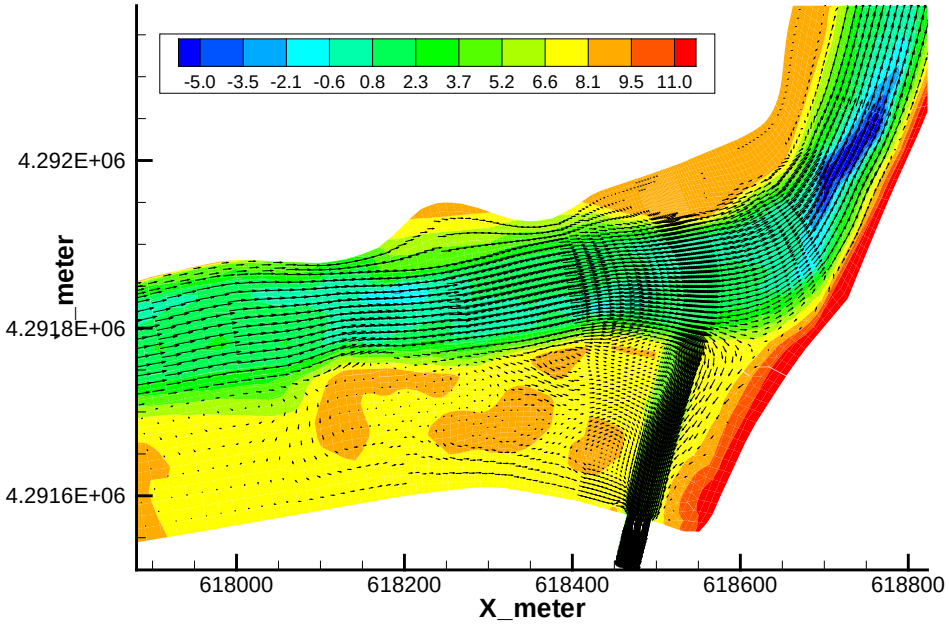


(b) Velocity vector with bed elevation (m) as background

Figure 19. Predicted flow velocity and flow pattern near the notch of Configuration 14 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 20. Predicted flow velocity and flow pattern near the notch of Configuration 14 at Day 18

3.3 Configuration 15 (Central Multi-Gate Intake with the Original BC)

The location and terrain of Configuration 15 are displayed in Figure **5** which is located at the central part of the Fremont Weir. The approach channel is “intake” type. This configuration consists of four gates named A, B, C and D as shown in Figure **21**. In the figure the invert of each gate is also marked. Each gate is being opened or closed at different river stages. For example, at stage 26.75 ft the flow is 3,000 cfs through gates A-C, but at stage 27 ft the flow is limited to 3,000 cfs through gates C and D. The timing for the gate opening and closing is dependent on the flow stages upstream of the gates. In the simulation the timing and the discharges through each gate are determined by the rating curves supplied to Reclamation from DWR. The four discharge versus stage rating curves are shown in Figure **22**. Note that the gate geometry and river terrain of Configuration 15 are the same as EIR/EIS Alternative 5.

An unsteady simulation is carried out for the Configuration from December 1, 2014 to January 5, 2015 using the original boundary conditions. The predicted time series discharges through all gates along with the stages upstream of the gates are plotted in Figure **23** through Figure **26**. Snapshots of the flow patterns in the notch area for the configuration are plotted in Figure **27** and Figure **28** at two different times.

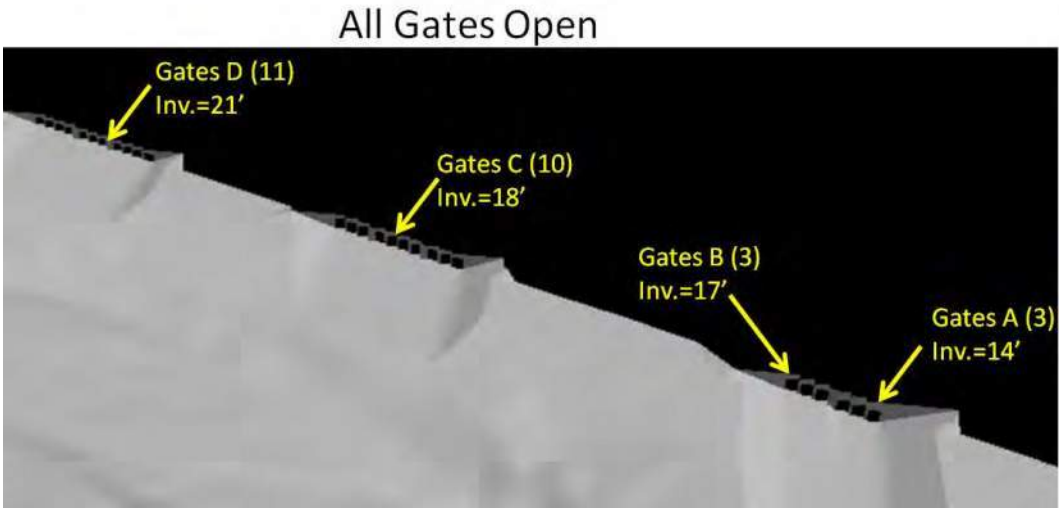


Figure 21. Location and gate invert of four gates on the river right (Yolo Bypass side) for Configuration 15

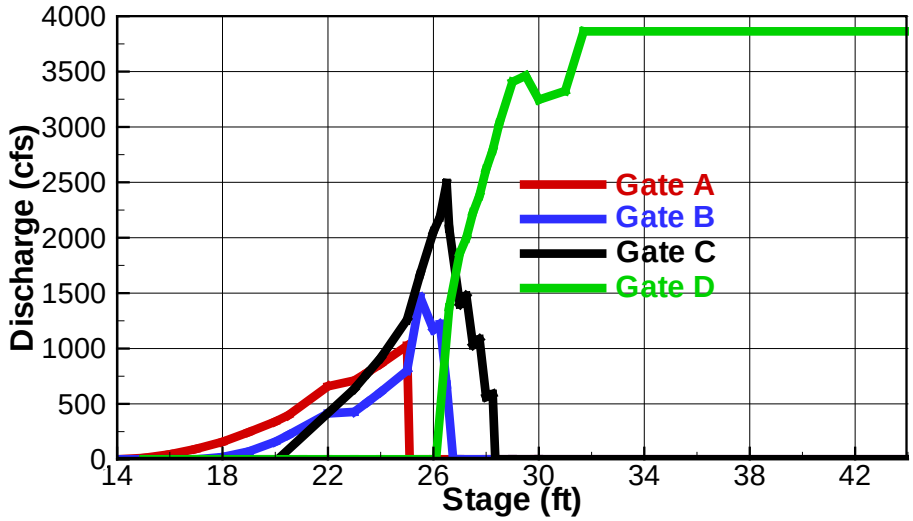


Figure 22. The rating curves used at four gates of Configuration 15 (Red=Gate A; blue=Gate B; Black=Gate C; Green=Gate D)

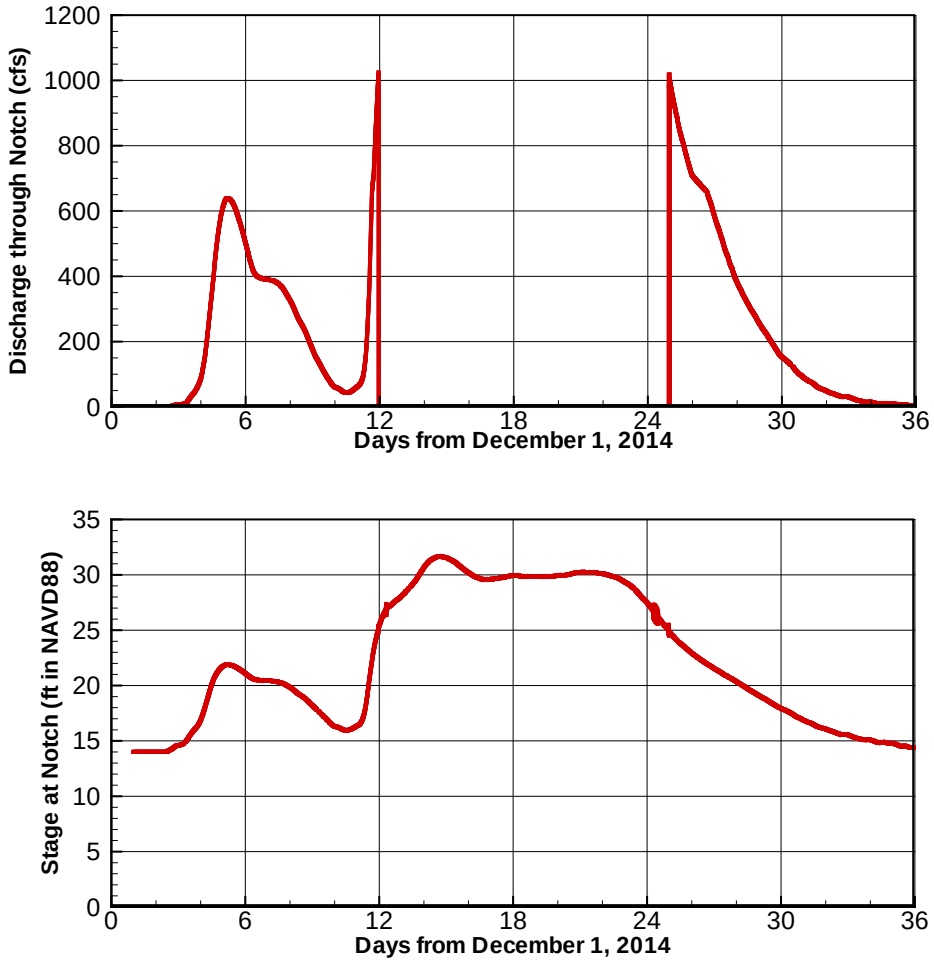


Figure 23. Time history of predicted discharge through Gate A and the stage upstream of Gate A for Configurations 15 (Central Multi-Gate Intake)

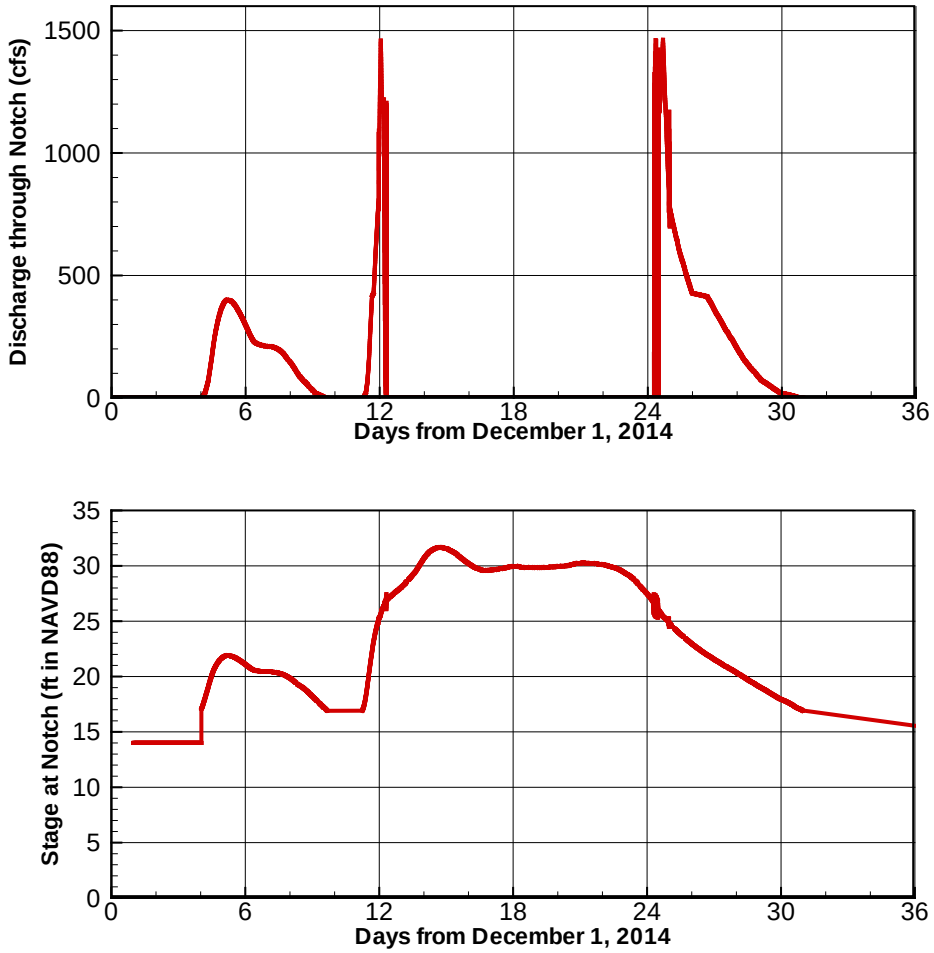


Figure 24. Time history of predicted discharge through Gate B and stage upstream of Gate B for Configurations 15 (Central Multi-Gate Intake)

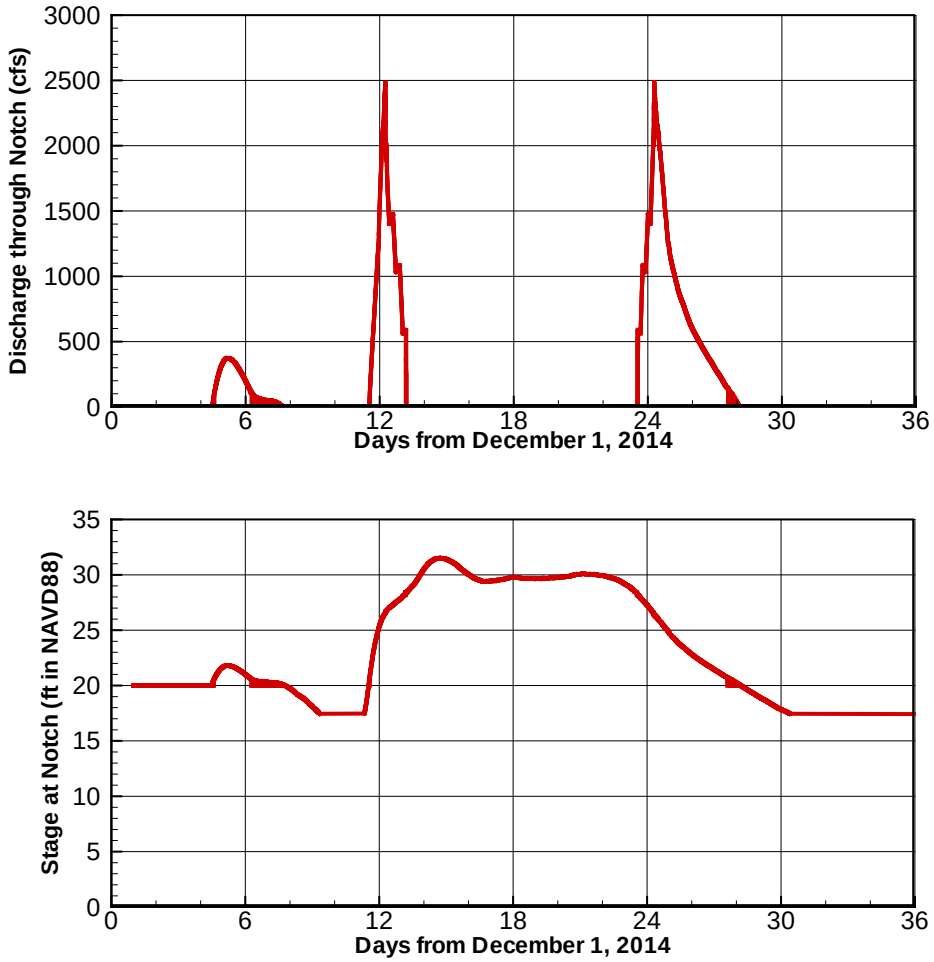


Figure 25. Time history of predicted discharge through Gate C and stage upstream of Gate C for Configurations 15 (Central Multi-Gate Intake)

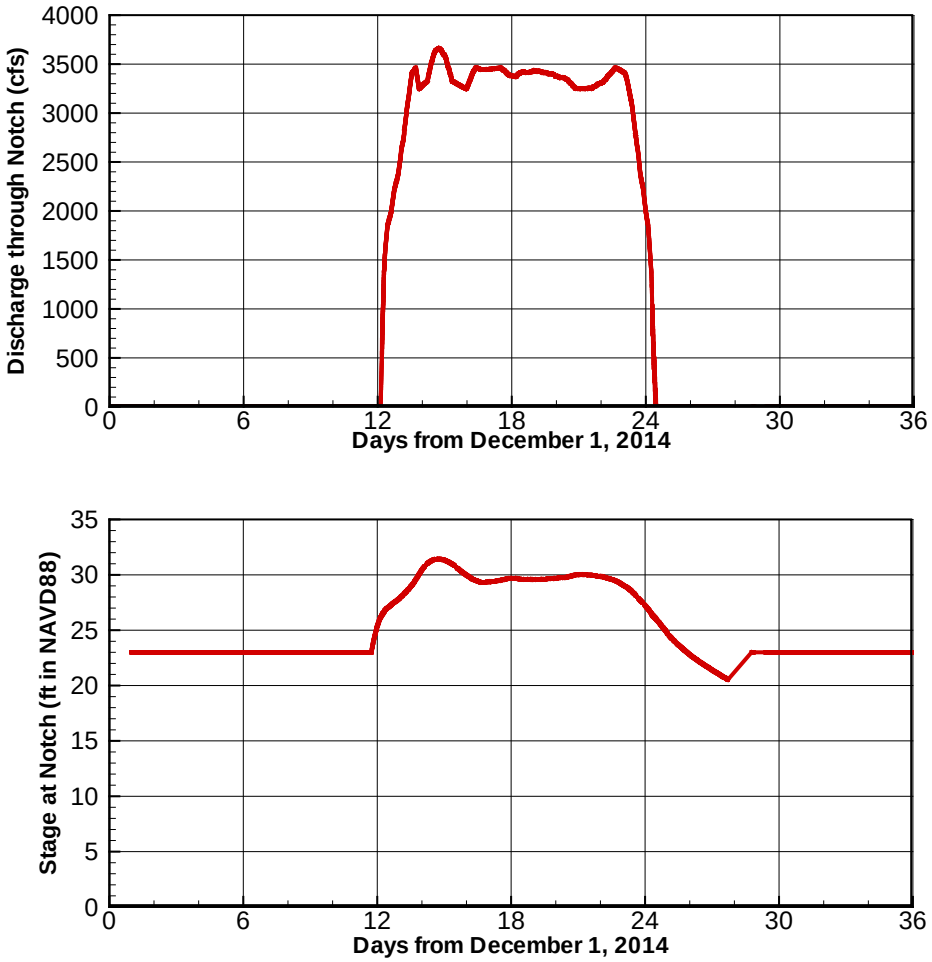
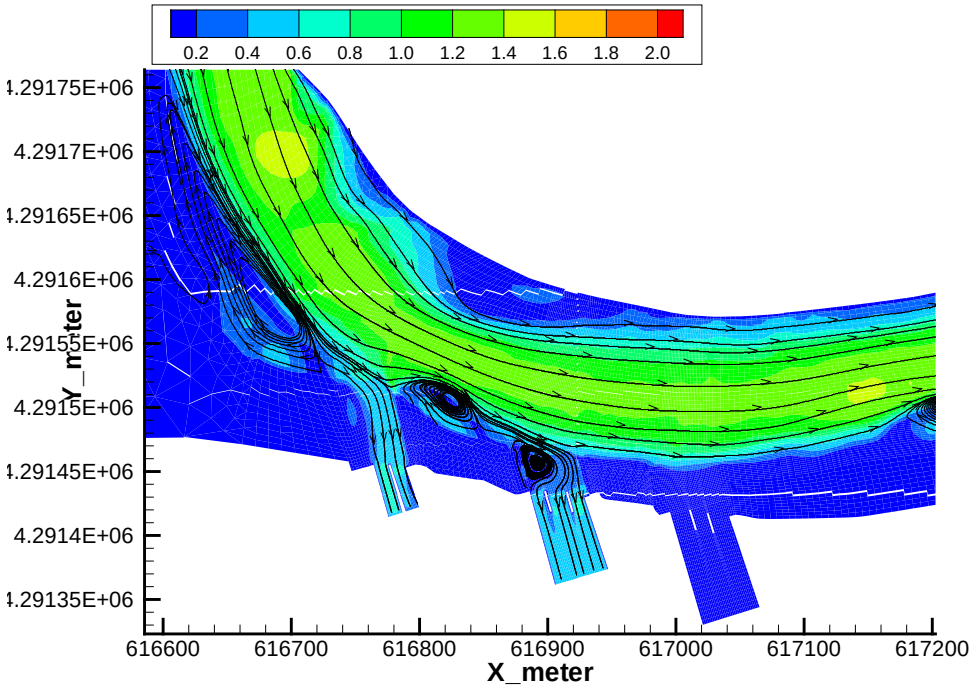
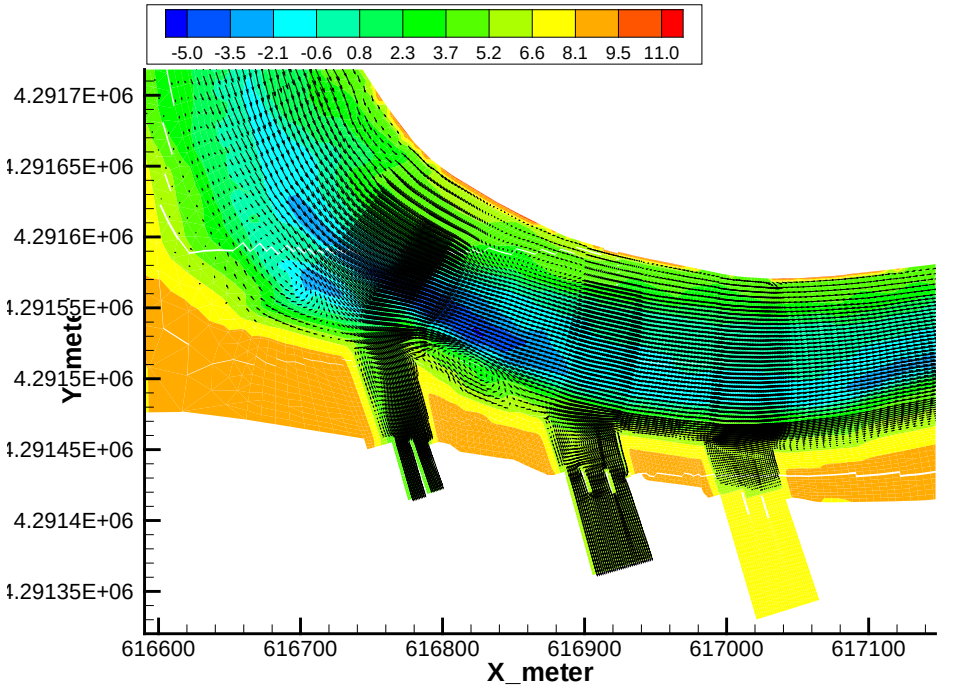


Figure 26. Time history of predicted discharge through Gate D and stage upstream of Gate D for Configurations 15 (Central Muli-Gate Intake)

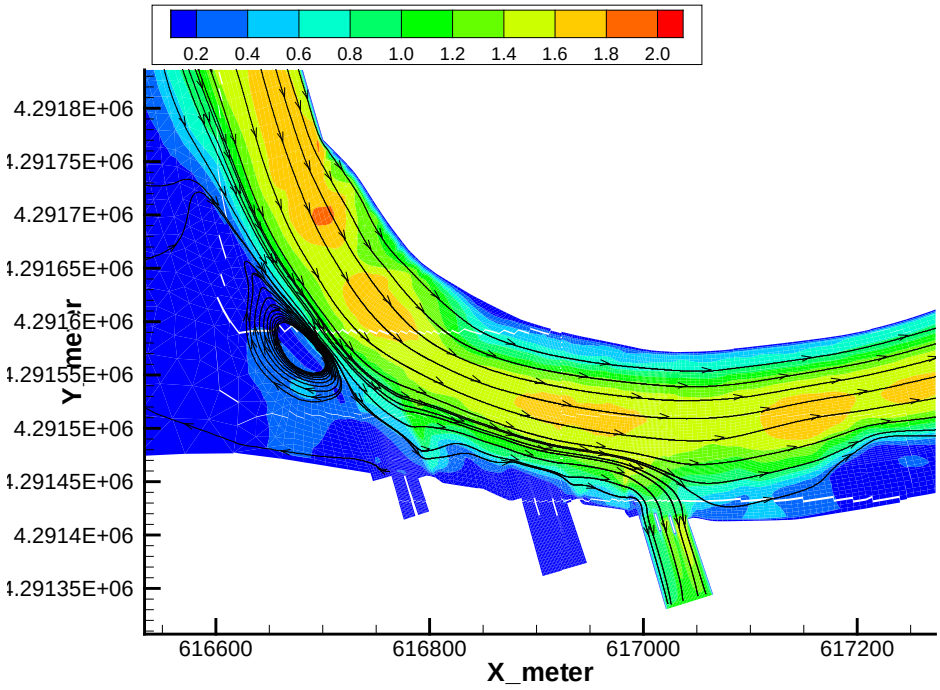


(a) Flow streamlines with velocity magnitude (m/s) as background

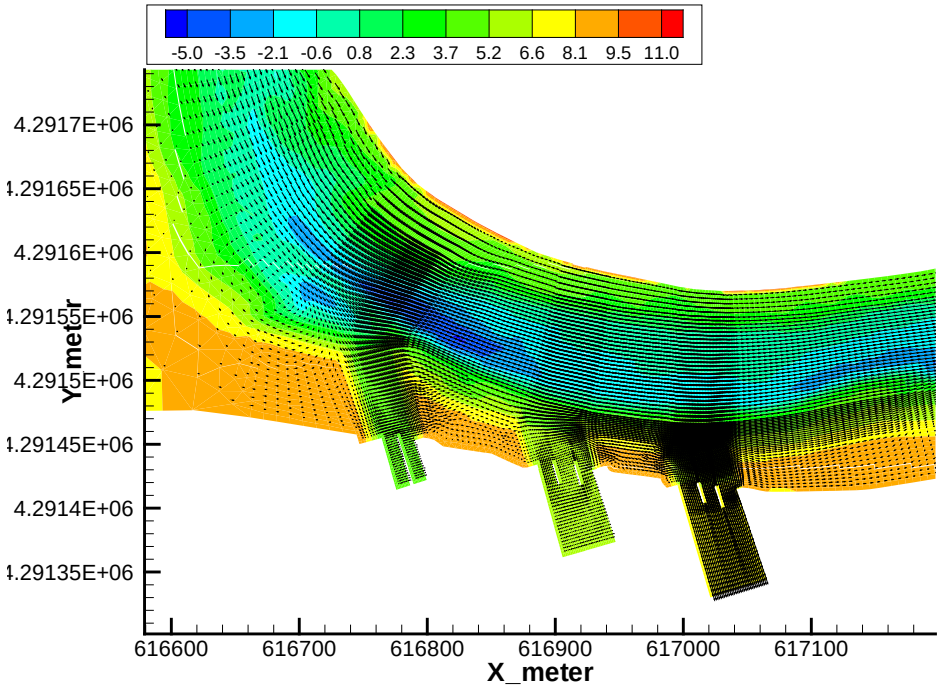


(b) Velocity vector with bed elevation (m) as background

Figure 27. Predicted flow velocity and flow pattern near the notch of Configuration 15 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 28. Predicted flow velocity and flow pattern near the notch of Configuration 15 at Day 18

3.4 Configuration 16 (West 3K Intake with the Original BC)

The location and terrain of Configuration 16 are displayed in Figure **6**. It is located at the west part of the Fremont Weir. The approach channel is "intake" type. The gate consists of two parts: a primary gate with an invert elevation of 16.1 ft and two secondary gates with an invert of 20.1 ft. The design maximum flow through the gate structure is 3,000 cfs at the upstream stage of 27 ft.

The flow through the gate is an additional boundary condition and a rating curve supplied by DWR is used which is shown in Figure **29**. The predicted discharge through the gate and the stage upstream of the gate are shown in Figure **30**. Snapshots of flow patterns at two times are plotted in Figure **31** and Figure 32.

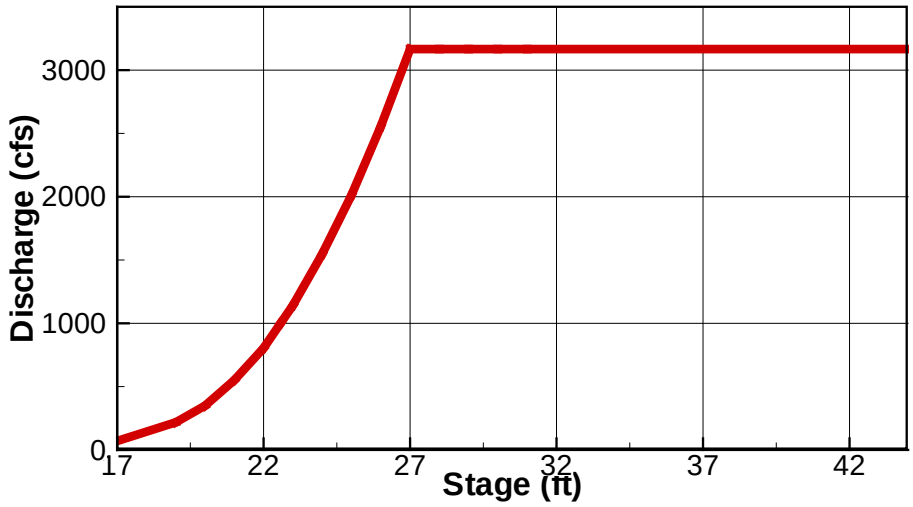


Figure 29. Rating curve used for Configuration 16 (West 3K Intake)

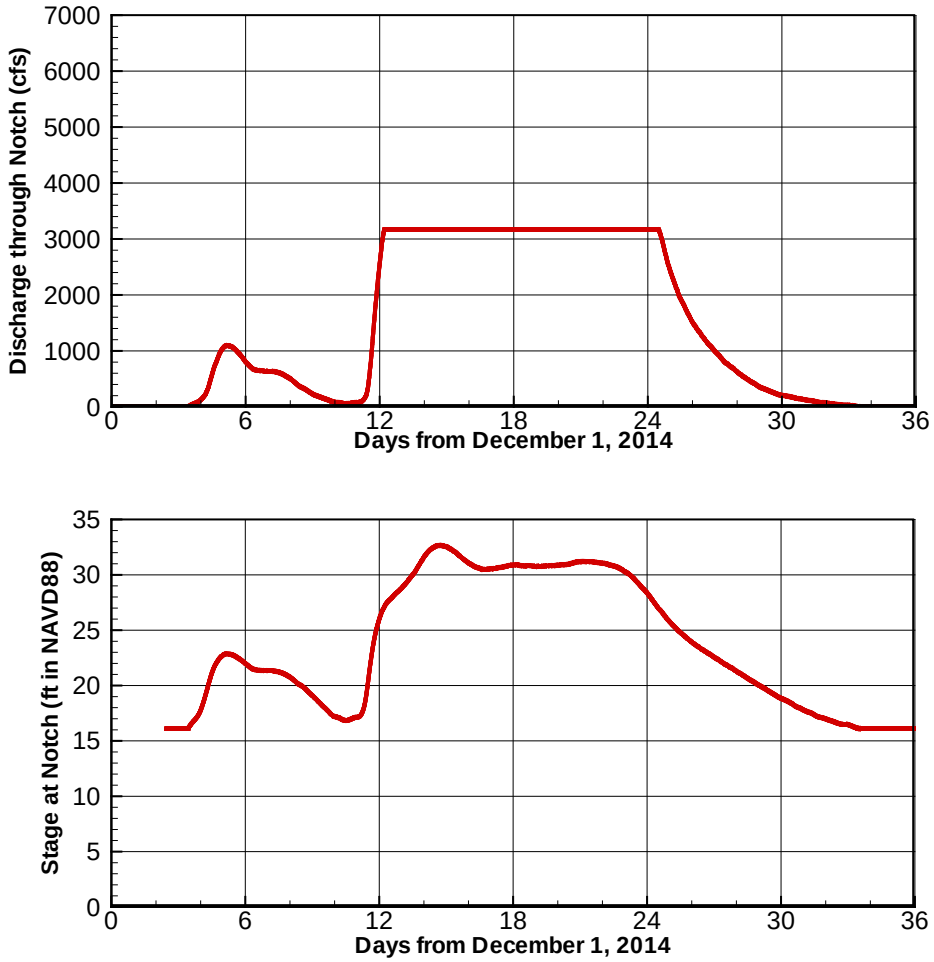
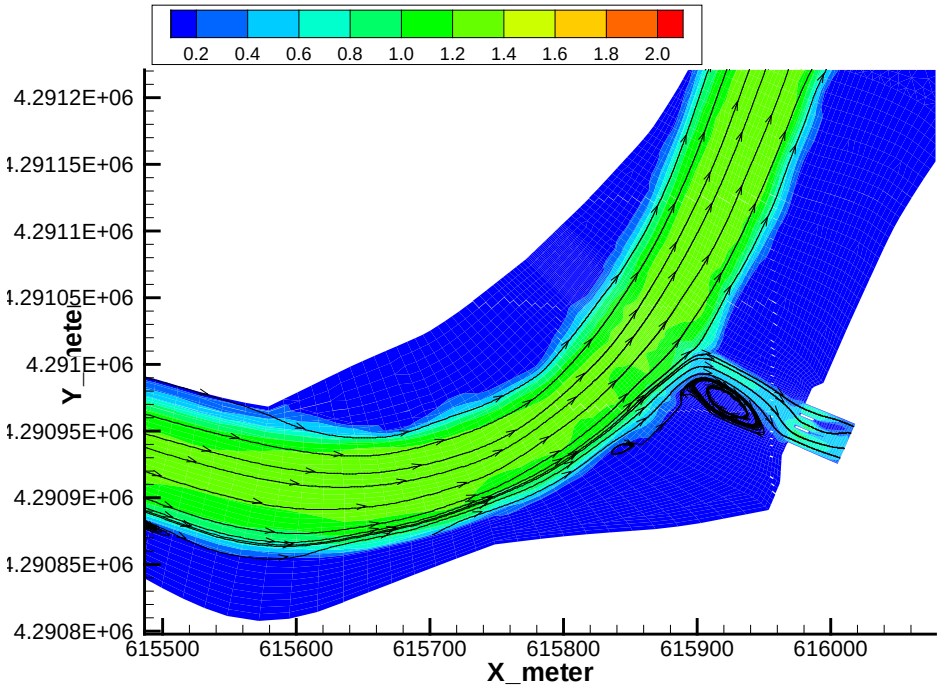
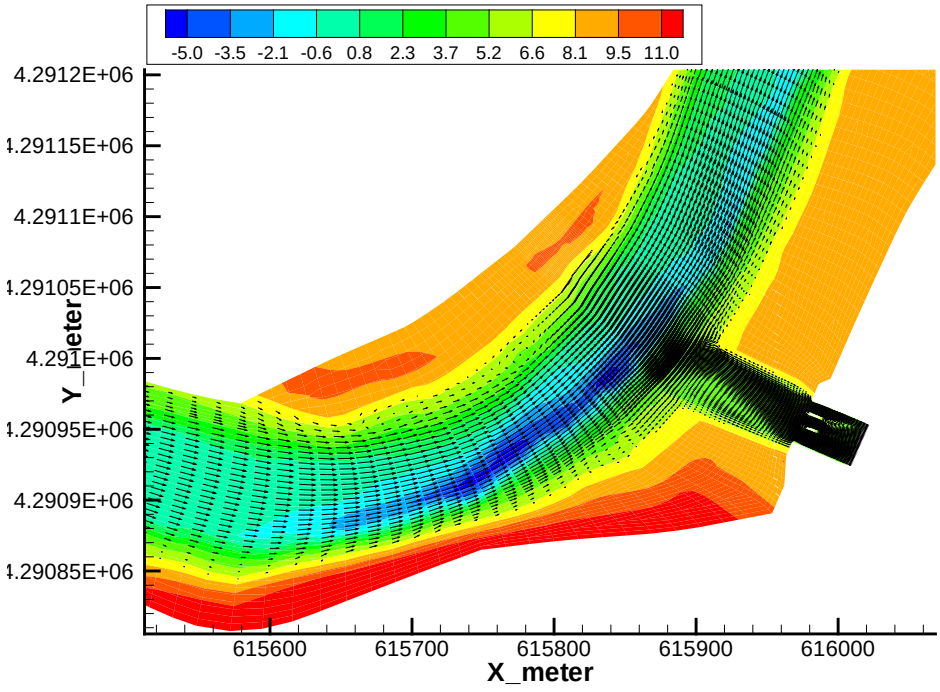


Figure 30. Time history of predicted discharge through the gate and stage upstream of the gate for Configuration 16 (West 3K Intake)

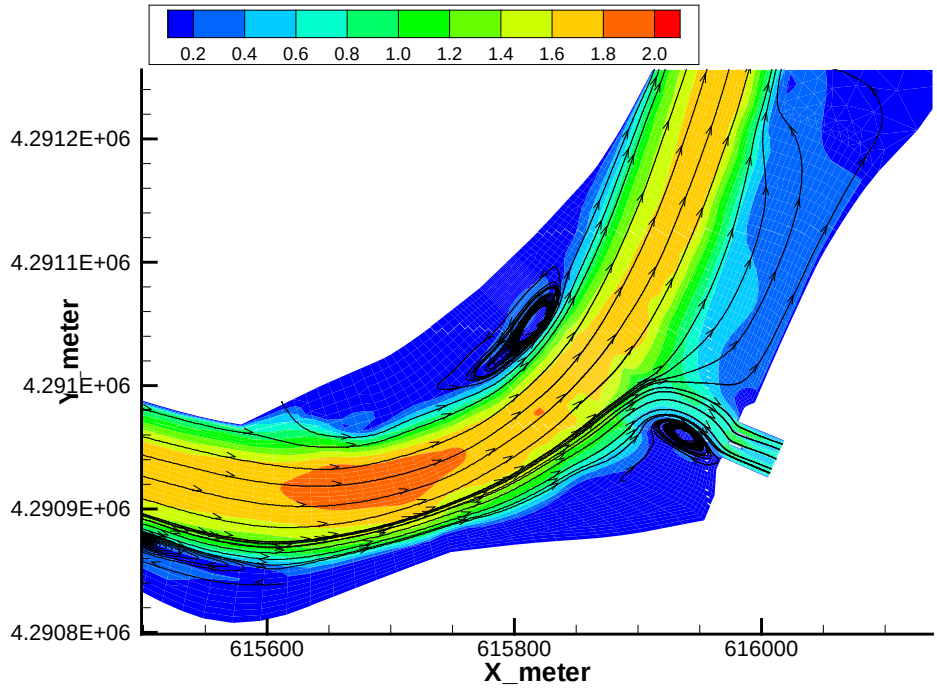


(a) Flow streamlines with velocity magnitude (m/s) as background

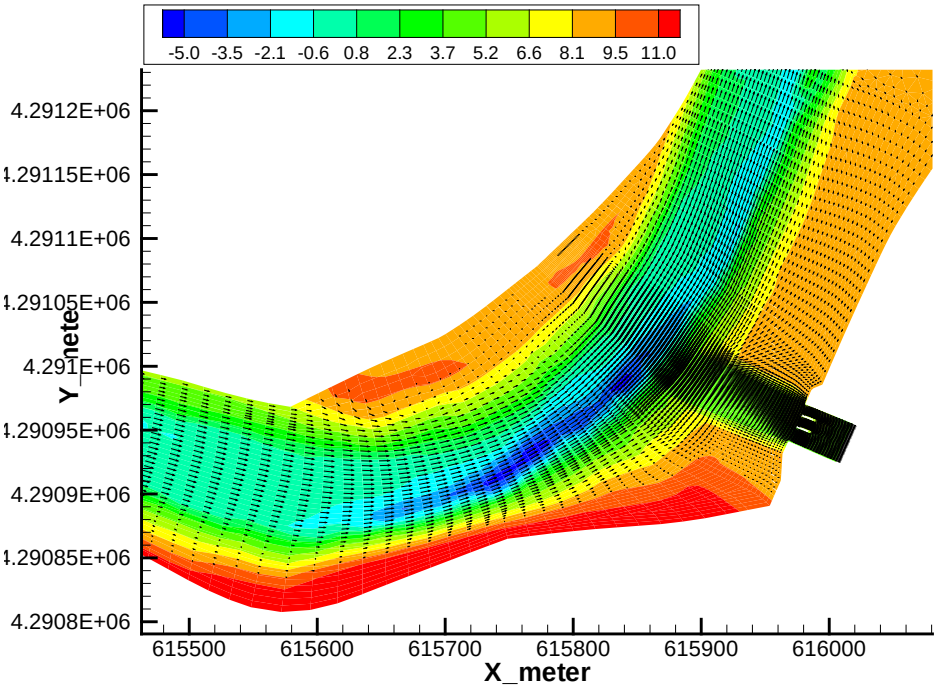


(b) Velocity vector with bed elevation (m) as background

Figure 31. Predicted flow velocity and flow pattern near the notch of Configuration 16 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 32. Predicted flow velocity and flow pattern near the notch of Configuration 3 at Day 18

3.5 EIR/EIS Alternative 1 (East 6K Intake with the USGS BC)

Starting with this notch scenario, six EIR/EIS alternatives are simulated and presented. Note that the new USGS rating curve is used as the boundary conditions for this set of EIR/EIS runs, as discussed above. Results of these alternatives using the original BC are imbedded with the previous 16 notch configurations and have been reported in Lai (2017) and the first 4 configurations presented above.

The location and terrain of EIR/EIS Alternative 1 are the same as Configuration 14 and may be examined in Figure **4**. The notch is located at the east part of the Fremont Weir. The approach channel is "intake" type. The gate structure consists of two parts: a primary gate having an invert elevation of 14 ft and two secondary gates with 18 ft invert. The design maximum flow through the gate structure is 6,000 cfs; it occurs at an upstream stage of 27.844 ft.

The flow through the gate is obtained using the rating curve boundary condition. The rating curve was developed by DWR and is shown in Figure **33**. The model predicted discharge through the gate and the stage upstream of the gate are shown in Figure **34**. Snapshots of flow patterns at two times are plotted in Figure **35** and Figure **36**.

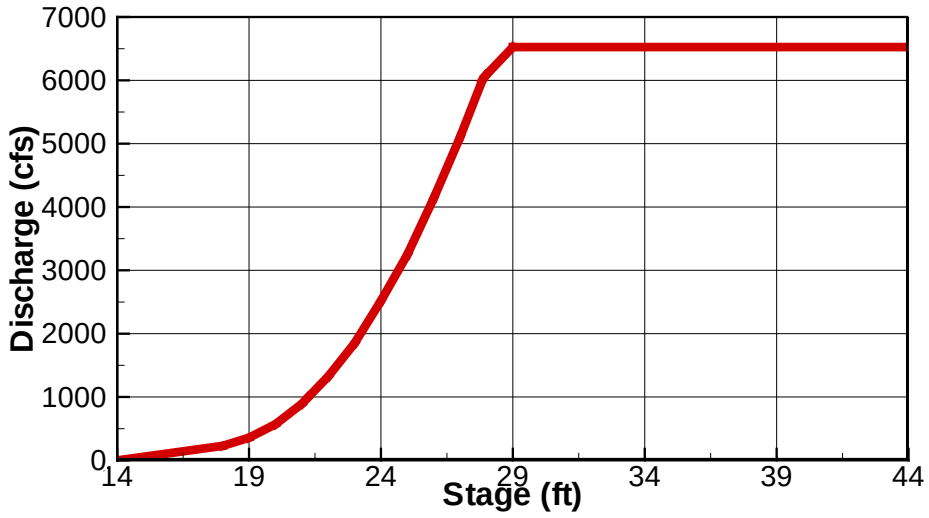


Figure 33. Rating curve used for EIR/EIS Alternative 1 (East 6K Intake)

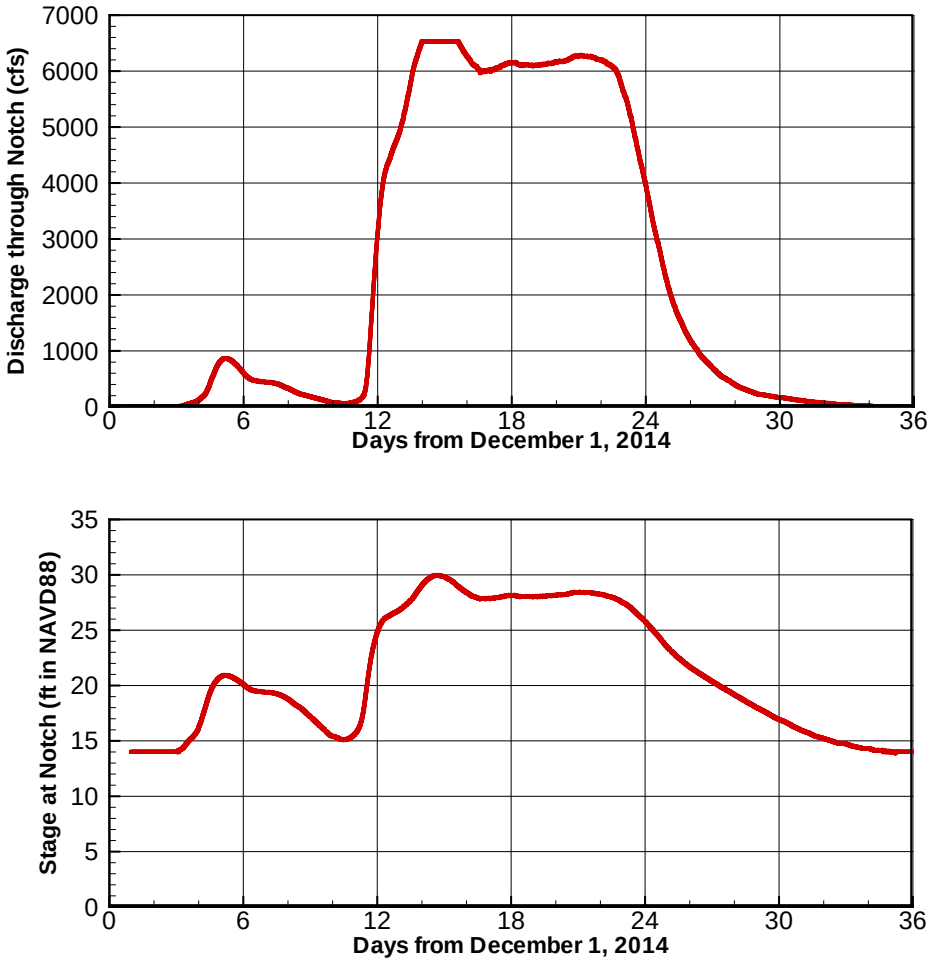
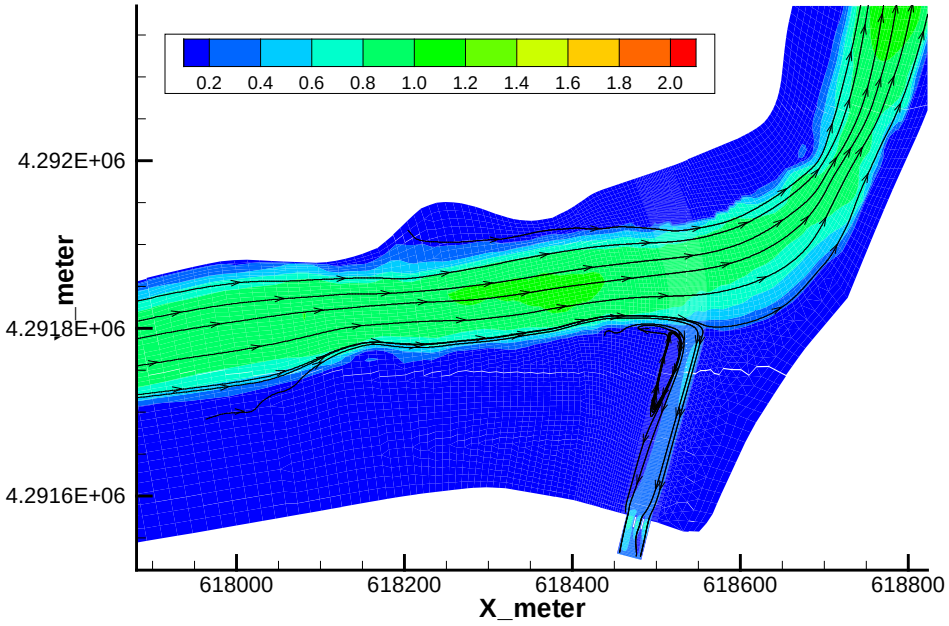
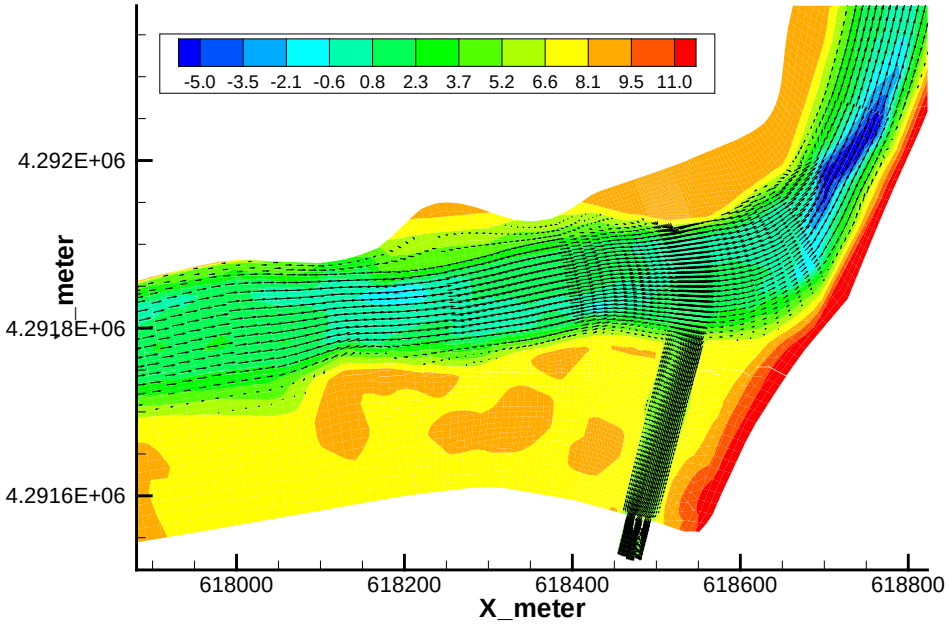


Figure 34. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 1 (East 6K Intake)

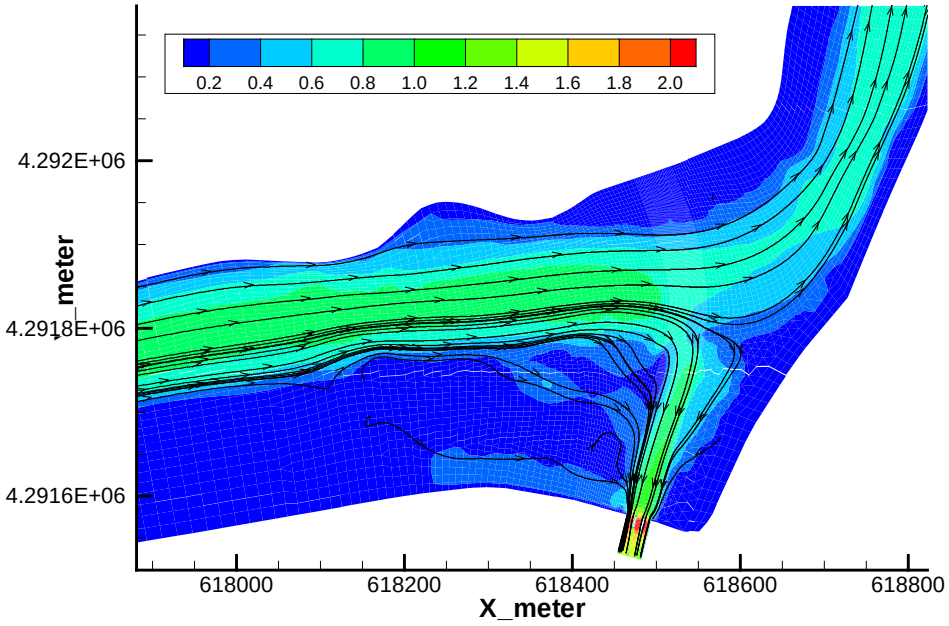


(a) Flow streamlines with velocity magnitude (m/s) as background

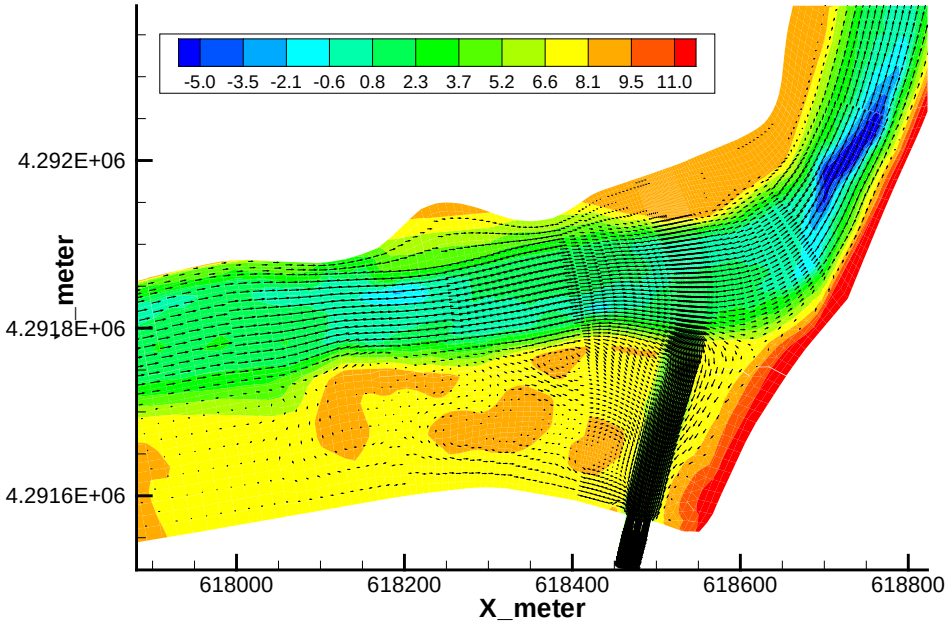


(b) Velocity vector with bed elevation (m) as background

Figure 35. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 1 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 36. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 1 at Day 18

3.6 EIR/EIS Alternative 2 (Central 6K Intake with the USGS BC)

The location and terrain of EIR/EIS Alternative 2 are the same as Configuration 13 and they are plotted in Figure **3**. The notch is located at the central part of the Fremont Weir. The approach channel is “intake” type and the gate structure consists of one gate with a primary opening and two elevated openings. The primary gate invert is 14.8 ft and the elevated invert is 18.8 ft. The design maximum flow through the gate structure is 6,000 cfs at an upstream stage of 29.348 ft

The boundary condition for the flow through the gate adopts the rating curve developed and supplied by DWR. The rating curve relates the discharge through the gate to the stage upstream of the gate. The rating curve used is shown in Figure **37**. An unsteady simulation is performed from December 1, 2014 to January 5, 2015 using the USGS rating curve boundary condition. The model simulated discharge through the gate and the stage upstream of the gate are plotted in Figure **38**. Predicted flow vectors and patterns near the notch are displayed in Figure **39** and Figure **40** at two times.

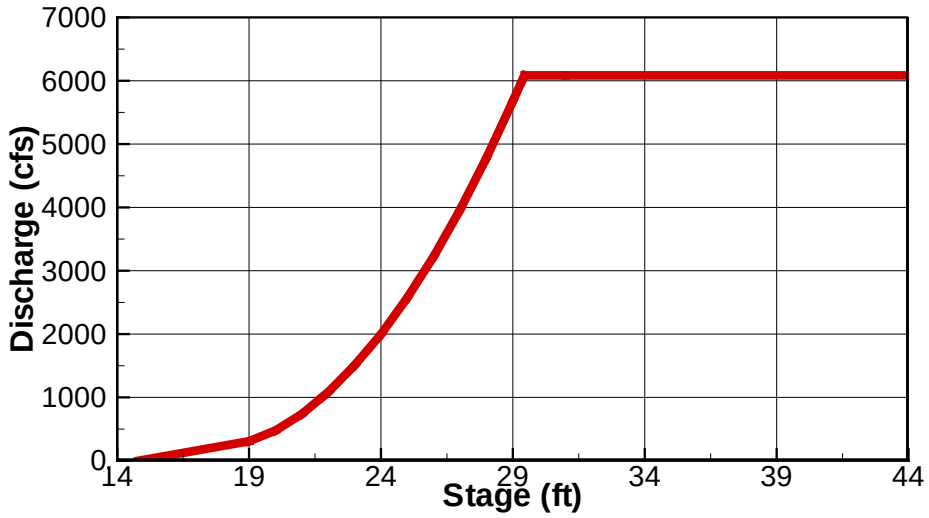


Figure 37. Rating curve used for EIR/EIS Alternative 2 (Central 6K Intake)

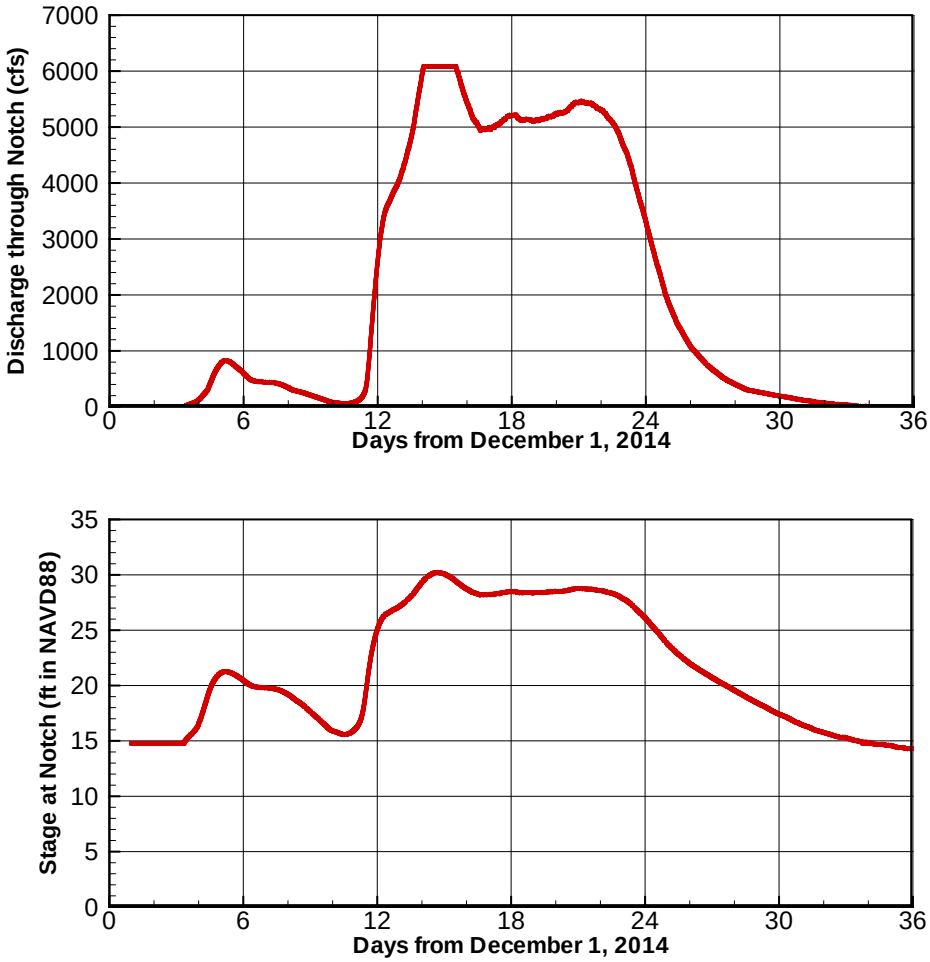
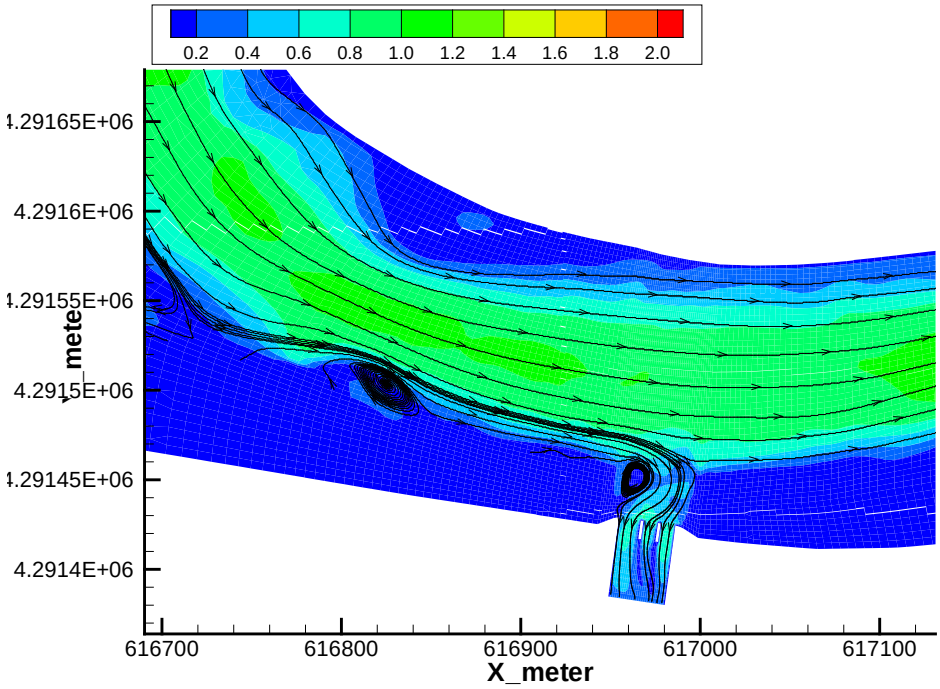
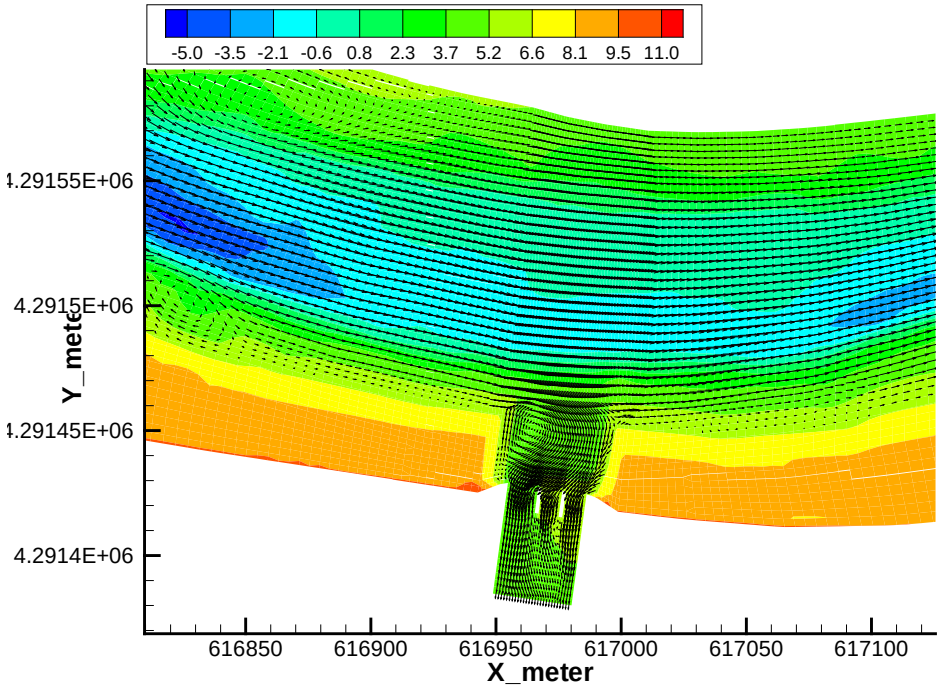


Figure 38. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 2 (Central 6K Intake)

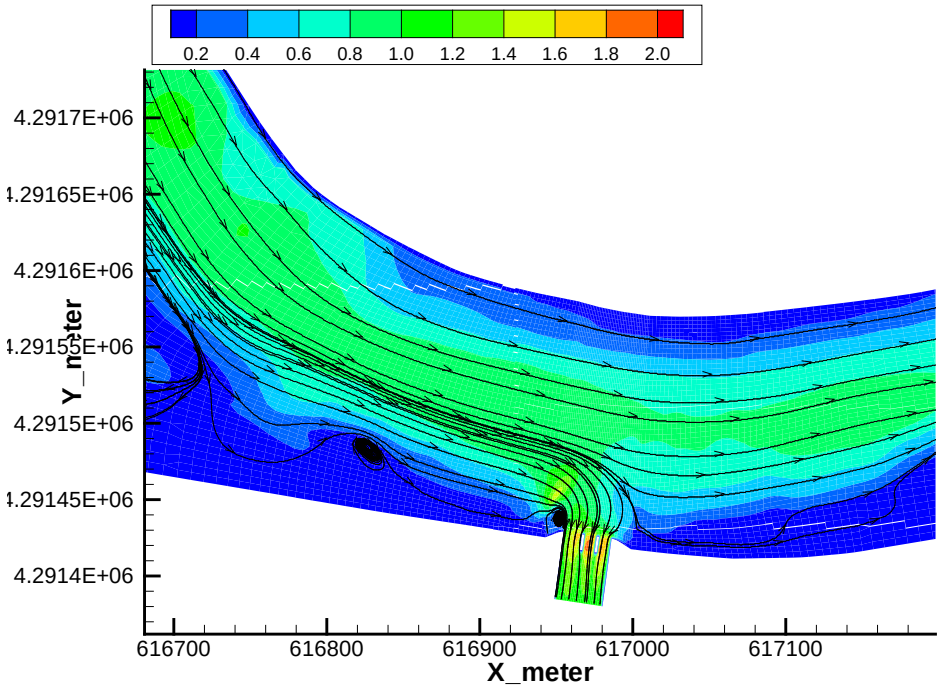


(a) Flow streamlines with velocity magnitude (m/s) as background

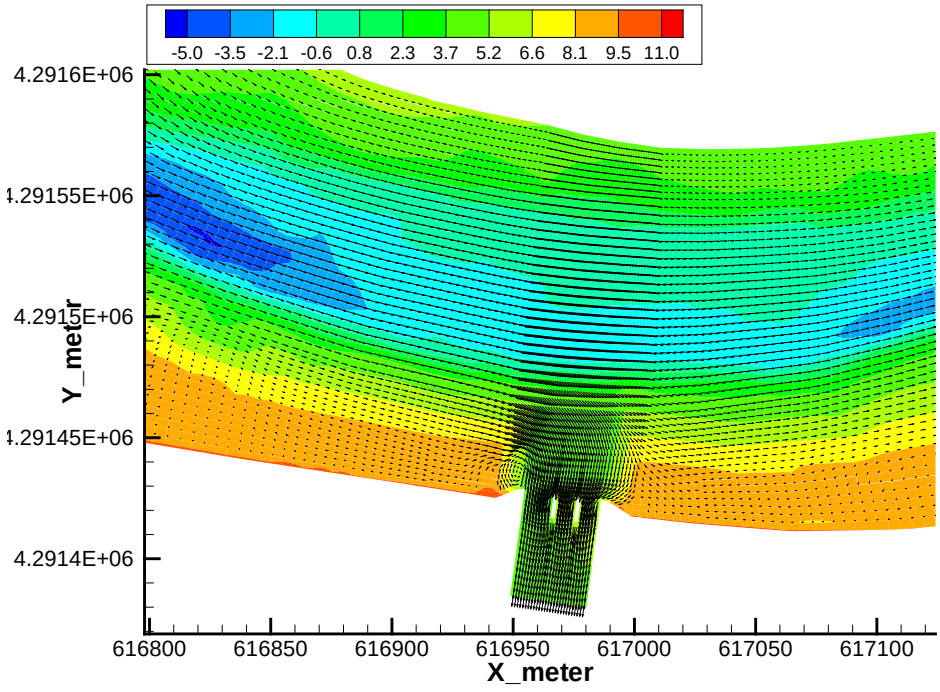


(b) Velocity vector with bed elevation (m) as background

Figure 39. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 2 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 40. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 2 at Day 18

3.7 EIR/EIS Alternative 3 (West 6K Intake with the USGS BC)

The location and terrain of EIR/EIS Alternative 3 are the same as Configurations 2 and 16; they are shown in Figure **6**. The notch is located at the west part of the Fremont Weir. The approach channel is “intake” type. The structure consists of three openings which are meshed by the model as shown in Figure **6**. The sill elevation (invert) of the primary opening is 16.1 ft while the sill elevation (invert) of other two elevated openings is 20.1 ft. The design maximum flow through the gate structure is 6,000 cfs at upstream stage of 30.868 ft.

The rating curve used to compute the flow through the gate, as a boundary condition, was developed by DWR. The rating curve relates the discharge through the gate to the stage upstream of the gate. The rating curve is shown in Figure **41**. An unsteady simulation from December 1, 2014 to January 5, 2015 is carried out using the USGS rating curve boundary condition. The predicted discharge through the gate and the stage upstream of the gate are shown in Figure **42**. Snapshots of flow patterns at two times are plotted in Figure **43**and Figure **44**.

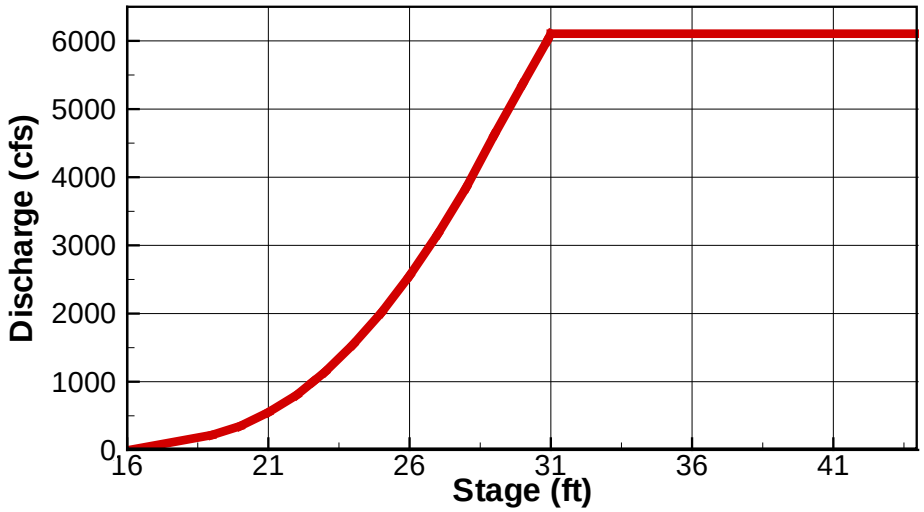


Figure 41. Rating curve used for EIR/EIS Alternative 3 (West 6K Intake)

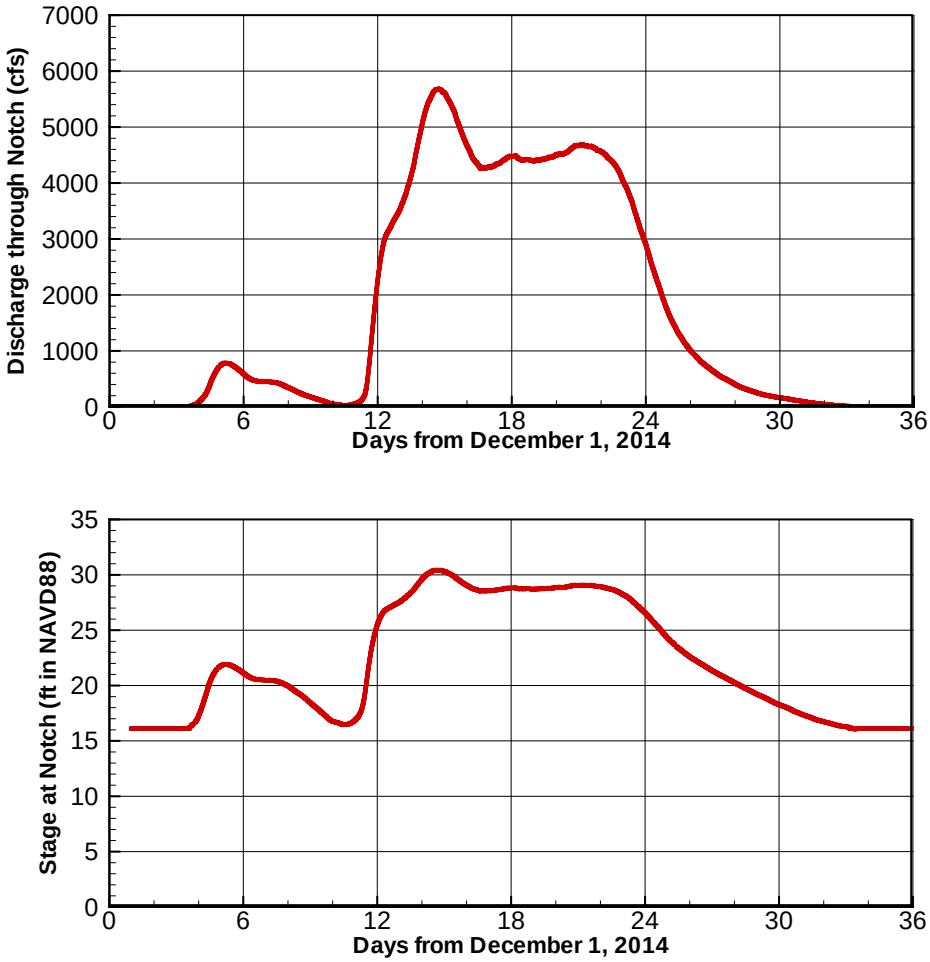
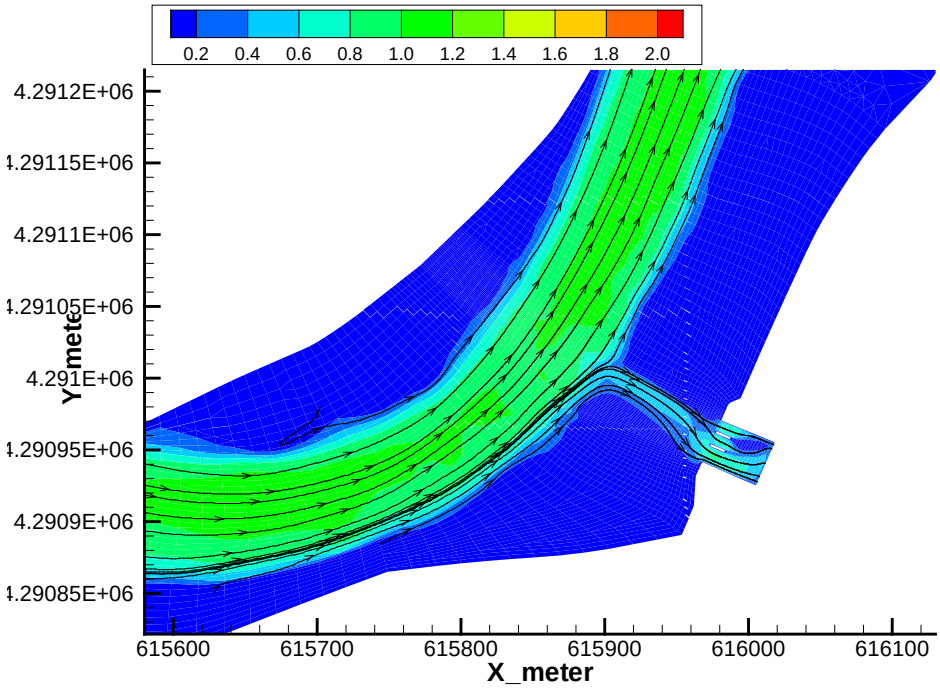
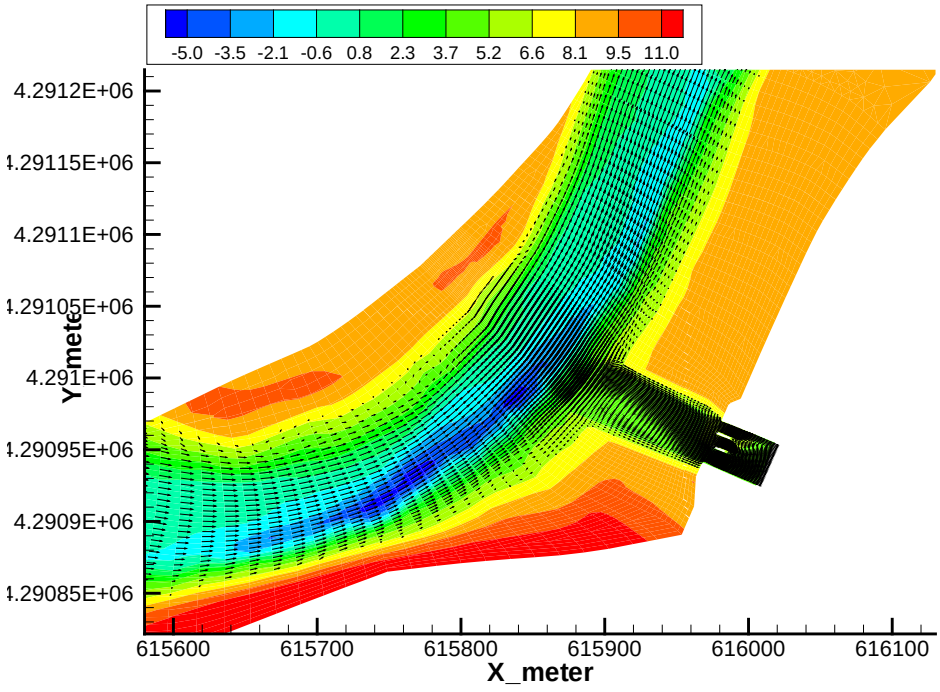


Figure 42. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 3(West 6K Intake)

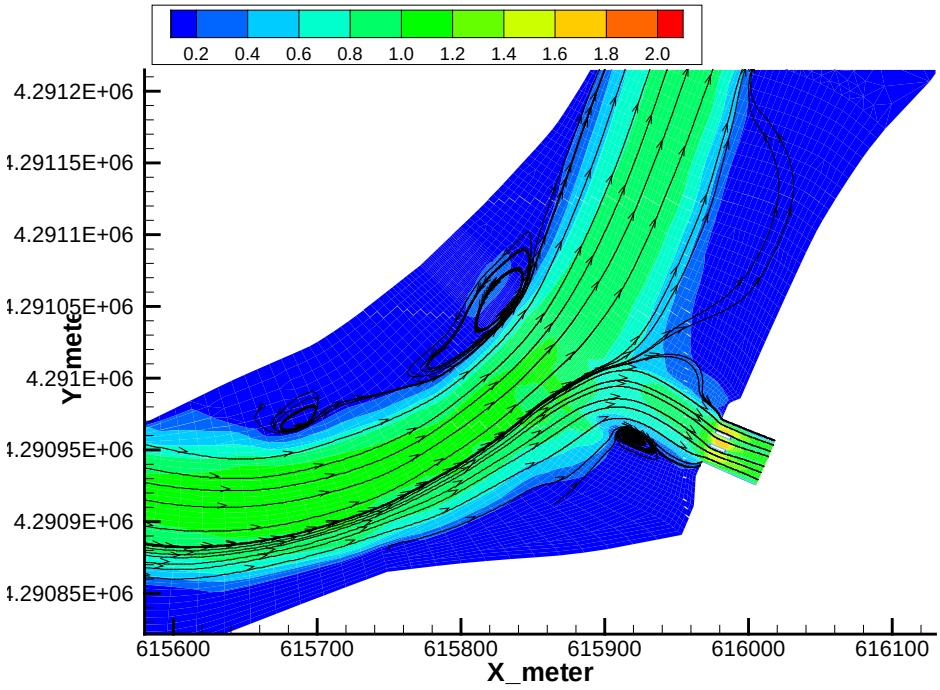


(a) Flow streamlines with velocity magnitude (m/s) as background

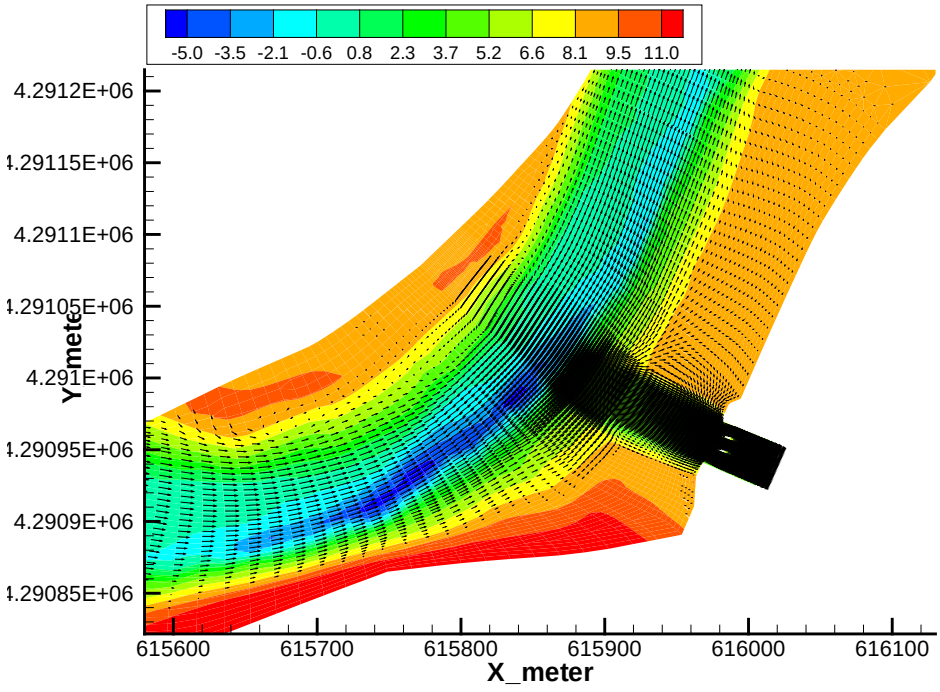


(b) Velocity vector with bed elevation (m) as background

Figure 43. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 3 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 44. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 3 at Day 18

3.8 EIR/EIS Alternative 4 (West 3K Intake with the USGS BC)

The location and terrain of EIR/EIS Alternative 4 are the same as EIR/EIS Alternative 3 (and also Configuration 16) and they are shown in Figure **6**. The notch is located at the west part of the Fremont Weir. The approach channel is "intake" type. The structure consists of three openings which are meshed by the model as shown in Figure **6**. The sill elevation (invert) of the primary opening is 16.1 ft while the sill elevation (invert) of other two elevated openings is 20.1 ft. The design maximum flow through the gate structure is 3,000 cfs at upstream stage of 27 ft.

The rating curve used to compute the flow through the gate, as a boundary condition, was developed by DWR. The rating curve relates the discharge through the gate to the stage upstream of the gate. The rating curve is the same as EIR/EIS Alternative 3 and is shown in Figure **41**. An unsteady simulation from December 1, 2014 to January 5, 2015 is carried out using the USGS rating curve boundary condition. The predicted discharge through the gate and the stage upstream of the gate are shown in Figure 45. Snapshots of flow patterns at two times are plotted in Figure **46** and Figure 47.

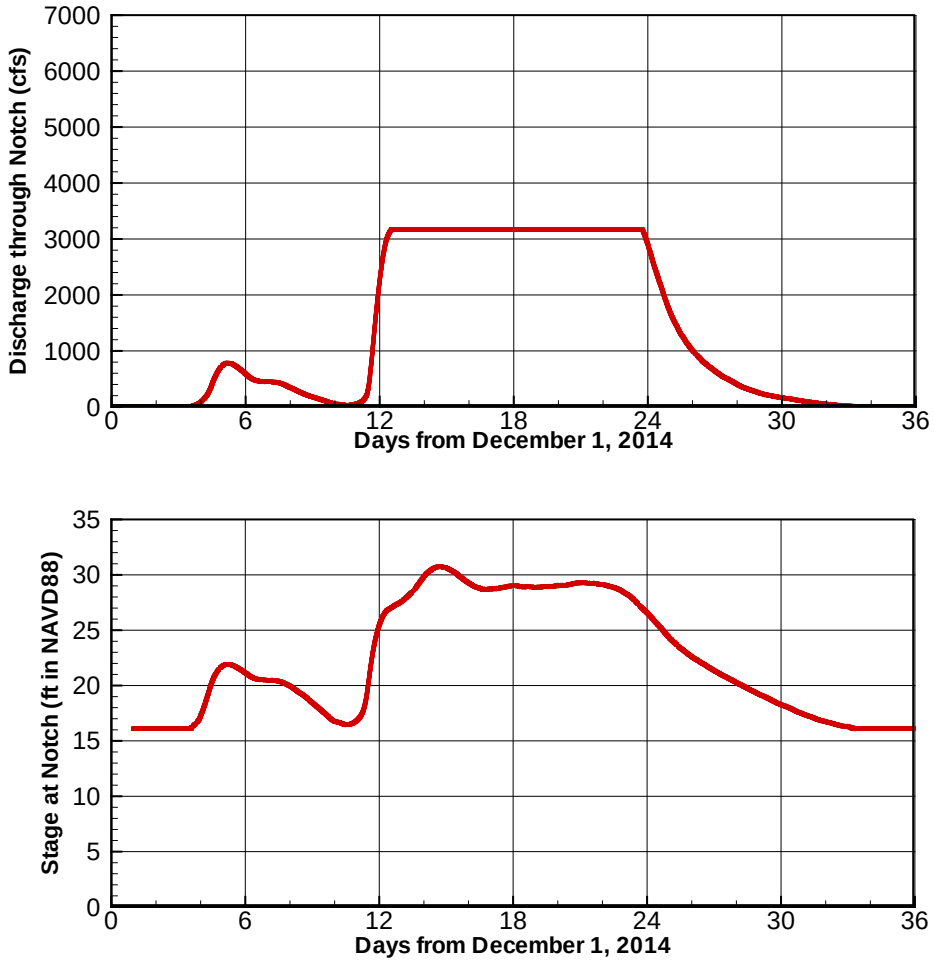
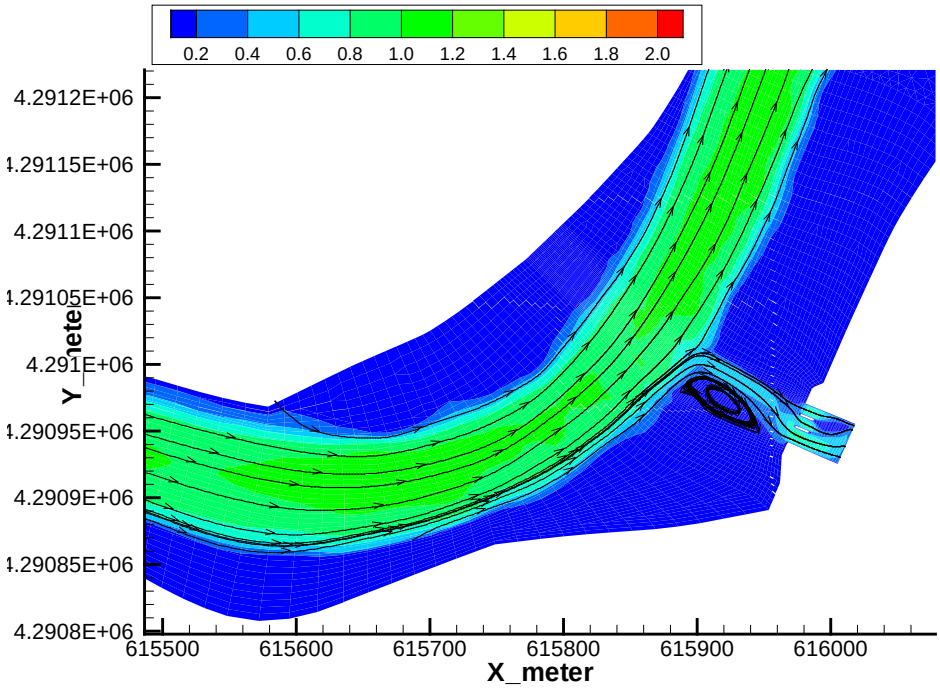
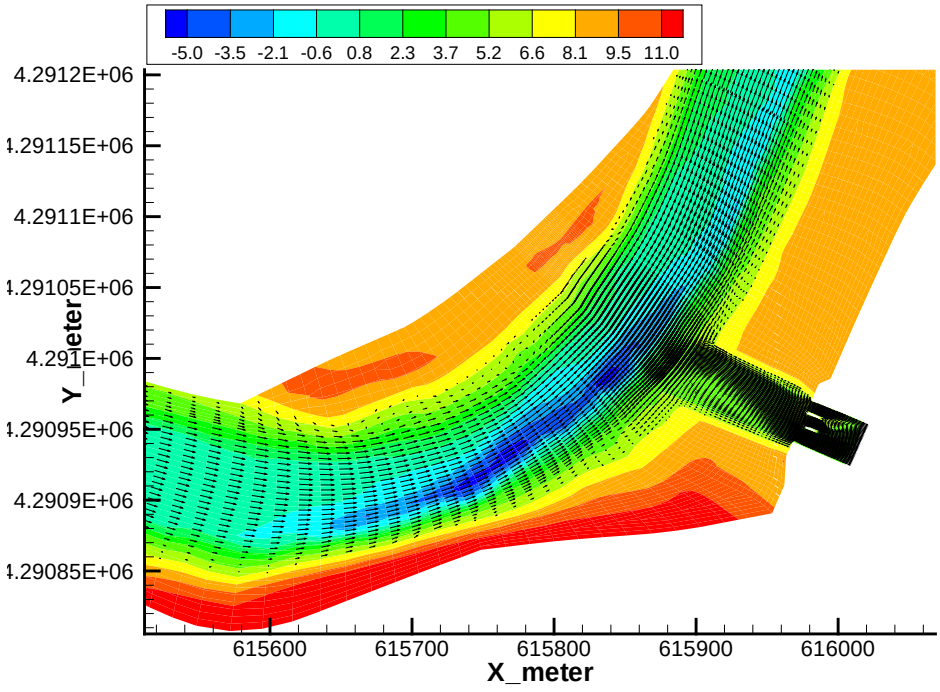


Figure 45. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 4 (West 3K Intake)

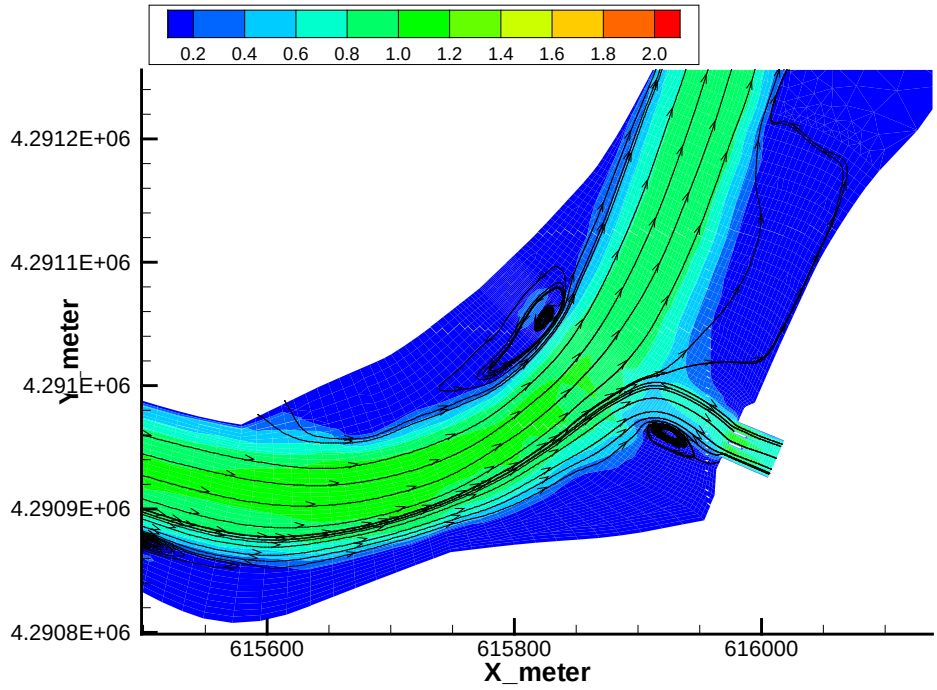


(a) Flow streamlines with velocity magnitude (m/s) as background

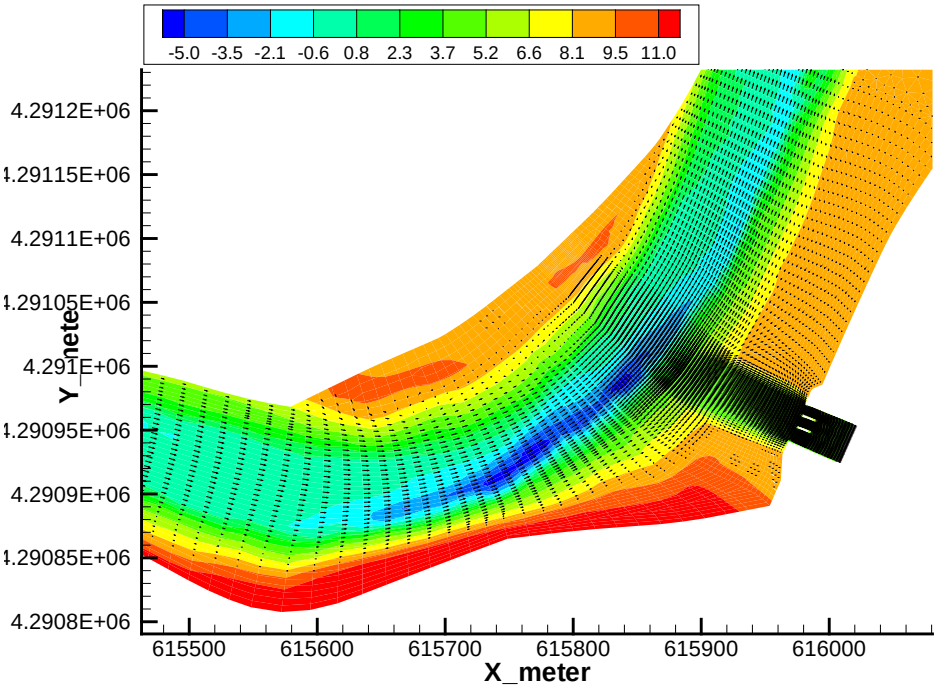


(b) Velocity vector with bed elevation (m) as background

Figure 46. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 4 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 47. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 4 at Day 18

3.9 EIR/EIS Alternative 5 (Central Multi-Gate Intake with the USGS BC)

The location and terrain of EIR/EIS Alternative 5 are the same as Configuration 15 and may be seen in Figure **5**. The notch is located at the central part of the Fremont Weir. The approach channel is “intake” type. This configuration consists of four gates named A, B, C and D as shown in Figure **21**. In the figure the inverts of all gates are also marked. Each gate is being opened or closed at different river stages. For example, at stage 26.75 ft the flow is 3,000 cfs through gates A-C, but at stage 27 ft the flow is limited to 3,000 cfs through gates C and D.

The timing for the gate opening and closing is dependent on the flow stages upstream of the gates. In the simulation the timing and the discharges through each gate are determined by the rating curves supplied to Reclamation by DWR. The four discharge versus stage rating curves are shown in Figure **22**.

An unsteady simulation is carried out for the alternative from December 1, 2014 to January 5, 2015 using the USGS rating curve boundary condition. The predicted time series discharges through all gates along with the stages upstream of the gates are plotted in Figure **48** through Figure **51**. Snapshots of the flow patterns in the notch area for the alternative are plotted in Figure **52** and Figure **53** at two different times.

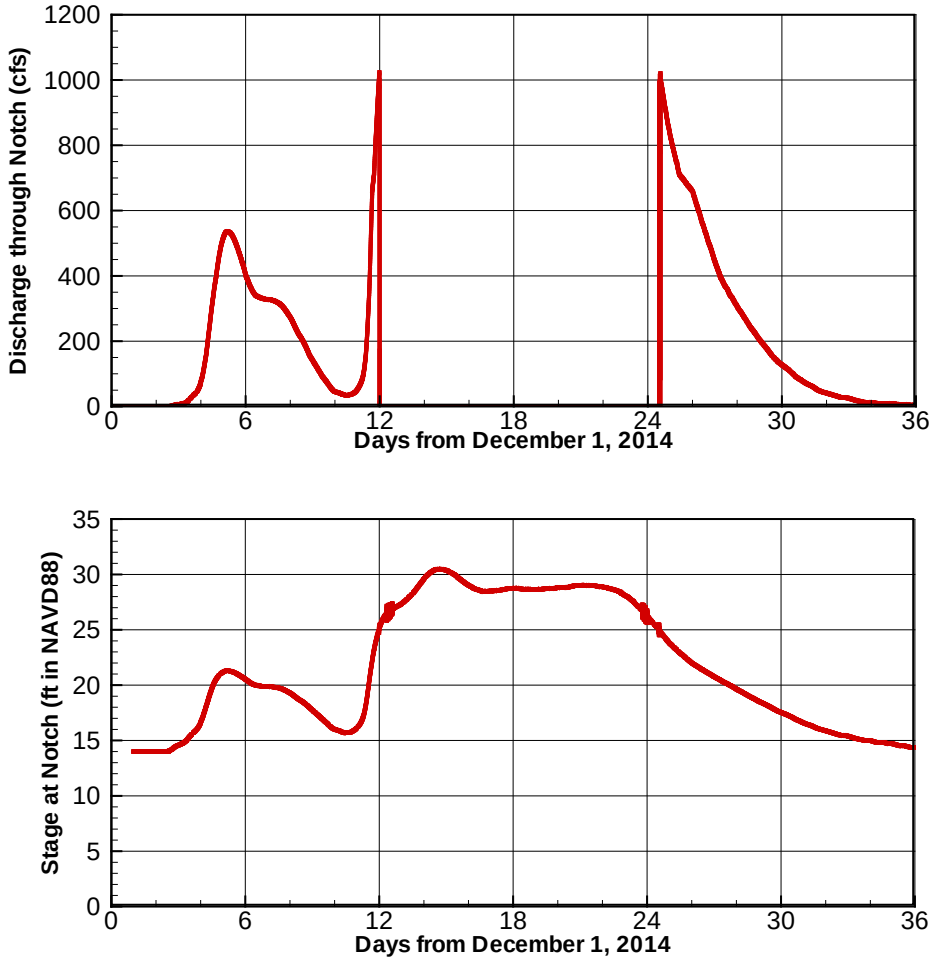


Figure 48. Time history of predicted discharge and stage at Gate A for EIR/EIS Alternative 5 (Central Multi-Gate Intake)

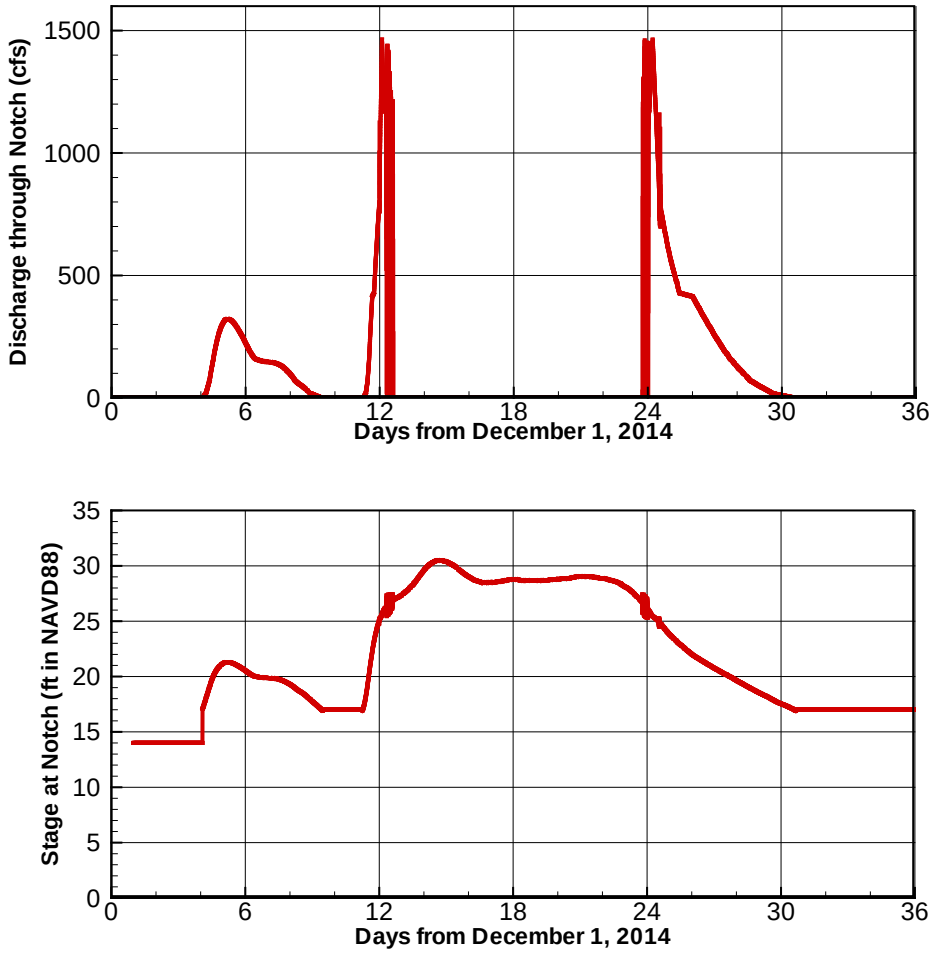


Figure 49. Time history of predicted discharge and stage at Gate B for EIR/EIS Alternative 5 (Central Multi-Gate Intake)

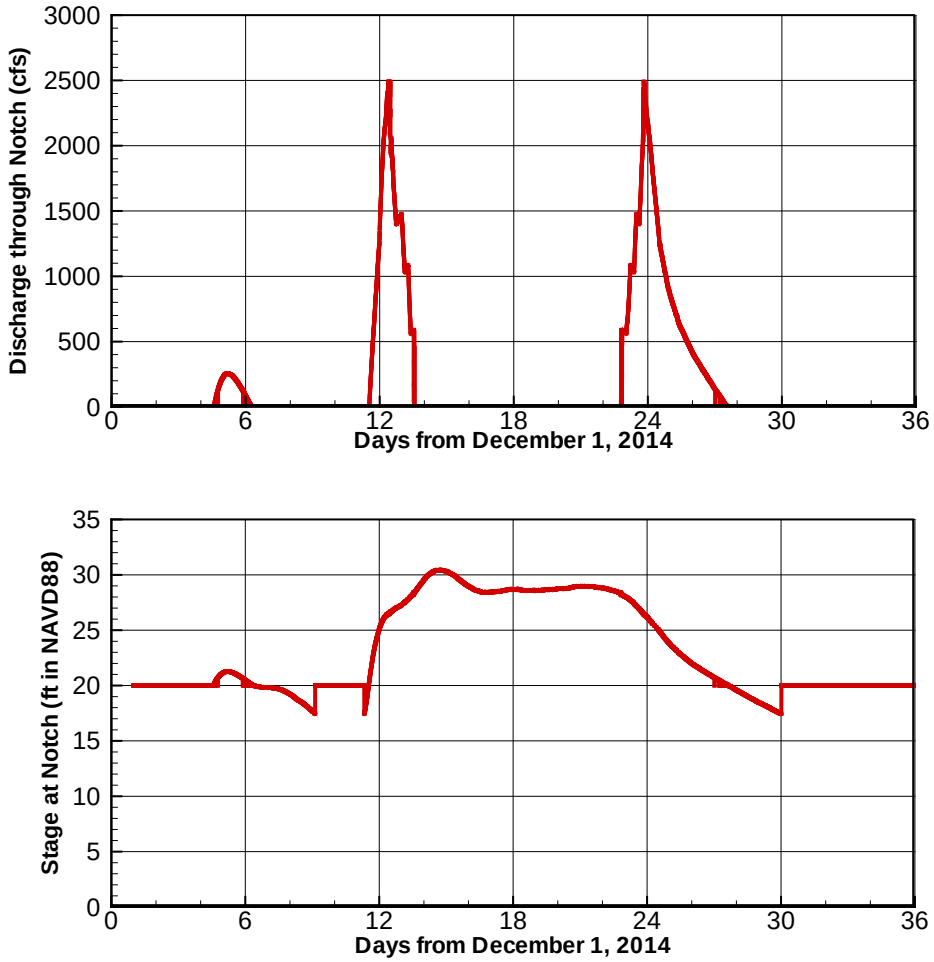


Figure 50. Time history of predicted discharge and stage at Gate C for EIR/EIS Alternative 5 (Central Multi-Gate Intake)

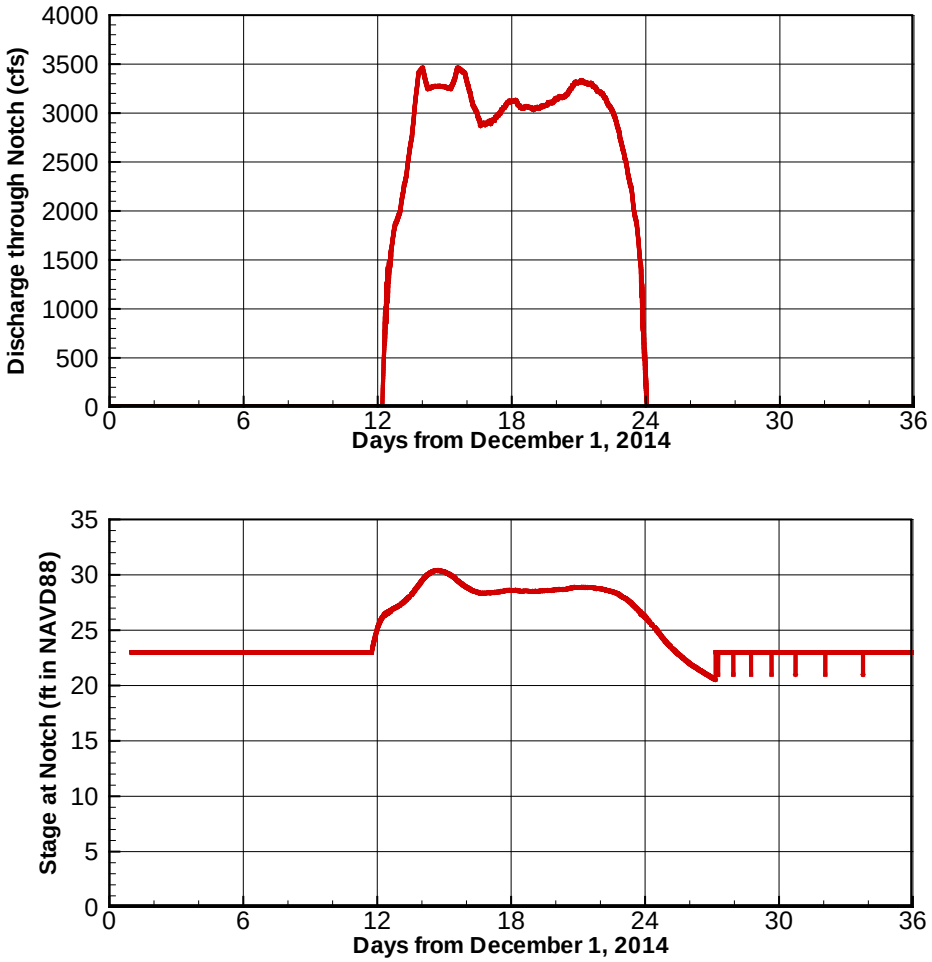
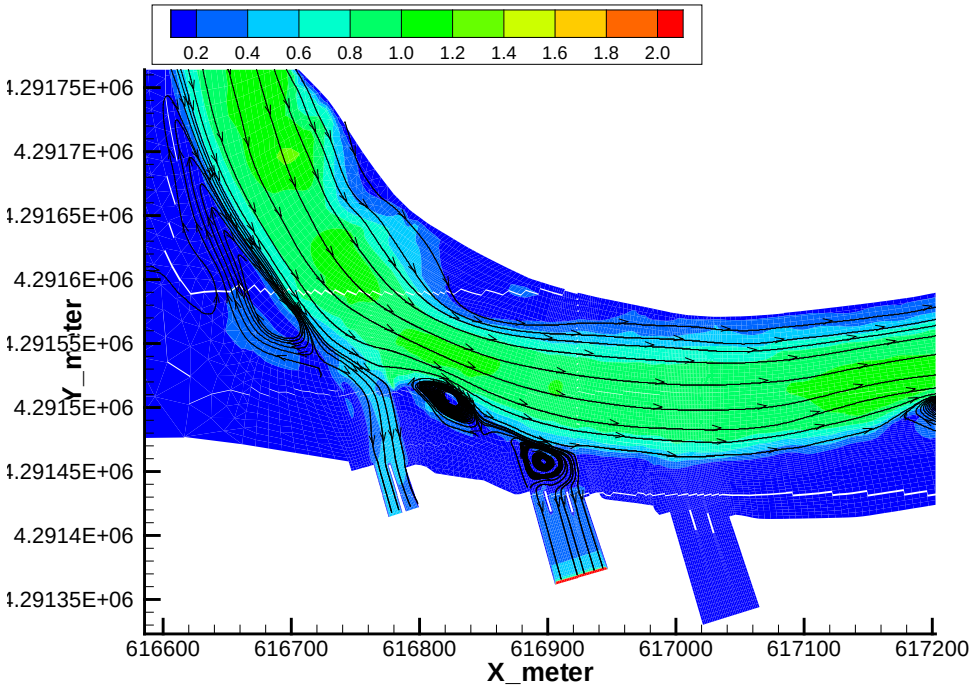
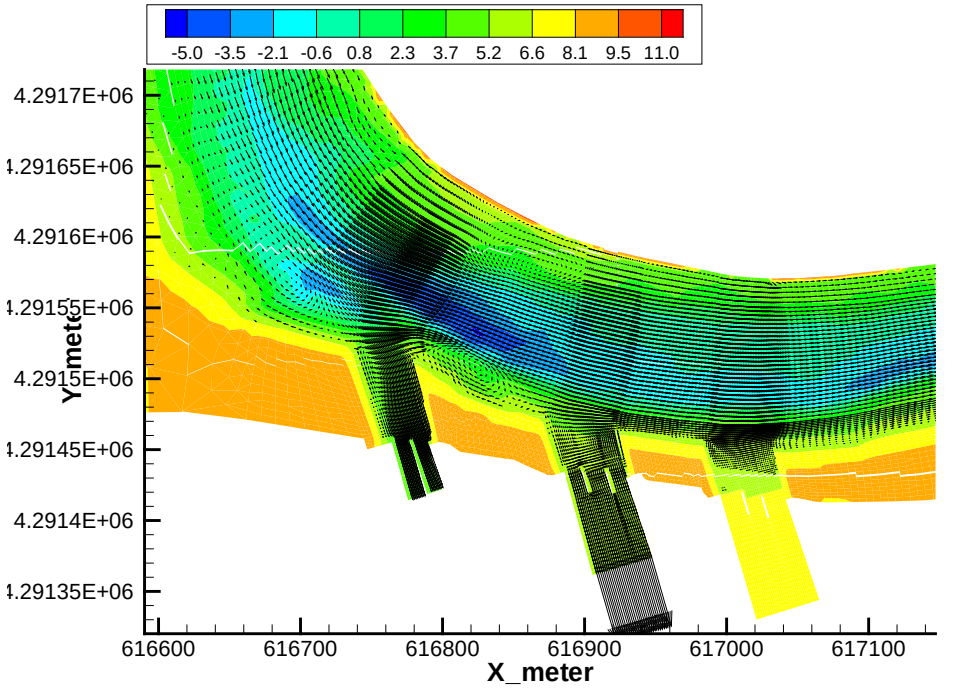


Figure 51. Time history of predicted discharge and stage at Gate D for EIR/EIS Alternative 5 (Central Muli-Gate Intake)

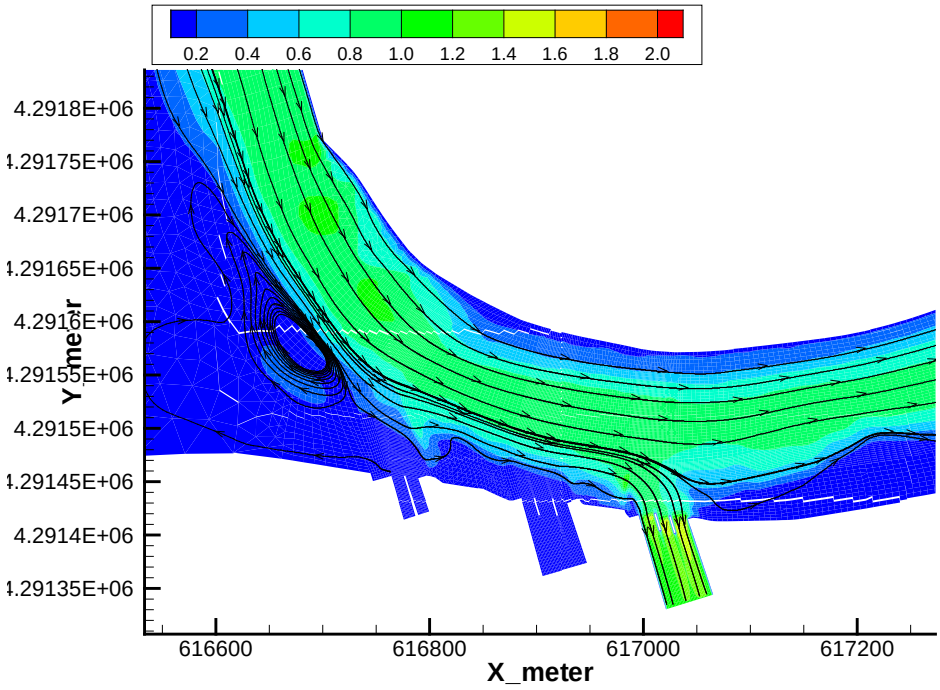


(a) Flow streamlines with velocity magnitude (m/s) as background

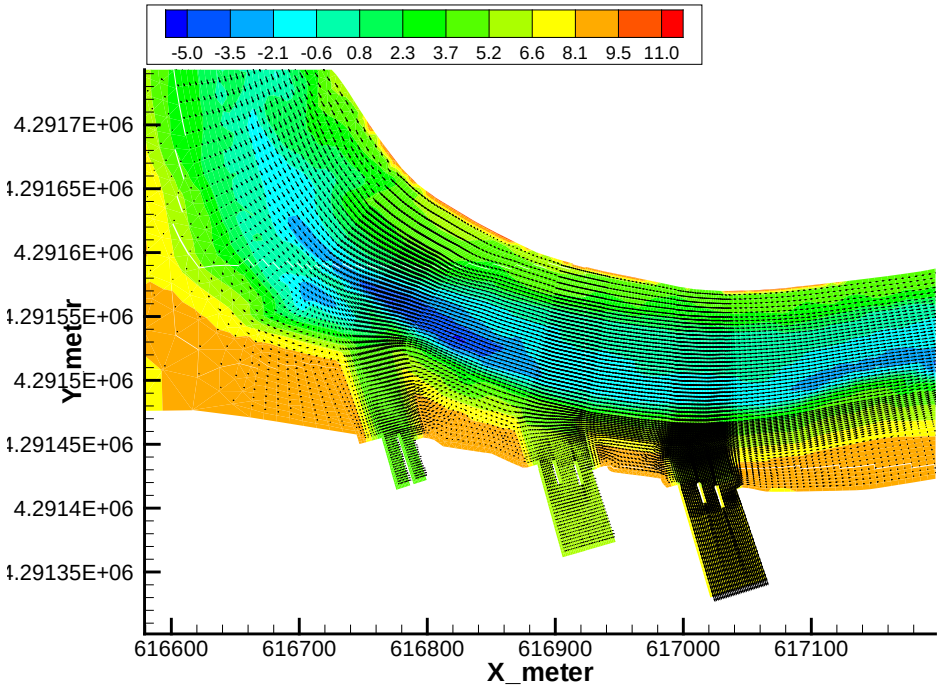


(b) Velocity vector with bed elevation (m) as background

Figure 52. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 5 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 53. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 5 at Day 18

4.10 EIR/EIS Alternative 6 (West 12K Intake with the USGS BC)

The location and terrain of EIR/EIS Alternative 6 are the same as Configuration 11 in the 2017 report and they are displayed in Figure 7. The notch is located at the west part of the Weir. The approach channel is “intake” type and the structure consists of five gates which are represented by the 2D mesh as shown in Figure **54**. All five gates have the same sill elevation (invert) of 16.1 ft. The design maximum flow through the gate structure is 12,000 cfs at upstream stage of 29.84 ft. Note that such a high flow diversion is unrealistic in practice; but its modeling is to show the sensitivity of entrainment to the amount of flow diversion.

The boundary condition used for the flow through the gate is obtained using the rating curve supplied by DWR which relates the discharge through the gate to the upstream flow stage. The rating curve is shown in Figure **55**. An unsteady simulation is performed from December 1, 2014 to January 5, 2015 using the USGS rating curve boundary condition. The predicted discharge through the gate and the stage upstream of the gate are shown in Figure **56**. Snapshots of flow patterns at two times are plotted Figure **57** and Figure **58**.

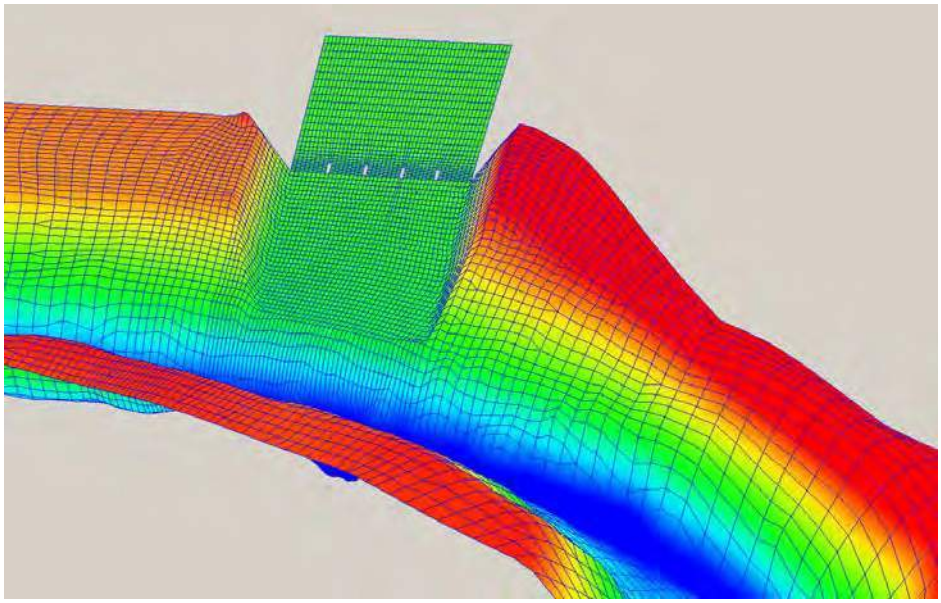


Figure 54. The mesh and bed elevation of the notch structure for EIR/EIS Alternative 6

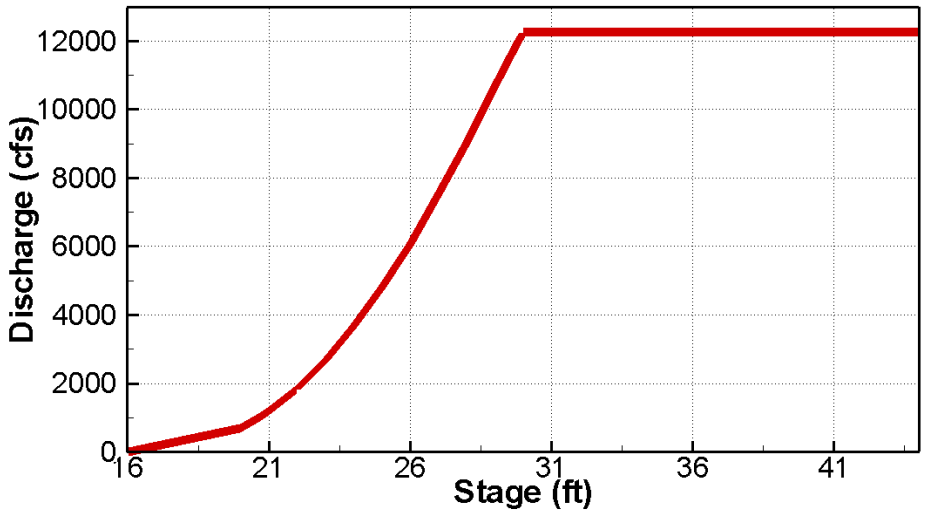


Figure 55. Rating curve used for EIR/EIS Alternative 6 (West 12K Intake)

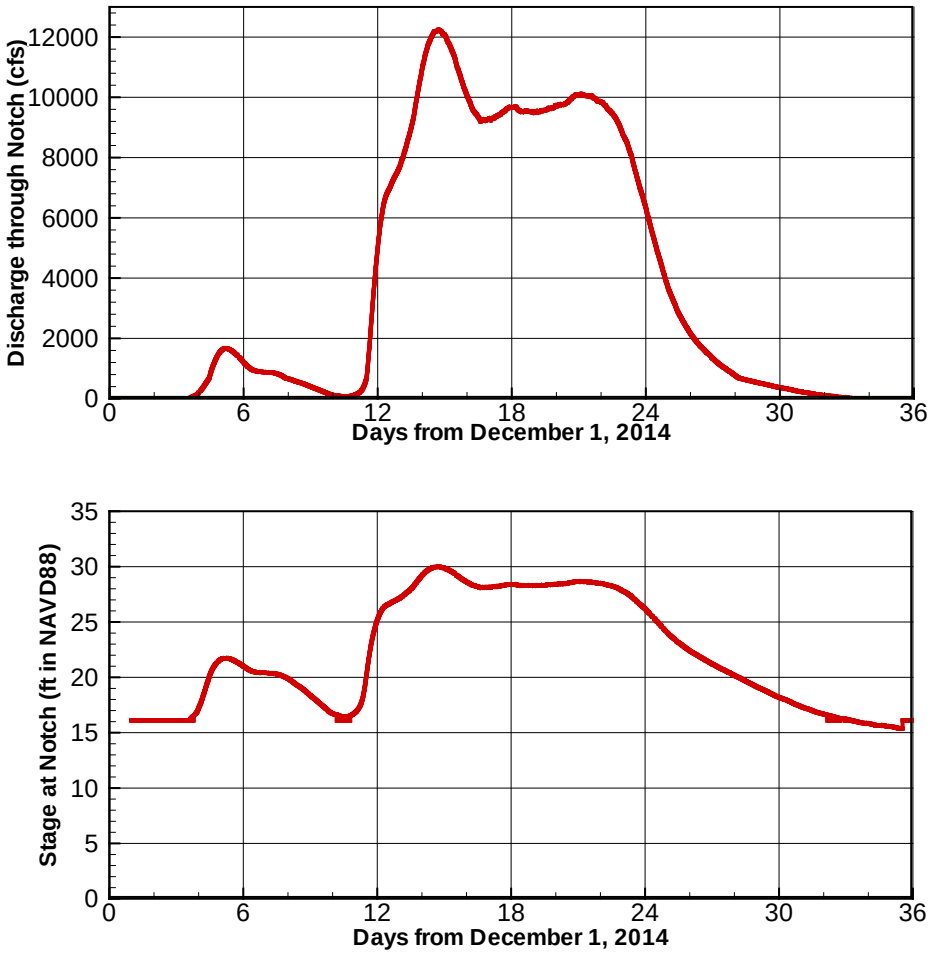
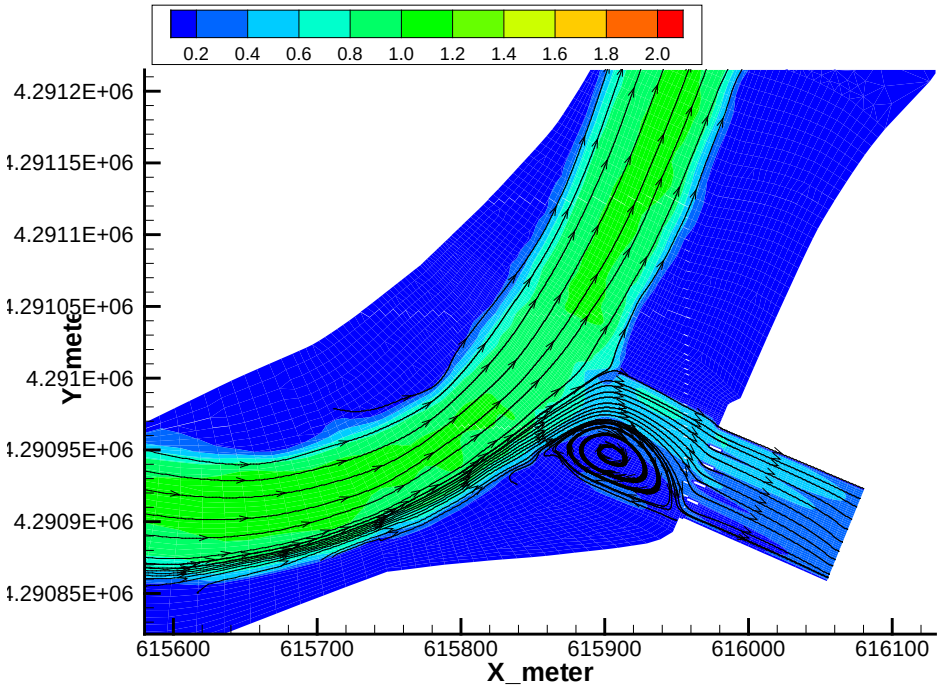
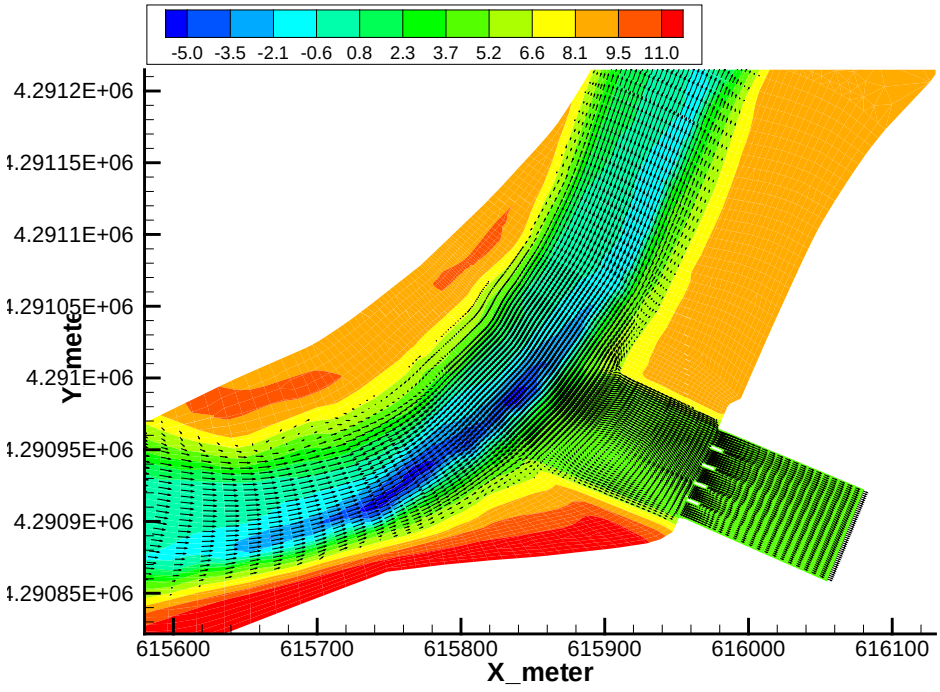


Figure 56. Time history of predicted discharge through the gate and stage upstream of the gate for EIR/EIS Alternative 6 (West 12K Intake)

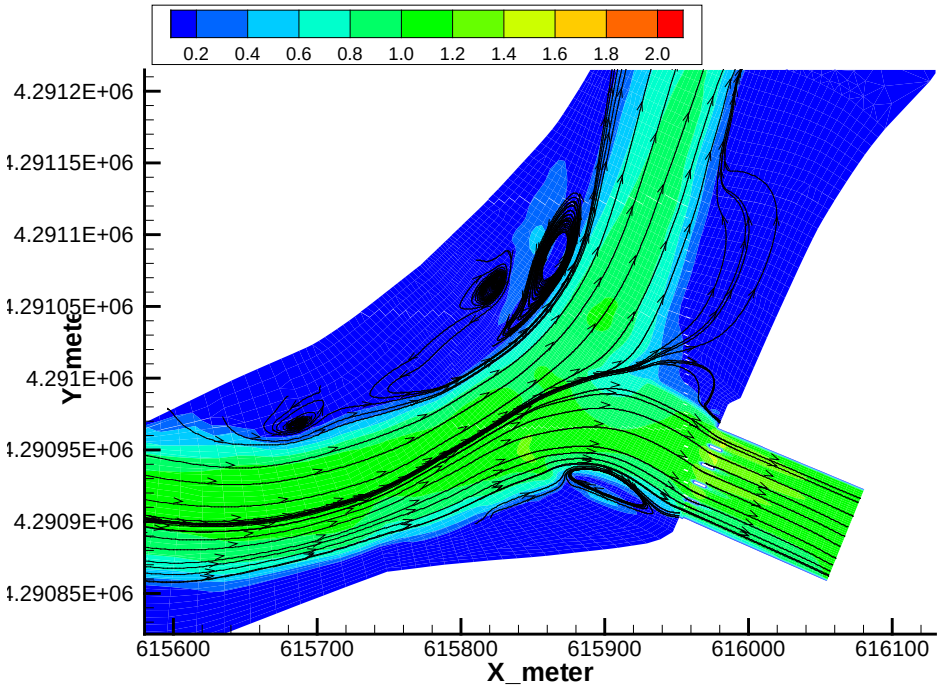


(a) Flow streamlines with velocity magnitude (m/s) as background

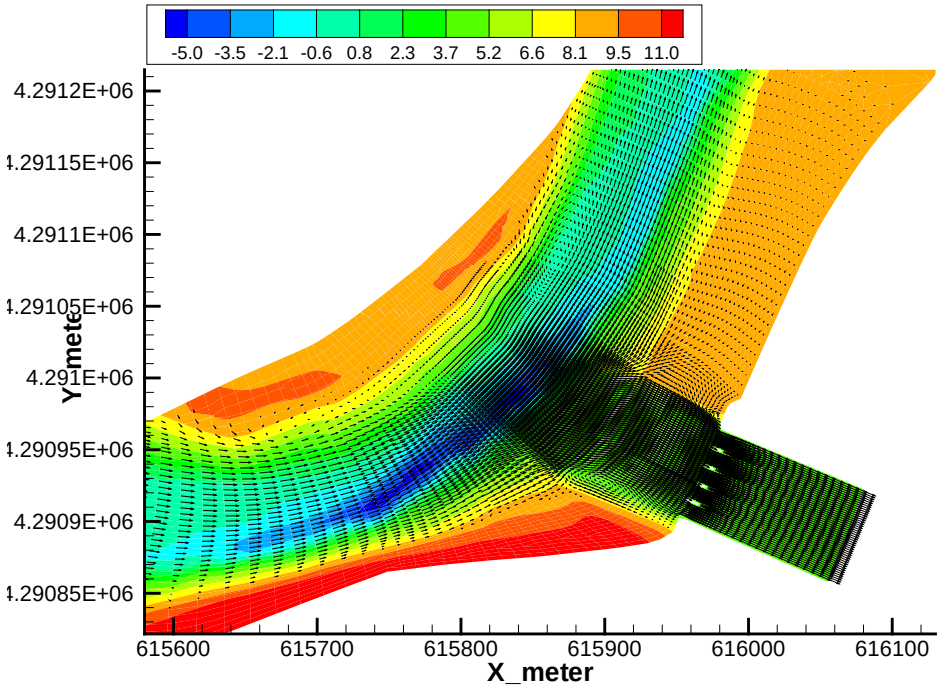


(b) Velocity vector with bed elevation (m) as background

Figure 57. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 6 at Day 6



(a) Flow streamlines with velocity magnitude (m/s) as background



(b) Velocity vector with bed elevation (m) as background

Figure 58. Predicted flow velocity and flow pattern near the notch of EIR/EIS Alternative 6 at Day 18

4.References

Lai, Y.G. (2015). “2D and 3D Flow Modeling along Fremont Weir Section of the Sacramento River in Support of Fish Tracking.” Technical Report No. SRH-2015-33, Technical Service Center, U.S. Bureau of Reclamation.

Lai, Y.G. (2017). “SRH-2D Modeling of Fremont Weir Notch Configurations in Support of Fish Movement Simulation.” Technical Report No. SRH-2017-19, Technical Service Center, U.S. Bureau of Reclamation.

Appendix A

Gate Sizing and Headworks Flow

Appendix A8

cbec eco engineering

Hydrology | Hydraulics | Geomorphology | Design | Field Services

TECHNICAL MEMORANDUM

Date:	December 20, 2016
To:	Marty Meisler (MWD)
From:	Chris Campbell, Matt Weber
Project:	16-1017 – Fremont Weir Alternative 5
Subject:	Gate Operations and Transport Channel Performance

ALTERNATIVE 5 CONFIGURATION

A 1D hydraulic model was built in HEC-RAS 5.0.1 to explore the operations of gated culverts for the three intakes defining Alternative 5 (see Sheet C1). The model was set up to test the following flow conditions necessary for fish passage:

- For structures less than 60 ft in length, the flow velocity should be less than 6 ft/s and the flow depth greater than 3 ft
- For transport channels, the flow velocity should be less than 4 ft/s and the flow depth greater than 5 ft

Alternative 5 includes three (3) intakes comprised of a combination of gated box culverts:

- Intake AB includes three (3) A gates 10 ft W x 10 ft H box culverts with in invert set at 14 ft and three (3) B gates 10 ft W x 10 ft H box culverts with in invert set at 17 ft
- Intake C gates include ten (10) 10 ft W x 10 ft H box culverts with in invert set at 20 ft
- Intake D gates include eleven (11) 10 ft W x 7 ft H box culverts with in invert set at 23 ft
- All box culverts include downstream bottom hinged gates

Alternative 5 includes three (3) transport channels between the intakes and a floodplain channel / swale complex (see Sheet C2 Section B):

- Channel AB is a rock lined compound trapezoidal channel 2250 ft long and a left floodplain bench set 3 ft above the channel bed
- Channel C is a rock lined trapezoidal channel 1930 ft long that connects to Channel AB at its floodplain bench
- Channel D is a rock lined trapezoidal channel 1400 ft long that connects to Channel C

- Channel side slopes are generally 3:1

Downstream of the AB-C connection, Channel AB continues as a rock lined compound trapezoidal channel for 1920 ft before transitioning to a floodplain channel 7000 ft long within a ±1000 ft wide corridor bounded by additional floodplain lowering and connector swales (see Sheet C3 Section F). Channel side slopes are generally 3:1. Floodplain side slopes are generally 5:1.

Hydraulic roughness or Manning's n-values for each channel segment is defined by Table 1. Channel AB includes a relatively clean channel with roughened overbanks/floodplains due to the presence of managed vegetation. Channels C and D are generally roughened due to the presence of managed vegetation. Roughened conditions in Channel C were needed to increase the operational range of the channel for optimal fish passage. Roughened conditions in Channel D were needed to create the desired tailwater conditions at the intake for optimal fish passage.

The downstream boundary condition in the HEC-RAS model is defined in Table 2 as derived from the TUFLOW model.

Table 1. Manning's n-values

Reach	Left Overbank	Channel	Right Overbank
AB-2	0.06	0.04	0.06
AB-1	0.06	0.04	0.06
C-2	0.06	0.06	0.06
C-1	0.06	0.06	0.06
D-1	0.06	0.06	0.06

Table 2. Downstream rating curve

WSE (ft, 88)	Flow (cfs)	WSE (ft, 88)	Flow (cfs)
12.5	0	20.4	1455
16.4	135	21	2089
17.3	264	21.3	2498
18.2	386	21.6	3022
18.8	544	22.1	4024
19.4	774	22.6	5021
19.8	994	23	5999
20.1	1187	23.4	6769

GATE OPERATIONS

Given the complexity of optimizing gate operations, a series of unsteady HEC-RAS models were created to explore gate operations for a range of river levels and assess their performance for meeting the fish passage criteria. Gate operations are shown in Table 3 and Figure 1. The gate sequencing targets a design discharge of 3000 cfs while optimizing for fish passage. The gates for each intake channel generally open when the river level is high enough to create 3 ft of depth at the end of the box culvert. The lower invert elevation gates begin to close when the total discharge exceeds 3000 cfs.

Intake AB A gates operate from 15 ft to 25 ft and are closed at higher river levels. Intake AB B gates operate from 17 ft (i.e., the intake invert elevation) to 26.5 ft. Above 25.5 ft, some Intake B gates begin to close to reduce flows up to a river level of 26.6 ft when the last Intake B gate is fully closed. While the velocity through the Intake AB B gates exceeds passage criteria above 25.5 ft, this is not an issue because passable conditions at this stage are provided by Intake C gates. Also, there are overlapping passable conditions between the Intake AB and C gates between 23 ft and 25 ft.

Intake C gates operate from 23 ft to 28.25 ft. Above 26.5 ft, some Intake C gates begin to close to reduce flows through the gates up to a river level of 28.5 ft when the last Intake C gate is fully closed. While the velocity through the Intake C gates exceeds passage criteria above 27 ft, this is not an issue because passable conditions at this stage are provided by Intake D gates. Also, there is a narrow window of overlapping passable conditions between Intake C and D gates between 26.6 ft and 26.9 ft.

Intake D gates operate from 26.6 ft to 31.7 ft, which is the just below the crest of the Fremont Weir. Above 29 ft, Intake D gates begin to close at higher river levels to restrict flows through the gates just prior to Fremont Weir overtopping. While the velocities exceed passage criteria above 29 ft and flows approach 3,900 cfs, a minimum of six (6) gates should remain open to prevent supercritical flow within the culverts.

In addition to the operations noted above, the iterative process to optimize the gate operations included the following general notes:

- The transitions between having all gates open for Intakes AB, C, or D were difficult to operate to meet the velocity criteria in the lower elevation gates, while maintaining a discharge near 3,000 cfs. When some of the lower elevation gates are closed, the velocity in the remaining gates rises dramatically and depths slightly decrease.
- While culvert velocities in the lower elevation channels exceed fish passage criteria during transitions as river levels rise, keeping some lower elevation gates open would prevent dewatering and stranding in the adjoining channels.

Furthermore on operations in general, and consistent with the operations of the other alternatives:

- Gates will operate from November 1st through March 15th
- Intake AB A gates will open once there is 1 ft of head above the invert of the A gates (i.e., a river level of 15 ft)
- Intake AB A gates will close once the river level drops below the invert of the A gates (i.e., a river level of 14 ft)
- Gate closure rates are not significant in the model and gates will be closed over 10 minutes
- Intake D gates will remain open per the last known configuration during Fremont Weir overtopping conditions

FISH PASSAGE PERFORMANCE

The performance of the transport channels downstream of the intakes is shown in Figures 2 through 4 for a range of river levels. In general, the transport channels and intake gates meet the fish passage criteria between a river level of 19.6 ft to 28.7 ft. More specifically, the Alternative 5 system of gates and channels are passable under the following set of conditions assuming the gate operations follow the sequencing in Table 3:

- Intake AB and Channel AB-2 are jointly passable from 19.6 ft (limited by channel depth) to 25 ft (limited by intake velocity after all the Intake A gates close)
- Intake C and Channel C are jointly passable from 23.1 ft (limited by channel depth) to 26.9 ft (limited by intake velocity after 7 of the Intake C gates close)
- Intake D and Channel D are jointly passable from 26.6 ft (limited by gate depth) to 28.7 ft (limited by channel velocity)
- Channel AB-1 is passable over the range of 19.6 ft to 28.7 ft
- Maximum system capacity is 3,900 cfs at a river level of 31.7 ft per the last known gate configuration

Channel design notes:

- For river levels higher than 23.1 ft, the velocity in Channel AB-1 exceeds 4 ft/s 7,000 ft upstream from Ag Crossing #1 (or HEC-RAS XS # 7989), where the compound channel transitions to a wide excavated floodplain. However, the left overbank bench meets depth and velocity criteria for passage, which was accomplished by lowering the bench elevation by +/- 0.5 ft from the design cross section.
- Channel velocities for Channels C and D above 3,000 cfs are near 4 ft/s. Manning's n-values were increased to 0.06 keeps these channels below the 4 ft/s threshold.

YBPASS spreadsheet notes:

- The first three tabs show when the 5 ft minimum channel depth criteria is first met (within 0.1 ft of river level):
    - **AB 5 ft Depth**: Channel AB first meets the 5-ft depth minimum at a river level of 19.6 ft. The minimum depth occurs in Channel AB-1 at HEC-RAS XS # 7790.
    - **C 5 ft Depth**: Channel C first meets the 5-ft depth minimum at a river level of 23.1 ft. The minimum depth occurs in Channel C-2 at HEC-RAS XS # 2138.
    - **D 5 ft Depth**: Channel D first meets the 5-ft depth minimum at a river level of 26.6 ft. The minimum depth occurs in Channel D-1 at HEC-RAS XS # 1650.
- The next four tabs show the condition when the velocity criteria is at the threshold (i.e., 4 ft/s in channel or 6 ft/s at the intakes):
    - **AB-1 Vel Max**: the channel velocity criteria is exceeded first in Channel AB-1 at a river level of 23.2 ft when HEC-RAS XS # 7989 exceeds 4 ft/s within the main channel (4.02

ft/s). However, AB-1 is still passable because the depth is greater than 5 ft on the left overbank bench with velocities slower than 4 ft/s.

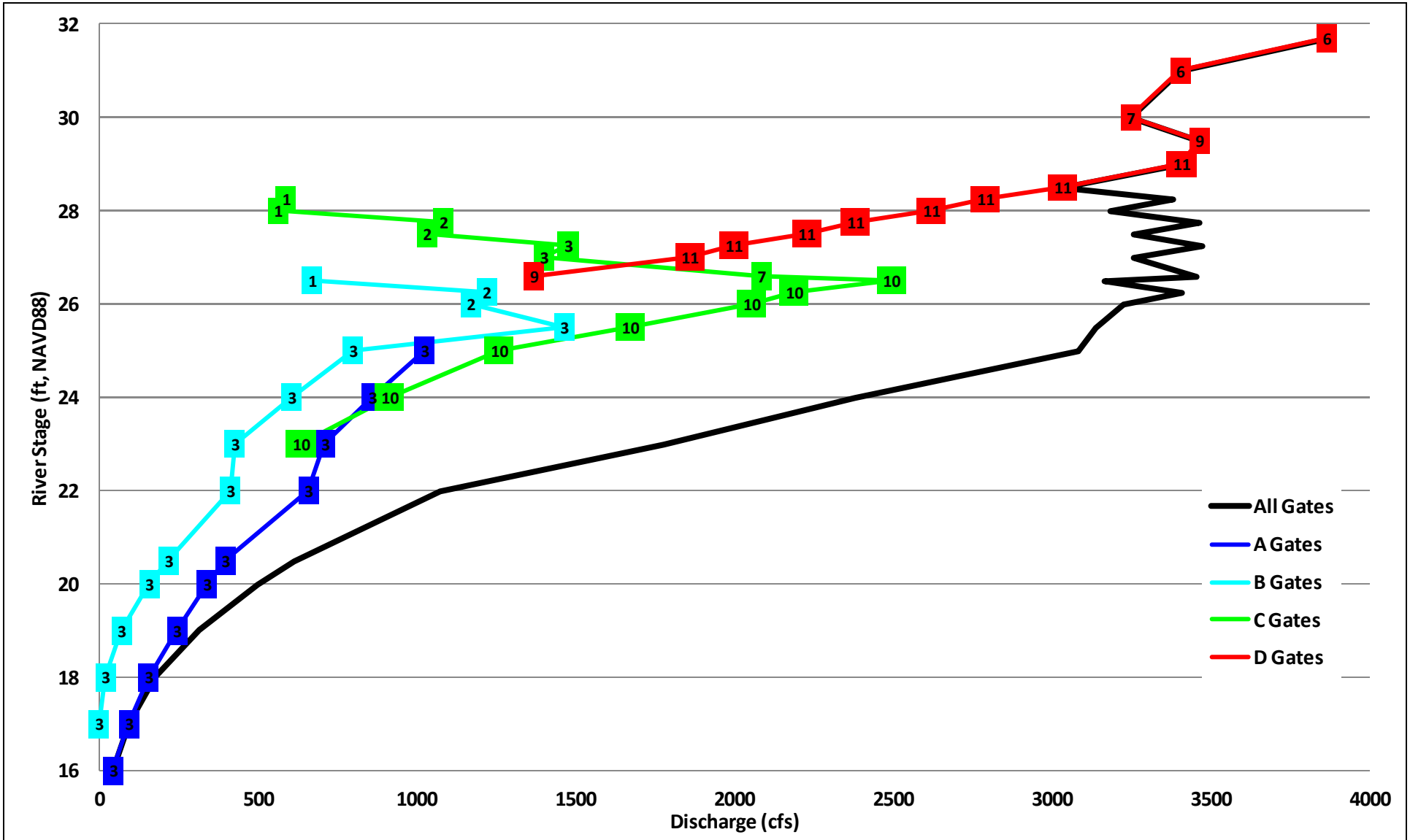
  - **AB-2 Vel Max**: the velocity criteria is exceeded first at Intake AB at a river level of 25.5 ft. This corresponds to closing the three A gates, which increases the velocity within the three remaining B gates. Passable conditions are maintained in Channel AB-2 up until the A gates are closed. At this stage, fish passage is provided within Channel C.
  - **C-2 Vel Max**: the velocity criteria is exceeded first at Intake C at a river level of 27 ft. This corresponds to closing seven of the ten C gates, which increases the velocity within the three remaining C gates. Passable conditions are maintained in Channel C-2 up until the seven C gates are closed. At this stage, fish passage is provided within Channel D.
  - **D-1 Vel Max**: the channel velocity criteria is last met in Channel D-2 at a river level of 28.7 ft. This is the last stage (within 0.01') when the system meets fish passage criteria.

- The last tab shows the system capacity:
  - **Max Stage**: the system is operable up to a river level of 31.7 ft (just below the crest of the Fremont Weir). At this level, intake and channel velocities are subcritical and flow is maintained within the channel banks. Max velocity within the Channel AB-1 left overbank bench is 3.09 ft/s at HEC-RAS XS # 7989, hence, the bench velocity never exceeds 4 ft/s for this design alternative.

Table 3. Intake velocity, depth, and flow for Intakes AB, C and D

River Level (ft)	# Gates Open				Intake A Gates			Intake B Gates			Intake C Gates			Intake D Gates			Total Flow (cfs)
	A (#/3)	B (#/3)	C (#/10)	D (#/11)	V (ft/s)	D[1] (ft)	Flow (cfs)	V (ft/s)	D[1] (ft)	Flow (cfs)	V (ft/s)	D[1] (ft)	Flow (cfs)	V (ft/s)	D[1] (ft)	Flow (cfs)	
31.70				6										12.0	5.4	3863	3863
31.00				6										11.7	4.9	3403	3403
30.00				7										9.9	4.7	3246	3246
29.50				9										7.6	5.1	3463	3463
29.00				11										6.0	5.1	3407	3407
28.50				11										5.9	4.7	3032	3032
28.25			1	11							12.0	4.9	589	5.6	4.5	2790	3379
28.00			1	11							12.1	4.7	563	5.6	4.3	2619	3182
27.75			2	11							10.5	5.2	1084	5.3	4.1	2381	3465
27.50			2	11							10.5	4.9	1032	5.3	3.8	2226	3258
27.25			3	11							9.2	5.4	1476	5.0	3.7	1998	3474
27.00			3	11							9.1	5.1	1400	5.0	3.4	1859	3259
26.60			7	9							4.9	6.0	2084	5.1	3.0	1369	3454
26.50		1	10					9.3	7.2	672	4.1	6.1	2493				3165
26.25		2	10					8.1	7.6	1220	3.7	5.9	2188				3408
26.00		2	10					7.9	7.4	1169	3.6	5.7	2054				3223
25.50		3	10					6.6	7.4	1464	3.2	5.3	1671				3136
25.00	3	3	10		3.4	10.0	1025	3.5	7.7	800	2.6	4.8	1259				3084
24.00	3	3	10		2.9	10.0	860	3.0	6.8	607	2.4	3.9	915				2381
23.00	3	3	10		2.7	8.8	711	2.4	5.8	428	2.2	2.9	636				1776
22.00	3	3			2.8	7.8	659	2.9	4.8	414							1073
20.50	3	3			2.1	6.4	398	2.2	3.4	219							617
20.00	3	3			1.9	5.9	340	1.8	2.9	158							498
19.00	3	3			1.7	5.0	245	1.2	2.0	71							316
18.00	3	3			1.3	4.0	157	0.7	1.0	20							177
17.00	3	3			1.1	3.0	94	0.0	0.0	0							94
16.00	3	3			0.8	2.0	45										45
15.00	3	3			0.4	1.0	12										12

Notes: [1] depth corresponds to the outlet of the box culverts; [2] green = meets passage criteria, yellow = marginally meets passage criteria, red = does not meet passage criteria



Notes: number of gates open shown as data labels

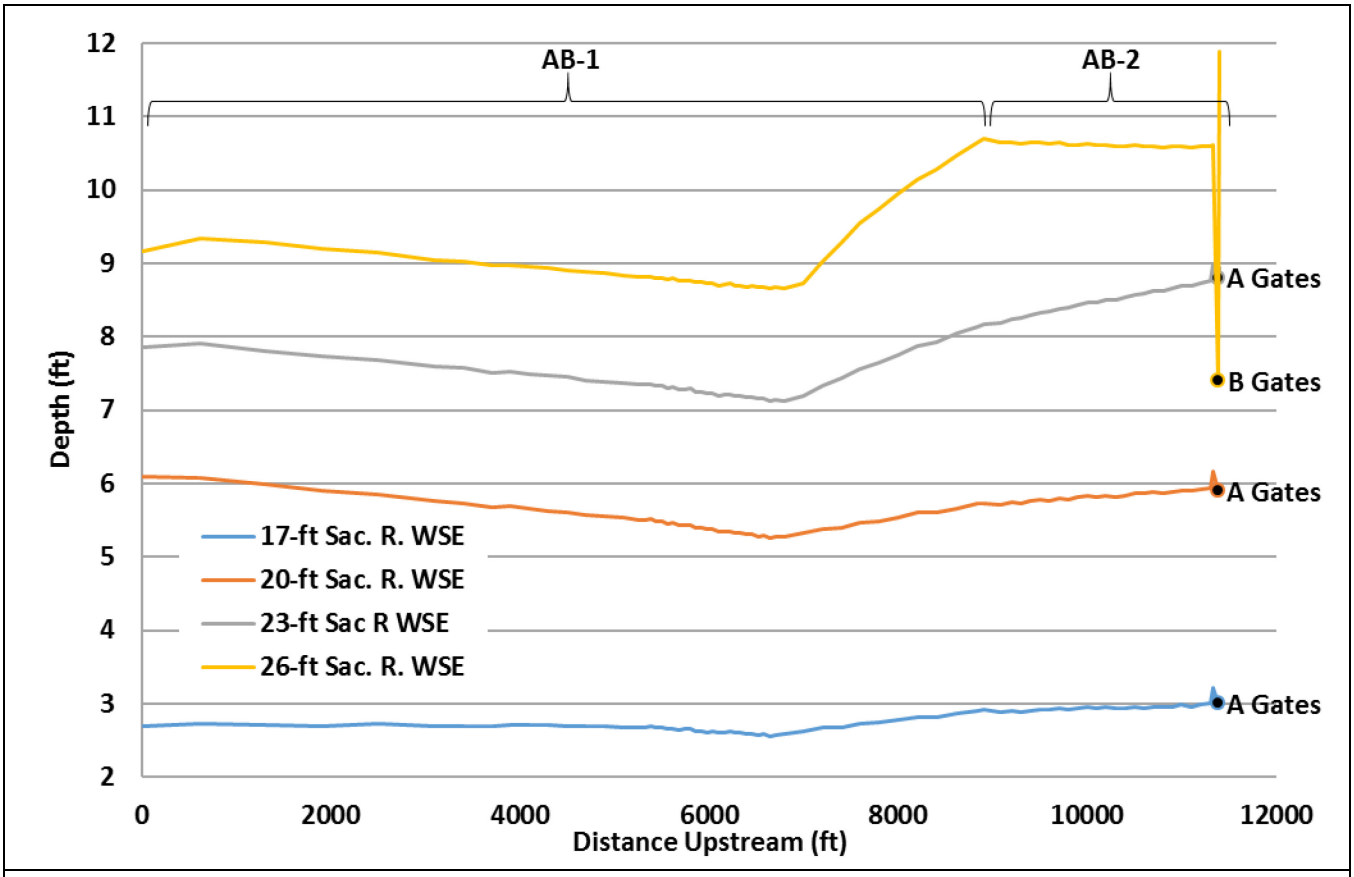
cbec eco engineering

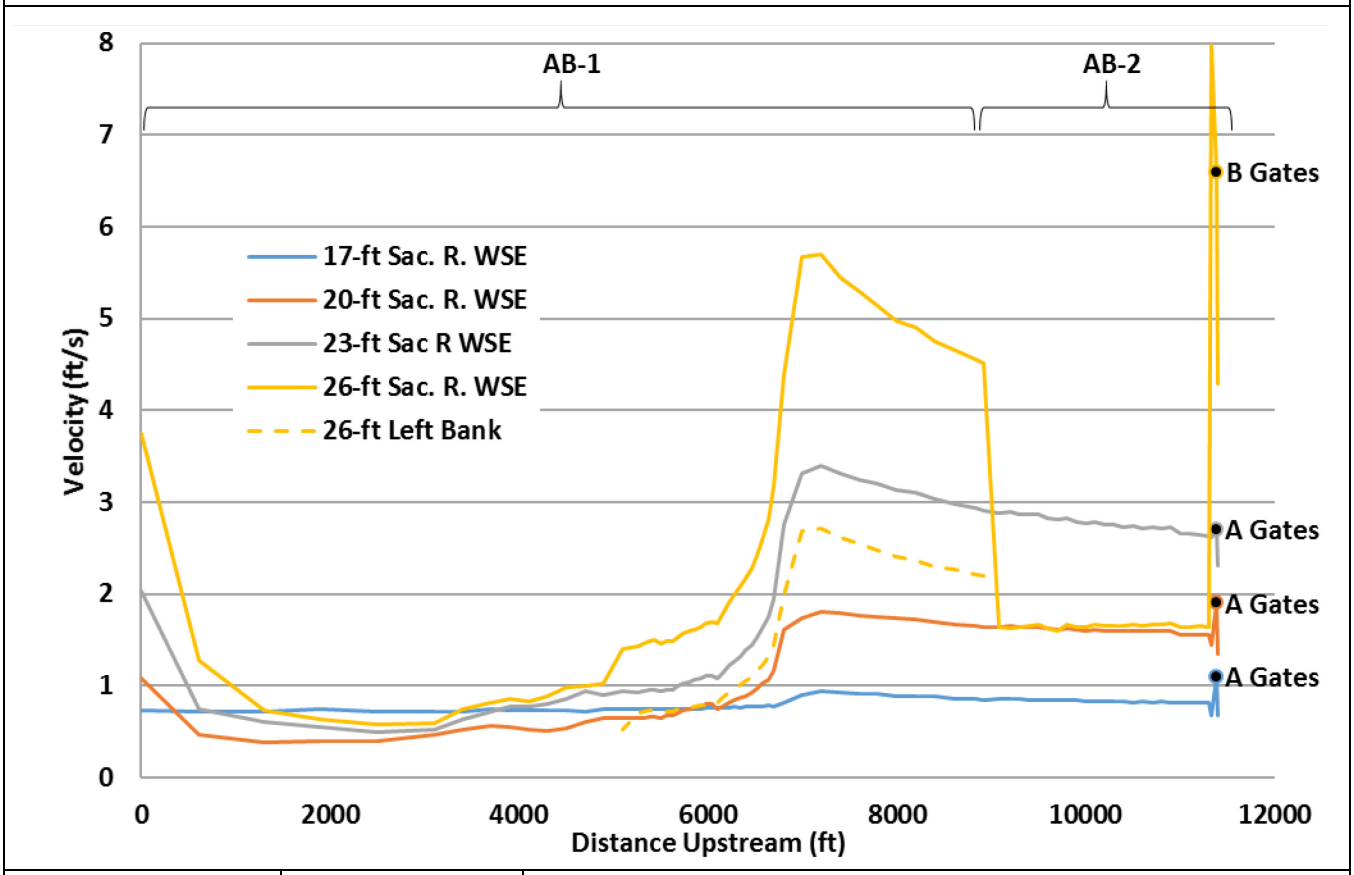
Fremont Weir Alt #5

Gate sequencing

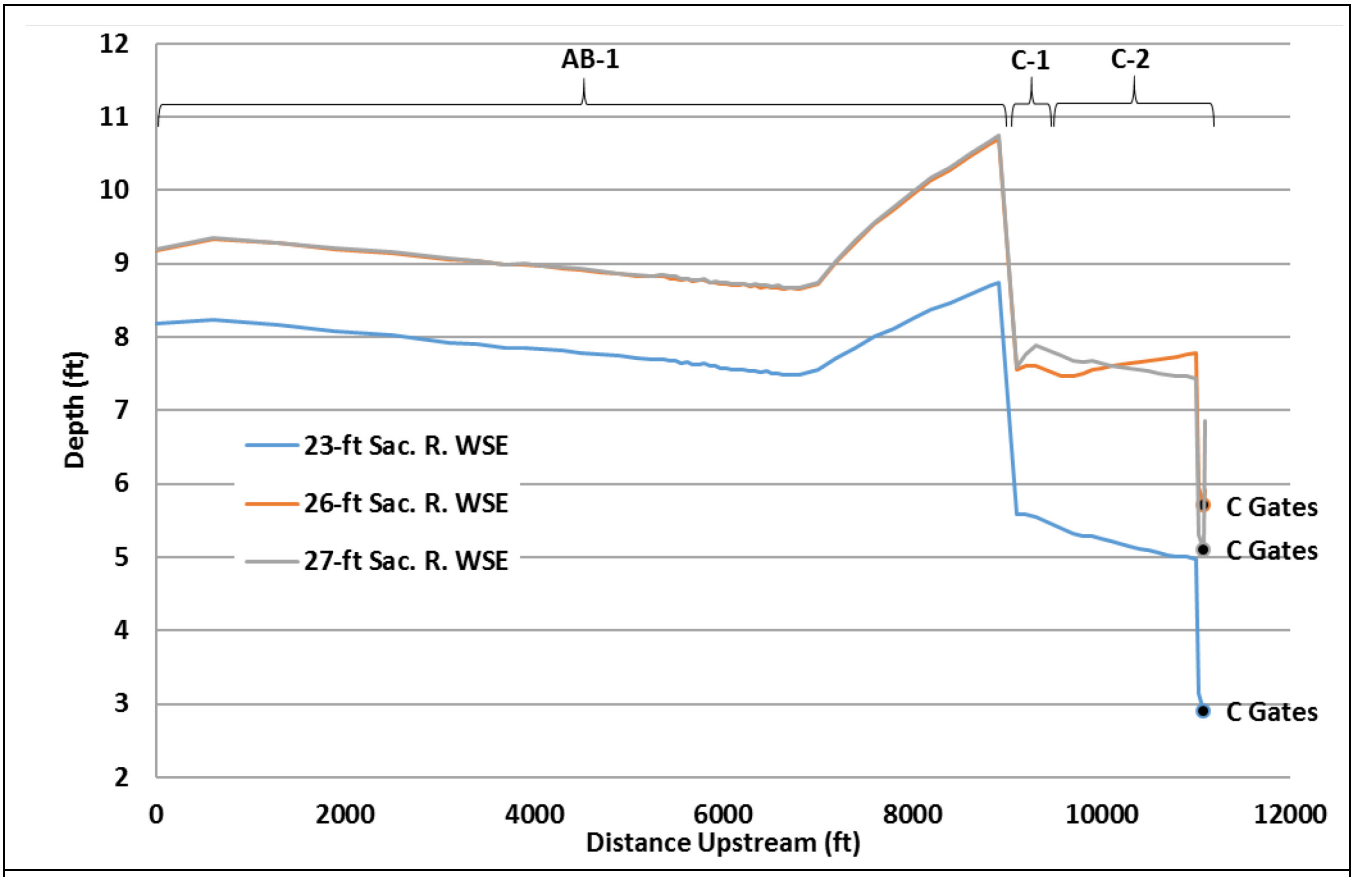
Project No. 16-1017 | Created By: MDW | **Figure 1**

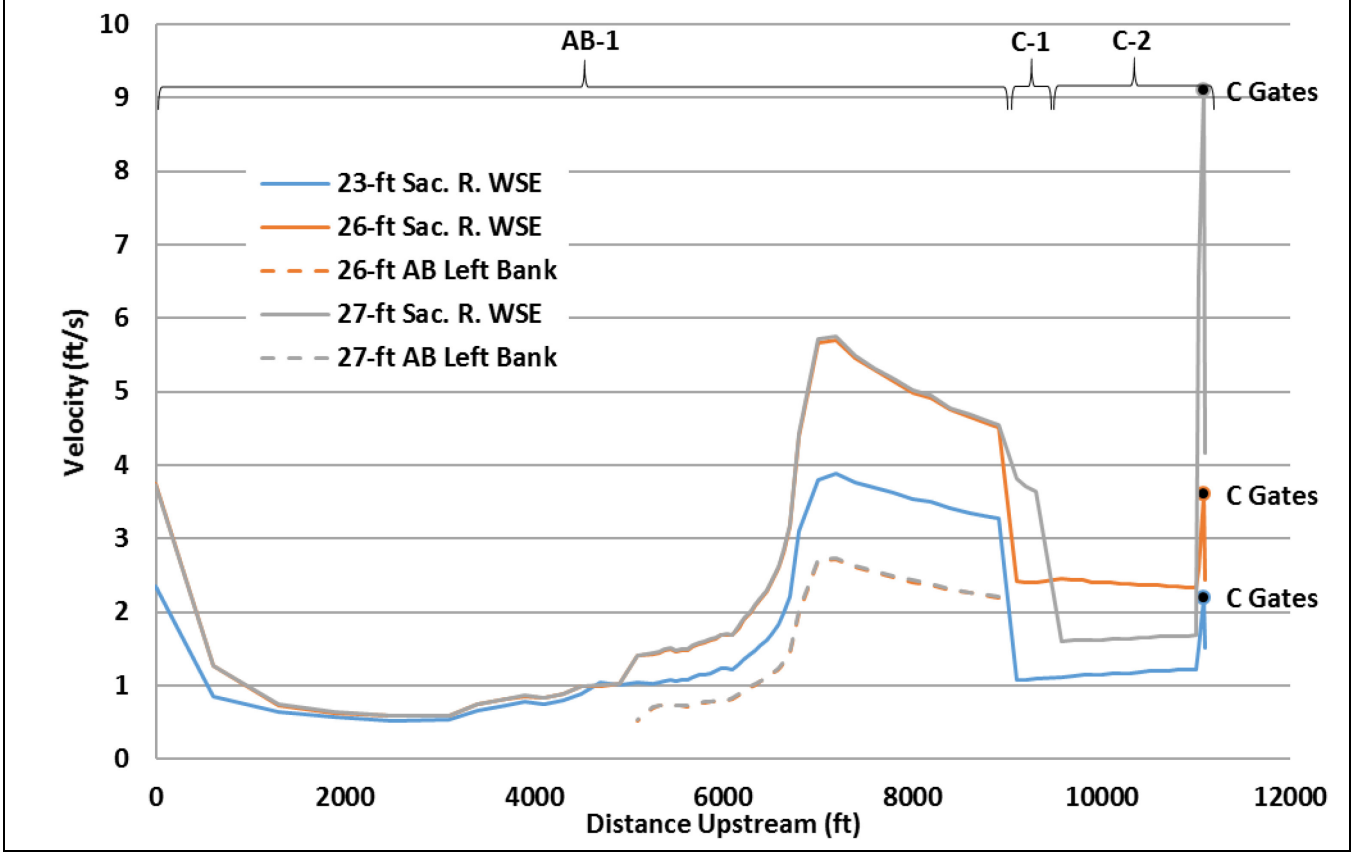
Figure_1_GateOperations.docx
12/20/2016





Notes: at 26-ft, passable conditions provided by C gates. Left bank provides passage in upper AB-1.	cbec eco engineering	*Fremont Weir Alt #5* **AB channel depth and velocity plots**		
		Project No. 16-1017	Created By: MDW	**Figure 2**





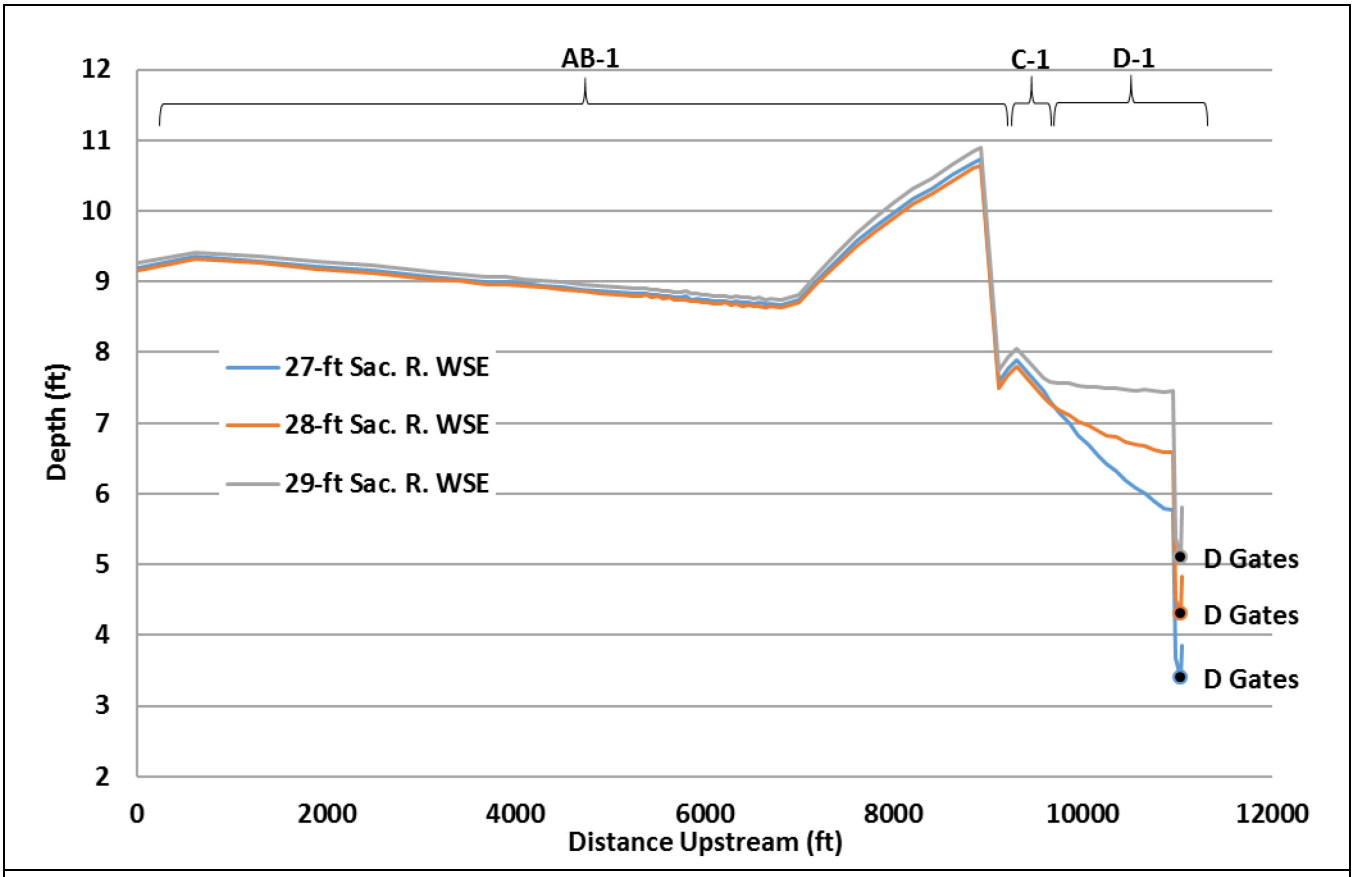
Notes: at 27-ft, passable conditions provided at D gates. Left bank provides passage in upper AB-1.

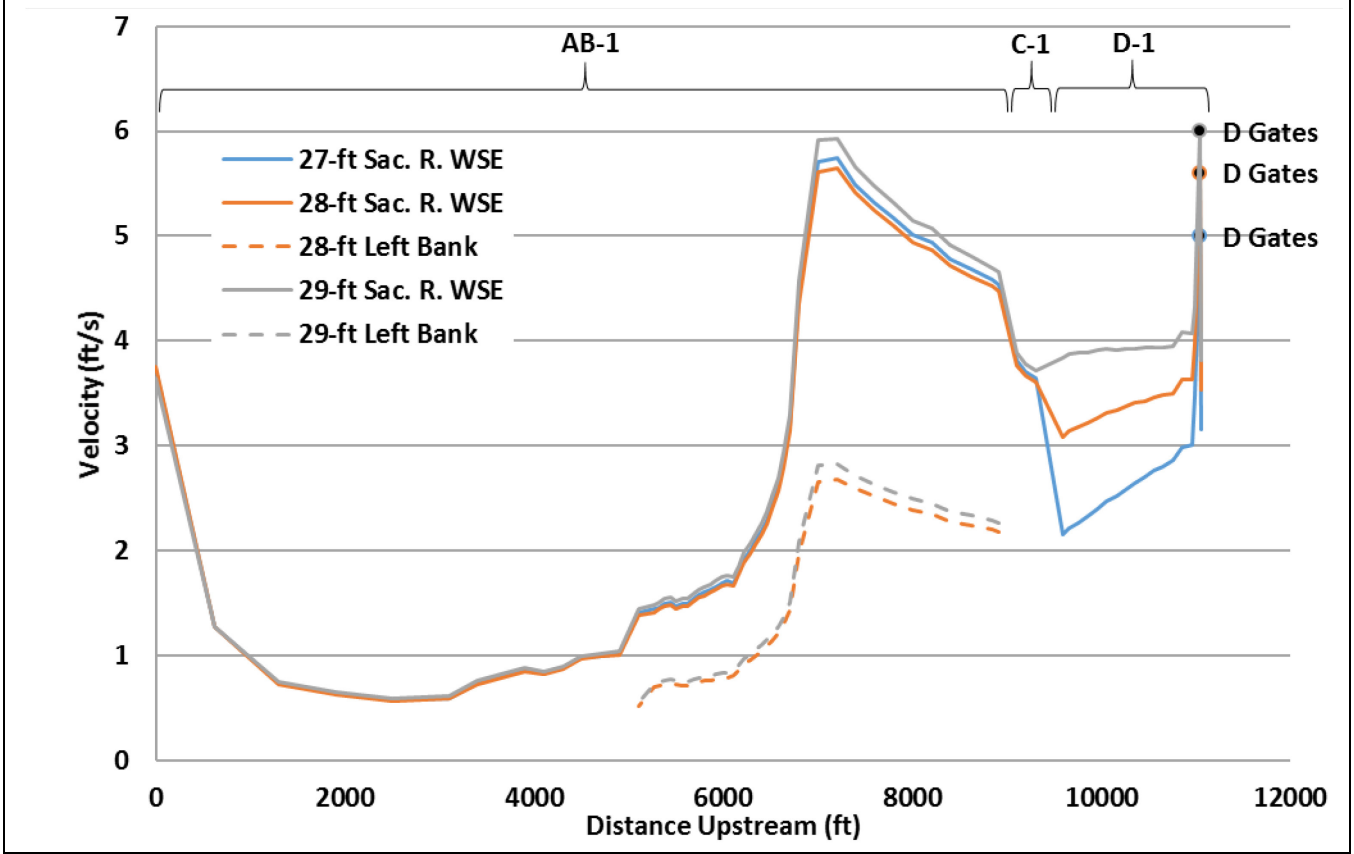
cbec eco engineering

Fremont Weir Alt #5

C-AB channel depth and velocity plots

Project No. 16-1017 | Created By: MDW | **Figure 3**





Notes: Left bank provides passage in upper AB-1.

cbec eco engineering

Fremont Weir Alt #5

D-C-AB channel depth and velocity plots

Project No. 16-1017	Created By: MDW	**Figure 4**

Figure_4_Channel_D-C-AB.docx
12/20/2016

AB Channel Minimum Depth Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Depth Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Depth in Channel (ft)	Water Surface Elevation in Sacramento River (ft)	Channel Depth Criterion Met
Headworks									
11750	418.15	10	N/A	19.61	N/A	0.26	9.61	19.61	Yes
11575	418.15	14	N/A	19.59	N/A	1.24	5.59	19.61	Yes
11550	Structure: 3 A Culverts and 3 B Culverts Open								
11520	418.15	13.75	17.75	19.54	0.57	1.31	5.79	19.61	Yes
AB-2 Channel									
11390	418.15	13.97	16.97	19.53	0.59	1.43	5.56	19.61	Yes
11290	418.15	13.97	16.97	19.51	0.59	1.43	5.54	19.61	Yes
11190	418.15	13.97	16.97	19.5	0.59	1.44	5.53	19.61	Yes
11089	418.15	13.94	16.94	19.48	0.6	1.43	5.54	19.61	Yes
10990	418.15	13.94	16.94	19.46	0.59	1.47	5.52	19.61	Yes
10891	418.15	13.94	16.94	19.44	0.59	1.46	5.5	19.61	Yes
10790	418.15	13.91	16.91	19.42	0.59	1.46	5.51	19.61	Yes
10690	418.15	13.91	16.91	19.4	0.59	1.46	5.49	19.61	Yes
10589	418.15	13.88	16.88	19.38	0.59	1.47	5.5	19.61	Yes
10489	418.15	13.88	16.88	19.36	0.59	1.46	5.48	19.61	Yes
10390	418.15	13.88	16.88	19.34	0.59	1.47	5.46	19.61	Yes
10289	418.15	13.84	16.84	19.32	0.6	1.47	5.48	19.61	Yes
10189	418.15	13.84	16.84	19.3	0.6	1.48	5.46	19.61	Yes
10089	418.15	13.81	16.81	19.28	0.6	1.47	5.47	19.61	Yes
9990	418.15	13.81	16.81	19.26	0.6	1.47	5.45	19.61	Yes
9890	418.15	13.81	16.81	19.24	0.6	1.5	5.43	19.61	Yes
9789	418.15	13.78	16.78	19.22	0.6	1.48	5.44	19.61	Yes
9690	418.15	13.78	16.78	19.2	0.6	1.48	5.42	19.61	Yes
9588	418.15	13.75	16.75	19.18	0.6	1.5	5.43	19.61	Yes
9488	418.15	13.75	16.75	19.16	0.6	1.5	5.41	19.61	Yes
9388	418.15	13.75	16.75	19.14	0.6	1.5	5.39	19.61	Yes
9288	418.15	13.72	16.72	19.12	0.6	1.51	5.4	19.61	Yes
9189	418.15	13.72	16.72	19.09	0.6	1.5	5.37	19.61	Yes
9000	428.15	13.66	16.66	19.09	0.62	1.52	5.43	19.61	Yes
8928	428.15	13.66	16.66	19.08	0.62	1.53	5.42	19.61	Yes
8810	428.15	13.66	16.66	19.03	0.62	1.55	5.37	19.61	Yes
5689	428.15	13.66	16.66	18.97	0.62	1.57	5.31	19.61	Yes
8589	428.15	13.62	16.62	18.93	0.63	1.6	5.31	19.61	Yes
8489	428.15	13.62	16.62	18.88	0.63	1.6	5.26	19.61	Yes
8389	428.15	13.62	16.62	18.83	0.63	1.62	5.21	19.61	Yes
8289	428.15	13.59	16.59	18.77	0.64	1.64	5.18	19.61	Yes
8189	428.15	13.59	16.49	18.72	0.64	1.65	5.13	19.61	Yes
8089	428.15	13.56	16.31	18.66	0.64	1.67	5.1	19.61	Yes
7989	428.15	13.56	15.81	18.61	0.61	1.61	5.05	19.61	Yes
7890	428.15	13.56	16.56	18.57	0.54	1.48	5.01	19.61	Yes
7790	428.15	13.56	16.56	18.56	0.4	1.1	5	19.61	Yes
7689	428.15	13.56	16.56	18.56	0.37	1.03	5	19.61	Yes
7589	428.15	13.53	16.53	18.55	0.35	0.98	5.02	19.61	Yes
7489	428.15	13.53	16.53	18.55	0.34	0.93	5.02	19.61	Yes
7389	428.15	13.5	16.5	18.54	0.33	0.89	5.04	19.61	Yes
7289	428.15	13.5	16.5	18.54	0.32	0.87	5.04	19.61	Yes
7187	428.15	13.47	16.47	18.53	0.31	0.84	5.06	19.61	Yes
7089	428.15	13.47	16.47	18.53	0.3	0.82	5.06	19.61	Yes

Minimum Depth (ft)
5

6989	428.15	13.44	16.44	18.53	0.28	0.79	5.09	19.61	Yes
6890	428.16	13.44	16.44	18.52	0.26	0.76	5.08	19.61	Yes
6789	428.15	13.44	16.44	18.52	0.25	0.73	5.08	19.61	Yes
6689	428.15	13.41	16.41	18.52	0.23	0.8	5.11	19.61	Yes
6589	428.15	13.41	16.41	18.51	0.23	0.8	5.1	19.61	Yes
6490	428.15	13.38	16.38	18.51	0.23	0.77	5.13	19.61	Yes
6390	428.15	13.38	16.38	18.51	0.23	0.76	5.13	19.61	Yes
6289	428.15	13.34	16.34	18.51	0.23	0.73	5.17	19.61	Yes
6189	428.15	13.34	16.34	18.5	0.23	0.72	5.16	19.61	Yes
6089	428.15	13.34	16.34	18.5	0.22	0.7	5.16	19.61	Yes
5989	428.16	13.31	16.31	18.5	0.22	0.67	5.19	19.61	Yes
5889	428.15	13.31	16.31	18.5	0.22	0.66	5.19	19.61	Yes
5789	428.15	13.28	16.28	18.49	0.23	0.64	5.21	19.61	Yes
5690	428.15	13.28	16.28	18.49	0.23	0.66	5.21	19.61	Yes
5589	428.15	13.25	16.25	18.49	0.24	0.65	5.24	19.61	Yes
5489	428.16	13.25	16.25	18.49	0.24	0.65	5.24	19.61	Yes
5389	428.16	13.25	16.25	18.48	0.24	0.64	5.23	19.61	Yes
5189	428.15	13.22	16.22	18.48	0.24	0.65	5.26	19.61	Yes
4989	428.15	13.19	16.19	18.47	0.23	0.63	5.28	19.61	Yes
4789	428.15	13.16	16.16	18.46	0.22	0.61	5.3	19.61	Yes
4589	428.14	13.12	16.12	18.46	0.2	0.52	5.34	19.61	Yes
4391	428.14	13.09	16.09	18.45	0.18	0.5	5.36	19.61	Yes
4191	428.16	13.06	16.06	18.45	0.17	0.51	5.39	19.61	Yes
3990	428.16	13.03	16.03	18.44	0.17	0.54	5.41	19.61	Yes
3789	428.15	13.03	16.03	18.44	0.16	0.56	5.41	19.61	Yes
3489	428.16	12.97	15.97	18.43	0.15	0.51	5.46	19.61	Yes
3189	428.15	12.94	15.94	18.43	0.14	0.45	5.49	19.61	Yes
2589	428.16	12.84	15.84	18.42	0.13	0.38	5.58	19.61	Yes
1991	428.15	12.78	15.78	18.41	0.14	0.39	5.63	19.61	Yes
1389	428.15	12.69	15.69	18.4	0.13	0.37	5.71	19.61	Yes
703	428.15	12.59	15.59	18.39	0.16	0.46	5.8	19.61	Yes
89	428.16	12.53	15.53	18.36	0.39	0.98	5.83	19.61	Yes

Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 60 ft)

HEC-RAS Model Output

Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
AB	2	11750	09JAN1990 2400	418.15	10	19.61		19.61	0.000003	0.26	1595.42	182.03	0.02		0.26	
AB	2	11575	09JAN1990 2400	418.15	14	19.59		19.61	0.000128	1.24	390.73	113.07	0.1	0.62	1.24	
AB	2	11550	Culvert													
AB	2	11520	09JAN1990 2400	418.15	13.75	19.54		19.57	0.000136	1.31	377.78	112.77	0.1	0.57	1.31	
AB	2	11390	09JAN1990 2400	418.15	13.97	19.53		19.56	0.000186	1.43	360.4	103.27	0.11	0.59	1.43	0.34
AB	2	11290	09JAN1990 2400	418.15	13.97	19.51		19.54	0.000186	1.43	360.07	103.28	0.11	0.59	1.43	0.34
AB	2	11190	09JAN1990 2400	418.15	13.97	19.5		19.52	0.00019	1.44	358	103.2	0.12	0.59	1.44	0.3
AB	2	11089	09JAN1990 2400	418.15	13.94	19.48		19.5	0.00019	1.44	358.48	103.17	0.12	0.6	1.43	0.28
AB	2	10990	09JAN1990 2400	418.15	13.94	19.46		19.49	0.000191	1.47	356.94	103.12	0.12	0.59	1.47	0.38
AB	2	10891	09JAN1990 2400	418.15	13.94	19.44		19.47	0.000193	1.46	355.55	103.04	0.12	0.59	1.46	0.37
AB	2	10790	09JAN1990 2400	418.15	13.91	19.42		19.45	0.000192	1.46	356.16	103.09	0.12	0.59	1.46	0.38
AB	2	10690	09JAN1990 2400	418.15	13.91	19.4		19.43	0.000195	1.46	354.2	103.02	0.12	0.59	1.46	0.38
AB	2	10589	09JAN1990 2400	418.15	13.88	19.38		19.41	0.000193	1.47	355.34	103.02	0.12	0.59	1.47	0.38
AB	2	10489	09JAN1990 2400	418.15	13.88	19.36		19.39	0.000196	1.46	353.35	102.95	0.12	0.59	1.46	0.38

AB	2	1039	09JAN1990	2400	418.15	13.88	19.34	19.37	0.000199	1.47	351.47	102.81	0.12	0.59	1.47	0.39
AB	2	1028	09JAN1990	2400	418.15	13.84	19.32	19.35	0.000197	1.47	352.89	102.84	0.12	0.6	1.47	0.39
AB	2	1018	09JAN1990	2400	418.15	13.84	19.3	19.33	0.000199	1.48	351.48	102.81	0.12	0.6	1.48	0.37
AB	2	1008	09JAN1990	2400	418.15	13.81	19.28	19.31	0.000198	1.47	351.88	102.73	0.12	0.6	1.47	0.36
AB	2	999	09JAN1990	2400	418.15	13.81	19.26	19.29	0.000201	1.48	350.17	102.71	0.12	0.6	1.47	0.39
AB	2	989	09JAN1990	2400	418.15	13.81	19.24	19.27	0.000204	1.5	348.26	102.62	0.12	0.6	1.5	0.4
AB	2	978	09JAN1990	2400	418.15	13.78	19.22	19.25	0.000203	1.48	348.9	102.56	0.12	0.6	1.48	0.37
AB	2	969	09JAN1990	2400	418.15	13.78	19.2	19.23	0.000206	1.49	347.31	102.58	0.12	0.6	1.48	0.38
AB	2	958	09JAN1990	2400	418.15	13.75	19.18	19.21	0.000205	1.51	347.49	102.49	0.12	0.6	1.5	0.38
AB	2	948	09JAN1990	2400	418.15	13.75	19.16	19.19	0.000208	1.5	345.76	102.41	0.12	0.6	1.5	0.37
AB	2	938	09JAN1990	2400	418.15	13.75	19.14	19.17	0.000211	1.5	344.13	102.38	0.12	0.6	1.5	0.37
AB	2	928	09JAN1990	2400	418.15	13.72	19.12	19.15	0.000211	1.51	344.06	102.38	0.12	0.6	1.51	0.38
AB	2	918	09JAN1990	2400	418.15	13.72	19.09	19.12	0.000214	1.5	342.36	102.26	0.12	0.6	1.5	0.34
AB	1	900	09JAN1990	2400	428.15	13.66	19.09	19.12	0.000215	1.53	348.01	102.56	0.12	0.62	1.52	0.36
AB	1	892	09JAN1990	2400	428.15	13.66	19.08	19.11	0.000217	1.53	346.34	102.46	0.12	0.62	1.53	0.36
AB	1	881	09JAN1990	2400	428.15	13.66	19.03	19.06	0.000226	1.55	341.3	102.17	0.13	0.62	1.55	0.36
AB	1	568	09JAN1990	2400	428.15	13.66	18.97	19.01	0.000236	1.57	336.06	101.81	0.13	0.62	1.57	0.4
AB	1	858	09JAN1990	2400	428.15	13.62	18.93	18.96	0.000238	1.6	334.68	101.7	0.13	0.63	1.6	0.41
AB	1	848	09JAN1990	2400	428.15	13.62	18.88	18.91	0.000249	1.6	330.12	101.46	0.13	0.63	1.6	0.35
AB	1	838	09JAN1990	2400	428.15	13.62	18.83	18.86	0.000257	1.63	325.29	101.27	0.13	0.63	1.62	0.39
AB	1	828	09JAN1990	2400	428.15	13.59	18.77	18.81	0.000263	1.64	322.89	101.04	0.14	0.64	1.64	0.41
AB	1	818	09JAN1990	2400	428.15	13.59	18.72	18.76	0.000275	1.66	317.39	100.75	0.14	0.64	1.65	0.4
AB	1	808	09JAN1990	2400	428.15	13.56	18.66	18.7	0.000282	1.68	314.62	100.5	0.14	0.64	1.67	0.45
AB	1	798	09JAN1990	2400	428.15	13.56	18.61	18.65	0.000263	1.61	325.68	104.89	0.13	0.61	1.61	0.39
AB	1	789	09JAN1990	2400	428.15	13.56	18.57	18.6	0.000221	1.48	352.15	115.8	0.12	0.54	1.48	0.32
AB	1	779	09JAN1990	2400	428.15	13.56	18.56	18.58	0.000122	1.1	607.45	254.48	0.09	0.4	1.1	0.39
AB	1	768	09JAN1990	2400	428.15	13.56	18.56	18.57	0.000107	1.03	685.85	302.19	0.09	0.37	1.03	0.36
AB	1	758	09JAN1990	2400	428.15	13.53	18.55	18.56	0.000095	0.98	752.2	340.95	0.08	0.35	0.98	0.34
AB	1	748	09JAN1990	2400	428.15	13.53	18.55	18.56	0.000087	0.93	804.45	372.28	0.08	0.34	0.93	0.33
AB	1	738	09JAN1990	2400	428.15	13.5	18.54	18.55	0.000081	0.89	853.56	400.77	0.07	0.33	0.89	0.31
AB	1	728	09JAN1990	2400	428.15	13.5	18.54	18.55	0.000076	0.87	899.42	429.18	0.07	0.32	0.87	0.3
AB	1	718	09JAN1990	2400	428.15	13.47	18.53	18.54	0.000071	0.85	941.98	455.97	0.07	0.31	0.84	0.29
AB	1	708	09JAN1990	2400	428.15	13.47	18.53	18.54	0.000067	0.82	985.4	482.08	0.07	0.3	0.82	0.28
AB	1	698	09JAN1990	2400	428.15	13.44	18.53	18.53	0.000062	0.79	1041.14	511.55	0.07	0.28	0.79	0.27
AB	1	689	09JAN1990	2400	428.16	13.44	18.52	18.53	0.000056	0.76	1115.88	555.74	0.06	0.26	0.76	0.26
AB	1	678	09JAN1990	2400	428.15	13.44	18.52	18.53	0.000053	0.73	1176.04	600.62	0.06	0.25	0.73	0.26
AB	1	668	09JAN1990	2400	428.15	13.41	18.52	18.52	0.000063	0.8	1092.7	635.81	0.07	0.23	0.8	0.29
AB	1	658	09JAN1990	2400	428.15	13.41	18.51	18.52	0.000062	0.8	1113.58	644.03	0.07	0.23	0.8	0.29
AB	1	649	09JAN1990	2400	428.15	13.38	18.51	18.52	0.000059	0.77	1143.09	652.65	0.06	0.23	0.77	0.29
AB	1	639	09JAN1990	2400	428.15	13.38	18.51	18.51	0.000056	0.76	1179.31	666.63	0.06	0.23	0.76	0.28
AB	1	628	09JAN1990	2400	428.15	13.34	18.51	18.51	0.000052	0.73	1213.14	667.45	0.06	0.23	0.73	0.27
AB	1	618	09JAN1990	2400	428.15	13.34	18.5	18.51	0.00005	0.72	1236.04	674.24	0.06	0.23	0.72	0.27
AB	1	608	09JAN1990	2400	428.15	13.34	18.5	18.5	0.000047	0.7	1277.74	689.65	0.06	0.22	0.7	0.26
AB	1	598	09JAN1990	2400	428.16	13.31	18.5	18.5	0.000043	0.67	1345.44	709.44	0.05	0.22	0.67	0.24
AB	1	588	09JAN1990	2400	428.15	13.31	18.5	18.5	0.000042	0.66	1358.84	702.06	0.05	0.22	0.66	0.23
AB	1	578	09JAN1990	2400	428.15	13.28	18.49	18.5	0.000041	0.64	1367.57	695.05	0.05	0.23	0.64	0.22
AB	1	569	09JAN1990	2400	428.15	13.28	18.49	18.49	0.000041	0.66	1361.29	691.5	0.05	0.23	0.66	0.22
AB	1	558	09JAN1990	2400	428.15	13.25	18.49	18.49	0.00004	0.65	1369.58	702.15	0.05	0.24	0.65	0.22
AB	1	548	09JAN1990	2400	428.16	13.25	18.49	18.49	0.00004	0.65	1386.79	718.49	0.05	0.24	0.65	0.21
AB	1	538	09JAN1990	2400	428.16	13.25	18.48	18.49	0.000039	0.64	1408.58	740.84	0.05	0.24	0.64	0.21
AB	1	518	09JAN1990	2400	428.15	13.22	18.48	18.48	0.000039	0.65	1416.56	751.31	0.05	0.24	0.65	0.2
AB	1	498	09JAN1990	2400	428.15	13.19	18.47	18.47	0.000037	0.63	1455.21	774.29	0.05	0.23	0.63	0.2
AB	1	478	09JAN1990	2400	428.15	13.16	18.46	18.47	0.000036	0.61	1477.87	780.11	0.05	0.22	0.61	0.2
AB	1	458	09JAN1990	2400	428.14	13.12	18.46	18.46	0.000027	0.52	1713.89	851.19	0.04	0.2	0.52	0.18
AB	1	439	09JAN1990	2400	428.14	13.09	18.45	18.46	0.000024	0.5	1838.72	906.54	0.04	0.18	0.5	0.18
AB	1	419	09JAN1990	2400	428.16	13.06	18.45	18.45	0.000024	0.51	1850.77	927.33	0.04	0.17	0.51	0.19
AB	1	399	09JAN1990	2400	428.16	13.03	18.44	18.45	0.000027	0.54	1798.31	994.05	0.04	0.17	0.54	0.2

AB	1	3789	09JAN1990 2400	428.15	13.03	18.44		18.44	0.00003	0.56	1739.59	1073.45	0.05	0.16	0.56	0.22
AB	1	3489	09JAN1990 2400	428.16	12.97	18.43		18.43	0.000023	0.51	1995.84	1171.91	0.04	0.15	0.51	0.19
AB	1	3189	09JAN1990 2400	428.15	12.94	18.43		18.43	0.000018	0.45	2344.17	1410.06	0.04	0.14	0.45	0.14
AB	1	2589	09JAN1990 2400	428.16	12.84	18.42		18.42	0.000012	0.38	2844.64	1547.33	0.03	0.13	0.38	0.12
AB	1	1991	09JAN1990 2400	428.15	12.78	18.41		18.41	0.000013	0.39	2699.37	1500.75	0.03	0.14	0.39	0.12
AB	1	1389	09JAN1990 2400	428.15	12.69	18.4		18.4	0.000012	0.37	2782.04	1437.95	0.03	0.13	0.37	0.12
AB	1	703	09JAN1990 2400	428.15	12.59	18.39		18.4	0.000017	0.46	2047.84	909.99	0.04	0.16	0.46	0.17
AB	1	89	09JAN1990 2400	428.16	12.53	18.36	14.01	18.37	0.000077	0.98	649.49	231.36	0.08	0.39	0.98	0.33

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (cfs)
AB		2 11750	9JAN1990 240	19.61	19.61	0	0.01			418.15		182.03
AB		2 11575	9JAN1990 240	19.61	19.59	0.02			66.77	351.38		113.07
AB		2 11550		Culvert								
AB		2 11520	9JAN1990 240	19.57	19.54	0.02	0.01		60.48	357.67		112.77
AB		2 11390	9JAN1990 240	19.56	19.53	0.03	0.02		63.61	352.17	2.37	103.27

Culvert Only

Channel	Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	EG. IC (ft)	E.G. OC (ft)	Min El Weir Flow (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
AB		2 11750 Culverts	9JAN1990 240	19.61	19.59	18.28	19.6	31.81	125.45		0.05	1.65	1.5
AB		2 11575 Culverts	9JAN1990 240	19.61	19.59	16.26	19.61	31.81	292.7		0.05	1.76	1.68

C Channel Minimum Depth Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Depth Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Depth in Channel (ft)	Water Surface Elevation in Sacramento River (ft)	Channel Depth Criterion Met
Headworks									
2338	662	10	N/A	23.1	N/A	0.29	13.1	23.1	Yes
2308	662	20	N/A	23.06	N/A	1.53	3.06	23.1	Yes
2300	Structure: 3 A Culverts, 3 B Culverts, and 10 C Culverts Open								
2238	662	19.75	N/A	22.98	N/A	1.53	3.23	23.1	Yes
C-2 Channel									
2138	662	17.91	N/A	22.98	N/A	1.24	5.07	23.1	Yes
2038	662	17.84	N/A	22.94	N/A	1.23	5.1	23.1	Yes
1938	662	17.81	N/A	22.91	N/A	1.23	5.1	23.1	Yes
1838	662	17.75	N/A	22.88	N/A	1.22	5.13	23.1	Yes
1738	662	17.69	N/A	22.84	N/A	1.22	5.15	23.1	Yes
1638	662	17.62	N/A	22.81	N/A	1.21	5.19	23.1	Yes
1538	662	17.56	N/A	22.78	N/A	1.2	5.22	23.1	Yes
1438	662	17.5	N/A	22.75	N/A	1.19	5.25	23.1	Yes
1338	662	17.44	N/A	22.72	N/A	1.19	5.28	23.1	Yes
1238	662	17.38	N/A	22.69	N/A	1.18	5.31	23.1	Yes
1138	662	17.31	N/A	22.66	N/A	1.17	5.35	23.1	Yes
1038	662	17.25	N/A	22.63	N/A	1.16	5.38	23.1	Yes
938	662	17.22	N/A	22.6	N/A	1.16	5.38	23.1	Yes
838	662	17.16	N/A	22.57	N/A	1.15	5.41	23.1	Yes
710	662	17.06	N/A	22.54	N/A	1.14	5.48	23.1	Yes
C-1 Channel									
438	667	16.91	N/A	22.54	N/A	1.11	5.63	23.1	Yes
338	667	16.84	N/A	22.51	N/A	1.1	5.67	23.1	Yes
267	667	16.81	N/A	22.49	N/A	1.1	5.68	23.1	Yes
AB-1 Channel									
9000	1839	13.66	16.66	22.49	1.58	3.33	8.83	23.1	Yes
8928	1839	13.66	16.66	22.45	1.59	3.35	8.79	23.1	Yes
8810	1839	13.66	16.66	22.33	1.62	3.41	8.67	23.1	Yes
5689	1839	13.66	16.66	22.2	1.64	3.47	8.54	23.1	Yes
8589	1839	13.62	16.62	22.08	1.68	3.57	8.46	23.1	Yes
8489	1839	13.62	16.62	21.95	1.7	3.6	8.33	23.1	Yes
8389	1839	13.62	16.62	21.81	1.73	3.69	8.19	23.1	Yes
8289	1839	13.59	16.59	21.67	1.76	3.76	8.08	23.1	Yes
8189	1839	13.59	16.49	21.51	1.79	3.84	7.92	23.1	Yes
8089	1839	13.56	16.31	21.35	1.83	3.96	7.79	23.1	Yes
7989	1839	13.56	15.81	21.19	1.79	3.88	7.63	23.1	Yes
7890	1839	13.56	16.56	21.11	1.4	3.16	7.55	23.1	Yes
7790	1839	13.56	16.56	21.12	1	2.25	7.56	23.1	Yes
7689	1839	13.56	16.56	21.11	0.91	2.01	7.55	23.1	Yes
7589	1839	13.53	16.53	21.1	0.85	1.86	7.57	23.1	Yes
7489	1839	13.53	16.53	21.09	0.8	1.74	7.56	23.1	Yes
7389	1839	13.5	16.5	21.09	0.77	1.64	7.59	23.1	Yes
7289	1839	13.5	16.5	21.08	0.73	1.57	7.58	23.1	Yes
7187	1839	13.47	16.47	21.07	0.7	1.51	7.6	23.1	Yes
7089	1839	13.47	16.47	21.07	0.67	1.44	7.6	23.1	Yes
6989	1839	13.44	16.44	21.06	0.65	1.38	7.62	23.1	Yes
6890	1839	13.44	16.44	21.06	0.61	1.3	7.62	23.1	Yes

Minimum Depth (ft)
5.07

6789	1839	13.44	16.44	21.06	0.57	1.23	7.62	23.1	Yes
6689	1839	13.41	16.41	21.05	0.55	1.26	7.64	23.1	Yes
6589	1839	13.41	16.41	21.05	0.55	1.25	7.64	23.1	Yes
6490	1839	13.38	16.38	21.04	0.54	1.21	7.66	23.1	Yes
6390	1839	13.38	16.38	21.04	0.53	1.19	7.66	23.1	Yes
6289	1839	13.34	16.34	21.04	0.53	1.17	7.7	23.1	Yes
6189	1839	13.34	16.34	21.03	0.52	1.16	7.69	23.1	Yes
6089	1839	13.34	16.34	21.03	0.51	1.13	7.69	23.1	Yes
5989	1839	13.31	16.31	21.02	0.49	1.09	7.71	23.1	Yes
5889	1839	13.31	16.31	21.02	0.5	1.08	7.71	23.1	Yes
5789	1839	13.28	16.28	21.02	0.5	1.07	7.74	23.1	Yes
5690	1839	13.28	16.28	21.01	0.51	1.09	7.73	23.1	Yes
5589	1839	13.25	16.25	21.01	0.51	1.08	7.76	23.1	Yes
5489	1839	13.25	16.25	21.01	0.5	1.06	7.76	23.1	Yes
5389	1839	13.25	16.25	21	0.49	1.04	7.75	23.1	Yes
5189	1839	13.22	16.22	21	0.38	1.06	7.78	23.1	Yes
4989	1839	13.19	16.19	20.99	0.31	1.04	7.8	23.1	Yes
4789	1839	13.16	16.16	20.98	0.2	0.92	7.82	23.1	Yes
4589	1839	13.12	16.12	20.97	0.2	0.92	7.85	23.1	Yes
4391	1839	13.09	16.09	20.96	0.21	0.81	7.87	23.1	Yes
4191	1839	13.06	16.06	20.96	0.21	0.75	7.9	23.1	Yes
3990	1839	13.03	16.03	20.95	0.22	0.78	7.92	23.1	Yes
3789	1839	13.03	16.03	20.94	0.21	0.73	7.91	23.1	Yes
3489	1839	12.97	15.97	20.94	0.2	0.65	7.97	23.1	Yes
3189	1839	12.94	15.94	20.93	0.18	0.54	7.99	23.1	Yes
2589	1839	12.84	15.84	20.93	0.17	0.51	8.09	23.1	Yes
1991	1839	12.78	15.78	20.92	0.2	0.57	8.14	23.1	Yes
1389	1839	12.69	15.69	20.91	0.28	0.65	8.22	23.1	Yes
703	1839	12.59	15.59	20.88	0.39	0.88	8.29	23.1	Yes
89	1839	12.53	15.53	20.76	0.89	2.4	8.23	23.1	Yes

Operation Criterion: Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec
Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec
Bench:
Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 60 ft)

HEC-RAS Model Output

Standard Table 1

Minimum Depth (ft)	Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Wi	Froude # C	Vel Left	Vel Chnl	Vel Right
5.07					(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
	C	2	23389	JAN1990 240	662.33	10	23.1		23.1	0.000003	0.29	2251.02	193.7	0.02		0.29	
	C	2	23089	JAN1990 240	662.33	20	23.06		23.1	0.000385	1.53	433.9	160.8	0.15		1.53	
	C	2	2300		Culvert												
	C	2	22389	JAN1990 240	662.33	19.75	22.98		23.02	0.000798	1.53	433.21	160.4	0.15		1.53	
	C	2	21389	JAN1990 240	662.33	17.91	22.98		23	0.000353	1.24	532.73	120.4	0.1		1.24	
	C	2	20389	JAN1990 240	662.33	17.84	22.94		22.97	0.000345	1.23	536.48	120.5	0.1		1.23	
	C	2	19389	JAN1990 240	662.33	17.81	22.91		22.93	0.000345	1.23	537.08	120.8	0.1		1.23	
	C	2	18389	JAN1990 240	662.33	17.75	22.88		22.9	0.000339	1.23	540.2	120.9	0.1		1.22	
	C	2	17389	JAN1990 240	662.34	17.69	22.84		22.87	0.000333	1.22	543.39	121	0.1		1.22	
	C	2	16389	JAN1990 240	662.33	17.62	22.81		22.83	0.000325	1.21	547.66	121.2	0.1		1.21	
	C	2	15389	JAN1990 240	662.33	17.56	22.78		22.8	0.000319	1.2	551.07	121.4	0.1		1.2	
	C	2	14389	JAN1990 240	662.33	17.5	22.75		22.77	0.000314	1.2	554	121.4	0.1		1.19	
	C	2	13389	JAN1990 240	662.33	17.44	22.72		22.74	0.000307	1.19	557.87	121.7	0.1		1.19	
	C	2	12389	JAN1990 240	662.33	17.38	22.69		22.71	0.000301	1.18	561.44	121.8	0.1		1.18	
	C	2	11389	JAN1990 241	662.34	17.31	22.66		22.68	0.000294	1.17	566.1	122.1	0.1		1.17	

C	2	10389JAN1990	241	662.34	17.25	22.63	22.65	0.000287	1.16	570.18	122.2	0.09		1.16	
C	2	9389JAN1990	241	662.33	17.22	22.6	22.62	0.000287	1.16	570.86	122.3	0.09		1.16	
C	2	8389JAN1990	241	662.33	17.16	22.57	22.59	0.00028	1.15	575.19	122.6	0.09		1.15	
C	2	7109JAN1990	241	662.33	17.06	22.54	22.56	0.000269	1.14	582.7	122.9	0.09		1.14	
C	1	4389JAN1990	241	667.34	16.91	22.54	22.56	0.000253	1.11	598.56	123.9	0.09		1.11	
C	1	3389JAN1990	241	667.34	16.84	22.51	22.53	0.000243	1.1	606.04	124	0.09		1.1	
C	1	2679JAN1990	241	667.33	16.81	22.49	22.51	0.000242	1.1	607.12	124.1	0.09		1.1	
AB	1	90009JAN1990	241	1839.12	13.66	22.49	22.62	0.000499	3.33	731.01	123	0.21	1.58	3.33	1.05
AB	1	89289JAN1990	241	1839.13	13.66	22.45	22.59	0.000508	3.35	726.26	122.8	0.21	1.59	3.35	1.05
AB	1	88109JAN1990	242	1839.12	13.66	22.33	22.47	0.000538	3.41	711.71	122.1	0.21	1.62	3.41	1.07
AB	1	56899JAN1990	242	1839.12	13.66	22.2	22.35	0.000571	3.48	696.04	121.1	0.22	1.64	3.47	1.12
AB	1	85899JAN1990	242	1839.13	13.62	22.08	22.24	0.000602	3.57	685.22	120.6	0.22	1.68	3.57	1.15
AB	1	84899JAN1990	242	1839.12	13.62	21.95	22.11	0.000636	3.6	670.46	119.9	0.23	1.7	3.6	1.09
AB	1	83899JAN1990	242	1839.12	13.62	21.81	21.98	0.00068	3.69	654.65	119.2	0.24	1.73	3.69	1.16
AB	1	82899JAN1990	242	1839.13	13.59	21.67	21.84	0.000723	3.77	640.46	118.4	0.24	1.76	3.76	1.19
AB	1	81899JAN1990	242	1839.12	13.59	21.51	21.7	0.00077	3.83	626.72	117.6	0.25	1.79	3.84	1.2
AB	1	80899JAN1990	242	1839.12	13.56	21.35	21.54	0.000814	3.92	617.13	116.6	0.26	1.83	3.96	1.3
AB	1	79899JAN1990	242	1839.12	13.56	21.19	21.37	0.000836	3.94	617.06	115.4	0.26	1.79	3.88	1.2
AB	1	78909JAN1990	242	1839.13	13.56	21.11	21.22	0.000551	3.16	882.56	226.9	0.21	1.4	3.16	1.01
AB	1	77909JAN1990	243	1839.12	13.56	21.12	21.16	0.000278	2.25	1290.63	280.6	0.15	1	2.25	1.04
AB	1	76899JAN1990	243	1839.12	13.56	21.11	21.15	0.000223	2.01	1490.03	327.9	0.13	0.91	2.01	0.94
AB	1	75899JAN1990	243	1839.13	13.53	21.1	21.13	0.000189	1.86	1654.48	366.6	0.12	0.85	1.86	0.87
AB	1	74899JAN1990	243	1839.12	13.53	21.09	21.12	0.000167	1.74	1785.43	397.8	0.12	0.8	1.74	0.81
AB	1	73899JAN1990	243	1839.12	13.5	21.09	21.11	0.000149	1.64	1905.96	426.2	0.11	0.77	1.64	0.77
AB	1	72899JAN1990	243	1839.12	13.5	21.08	21.1	0.000136	1.57	2023.22	454.7	0.1	0.73	1.57	0.73
AB	1	71879JAN1990	243	1839.12	13.47	21.07	21.09	0.000124	1.51	2132.44	481.3	0.1	0.7	1.51	0.7
AB	1	70899JAN1990	243	1839.12	13.47	21.07	21.08	0.000115	1.44	2241.33	507.5	0.1	0.67	1.44	0.67
AB	1	69899JAN1990	243	1839.12	13.44	21.06	21.08	0.000104	1.38	2370.96	537	0.09	0.65	1.38	0.64
AB	1	68909JAN1990	243	1839.12	13.44	21.06	21.07	0.000091	1.3	2557.44	581.4	0.09	0.61	1.3	0.6
AB	1	67899JAN1990	244	1839.12	13.44	21.06	21.07	0.000082	1.23	2730.47	626.1	0.08	0.57	1.23	0.57
AB	1	66899JAN1990	244	1839.12	13.41	21.05	21.06	0.000086	1.26	2734.84	660.9	0.08	0.55	1.26	0.59
AB	1	65899JAN1990	244	1839.11	13.41	21.05	21.06	0.000084	1.25	2776.04	669.1	0.08	0.55	1.25	0.58
AB	1	64909JAN1990	244	1839.12	13.38	21.04	21.05	0.00008	1.22	2827.62	678.1	0.08	0.54	1.21	0.57
AB	1	63909JAN1990	244	1839.12	13.38	21.04	21.05	0.000077	1.19	2898.18	691.9	0.08	0.53	1.19	0.55
AB	1	62899JAN1990	244	1839.12	13.34	21.04	21.04	0.000074	1.17	2933.81	692.8	0.08	0.53	1.17	0.55
AB	1	61899JAN1990	244	1839.11	13.34	21.03	21.04	0.000072	1.16	2973.23	699.7	0.08	0.52	1.16	0.54
AB	1	60899JAN1990	244	1839.12	13.34	21.03	21.04	0.000068	1.13	3054.52	715.9	0.07	0.51	1.13	0.53
AB	1	59899JAN1990	244	1839.13	13.31	21.02	21.03	0.000063	1.09	3170.36	735.1	0.07	0.49	1.09	0.51
AB	1	58899JAN1990	244	1839.13	13.31	21.02	21.03	0.000063	1.08	3164.35	727.8	0.07	0.5	1.08	0.51
AB	1	57899JAN1990	245	1839.13	13.28	21.02	21.02	0.000062	1.07	3154.3	720.8	0.07	0.5	1.07	0.5
AB	1	56909JAN1990	245	1839.13	13.28	21.01	21.02	0.000063	1.09	3137.49	716.9	0.07	0.51	1.09	0.5
AB	1	55899JAN1990	245	1839.13	13.25	21.01	21.02	0.000062	1.08	3172.1	727.6	0.07	0.51	1.08	0.49
AB	1	54899JAN1990	245	1839.12	13.25	21.01	21.01	0.00006	1.06	3229.57	743.9	0.07	0.5	1.06	0.49
AB	1	53899JAN1990	245	1839.12	13.25	21	21.01	0.000058	1.04	3306.9	766.1	0.07	0.49	1.04	0.47
AB	1	51899JAN1990	245	1839.12	13.22	21	21	0.000059	1.06	3559.41	967.6	0.07	0.38	1.06	0.48
AB	1	49899JAN1990	245	1839.11	13.19	20.99	20.99	0.000057	1.04	3851.01	1228	0.07	0.31	1.04	0.47
AB	1	47899JAN1990	245	1839.14	13.16	20.98	20.98	0.000046	0.92	5231.87	2688	0.06	0.2	0.92	0.42
AB	1	45899JAN1990	245	1839.17	13.12	20.97	20.97	0.000046	0.92	5322.82	2789	0.06	0.2	0.92	0.43
AB	1	43919JAN1990	245	1839.11	13.09	20.96	20.96	0.000035	0.81	6146.26	2764	0.05	0.21	0.81	0.38
AB	1	41919JAN1990	246	1839.14	13.06	20.96	20.96	0.000029	0.75	6645.51	2778	0.05	0.21	0.75	0.35
AB	1	39909JAN1990	246	1839.13	13.03	20.95	20.95	0.000031	0.78	6480.75	2784	0.05	0.22	0.78	0.37
AB	1	37899JAN1990	246	1839.15	13.03	20.94	20.95	0.000028	0.73	6787.63	2804	0.05	0.21	0.73	0.34
AB	1	34899JAN1990	246	1839.15	12.97	20.94	20.94	0.000022	0.65	7864.49	3154	0.04	0.2	0.65	0.22
AB	1	31899JAN1990	246	1839.13	12.94	20.93	20.93	0.000015	0.54	9763.2	3957	0.03	0.18	0.54	0.15
AB	1	25899JAN1990	246	1839.12	12.84	20.93	20.93	0.000013	0.51	10514	4255	0.03	0.17	0.51	0.15
AB	1	19919JAN1990	246	1839.14	12.78	20.92	20.92	0.000017	0.57	9548.49	4225	0.04	0.2	0.57	0.16
AB	1	13899JAN1990	246	1839.2	12.69	20.91	20.91	0.000021	0.65	7960.76	3605	0.04	0.28	0.65	0.16

AB	1	7039	JAN1990 246	1839.14	12.59	20.88		20.89	0.000037	0.88	4681.45	1328	0.06	0.39	0.88	0.32
AB	1	899	JAN1990 246	1839.16	12.53	20.76	16.39	20.82	0.000279	2.4	1359.93	380.7	0.15	0.89	2.4	0.78

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	op Width (cfs)
C	2	23389	JAN1990 240	23.1	23.1	0	0.02			662.33		193.7
C	2	23089	JAN1990 240	23.1	23.06	0.04				662.33		160.8
C	2	2300		Culvert								
C	2	22389	JAN1990 240	23.02	22.98	0.04	0.02			662.33		160.4
C	2	21389	JAN1990 240	23	22.98	0.02	0.03			662.33		120.4
AB	2	117509	JAN1990 240	23.1	23.1	0	0.01			1171.79		193.7
AB	2	115759	JAN1990 240	23.11	23.06	0.04			296.39	875.4		134
AB	2	11550		Culvert								
AB	2	115209	JAN1990 240	22.99	22.94	0.06	0.01		257.06	914.73		133.2
AB	2	113909	JAN1990 240	22.99	22.94	0.05	0.02		278.02	863.76	30.01	123.7

Culvert Only

Channel	Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	EG. IC (ft)	E.G. OC (ft)	Min El Wei (ft)	Q Culv Gro (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Ve (ft/s)	Culv Vel DS (ft/s)
C	2	2300 Culverts	JAN1990 240	23.1	23.06	21.74	23.1	31.81	662.33		0.08	2.22	2.05
AB	2	11750 Culverts	JAN1990 240	23.1	23.06	19.98	23.08	31.81	442.59		0.13	2.48	2.38
AB	2	11575 Culverts	JAN1990 240	23.1	23.06	18.15	23.11	31.81	729.2		0.13	2.72	2.65

D Channel Minimum Depth Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Depth Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Depth in Channel (ft)	Water Surface Elevation in Sacramento River (ft)	Channel Depth Criterion Met
Headworks									
1850	1369.23	10	N/A	26.6	N/A	0.46	16.6	26.6	Yes
1820	1369.23	23	N/A	26.5	N/A	2.56	3.5	26.6	Yes
1800	Structure: 7 C Culverts and 9 D Culverts Open								
1750	1369.23	22.75	N/A	25.98	N/A	2.91	3.23	26.6	Yes
D-1 Channel									
1650	1369.23	20.62	N/A	25.95	N/A	2.43	5.33	26.6	Yes
1550	1369.23	20.41	N/A	25.83	N/A	2.38	5.42	26.6	Yes
1450	1369.23	20.16	N/A	25.73	N/A	2.25	5.57	26.6	Yes
1350	1369.23	19.91	N/A	25.63	N/A	2.18	5.72	26.6	Yes
1250	1369.23	19.69	N/A	25.54	N/A	2.12	5.85	26.6	Yes
1150	1369.23	19.44	N/A	25.46	N/A	2.05	6.02	26.6	Yes
1050	1369.23	19.19	N/A	25.39	N/A	1.99	6.2	26.6	Yes
950	1369.23	18.97	N/A	25.32	N/A	1.93	6.35	26.6	Yes
850	1369.23	18.72	N/A	25.26	N/A	1.86	6.54	26.6	Yes
750	1369.23	18.49	N/A	25.21	N/A	1.81	6.72	26.6	Yes
650	1369.23	18.25	N/A	25.16	N/A	1.74	6.91	26.6	Yes
550	1369.23	18	N/A	25.12	N/A	1.68	7.12	26.6	Yes
450	1369.23	17.77	N/A	25.08	N/A	1.63	7.31	26.6	Yes
350	1369.24	17.53	N/A	25.04	N/A	1.58	7.51	26.6	Yes
281	1369.24	17.34	N/A	25.02	N/A	1.53	7.68	26.6	Yes
C-1 Channel									
438	3453.6	16.91	N/A	25.02	N/A	3.74	8.11	26.6	Yes
338	3453.6	16.84	N/A	24.82	N/A	3.8	7.98	26.6	Yes
267	3453.6	16.81	N/A	24.61	N/A	3.91	7.8	26.6	Yes
AB-1 Channel									
9000	3458.6	13.66	16.66	24.61	2.29	4.69	10.95	26.6	Yes
8928	3458.6	13.66	16.66	24.55	2.3	4.72	10.89	26.6	Yes
8810	3458.6	13.66	16.66	24.37	2.35	4.83	10.71	26.6	Yes
5689	3458.6	13.66	16.66	24.17	2.4	4.94	10.51	26.6	Yes
8589	3458.6	13.62	16.62	23.98	2.47	5.11	10.36	26.6	Yes
8489	3458.6	13.62	16.62	23.78	2.52	5.19	10.16	26.6	Yes
8389	3458.6	13.62	16.62	23.55	2.58	5.36	9.93	26.6	Yes
8289	3458.6	13.59	16.59	23.31	2.66	5.52	9.72	26.6	Yes
8189	3458.6	13.59	16.49	23.03	2.74	5.71	9.44	26.6	Yes
8089	3458.6	13.56	16.31	22.72	2.85	5.98	9.16	26.6	Yes
7990	3458.6	13.56	15.81	22.4	2.84	5.97	8.84	26.6	Yes
7890	3458.6	13.56	16.56	22.32	2.09	4.61	8.76	26.6	Yes
7790	3458.6	13.56	16.56	22.34	1.52	3.33	8.78	26.6	Yes
7689	3458.6	13.56	16.56	22.33	1.38	2.95	8.77	26.6	Yes
7589	3458.6	13.53	16.53	22.32	1.28	2.72	8.79	26.6	Yes
7489	3458.6	13.53	16.53	22.31	1.22	2.54	8.78	26.6	Yes
7389	3458.6	13.5	16.5	22.3	1.16	2.39	8.8	26.6	Yes
7289	3458.6	13.5	16.5	22.29	1.11	2.28	8.79	26.6	Yes

Minimum Depth (ft)

5.33

7187	3458.6	13.47	16.47	22.28	1.06	2.18	8.81	26.6	Yes
7089	3458.59	13.47	16.47	22.27	1.02	2.09	8.8	26.6	Yes
6989	3458.59	13.44	16.44	22.26	0.98	2	8.82	26.6	Yes
6890	3458.6	13.44	16.44	22.26	0.92	1.87	8.82	26.6	Yes
6789	3458.6	13.44	16.44	22.25	0.86	1.76	8.81	26.6	Yes
6689	3458.59	13.41	16.41	22.24	0.83	1.77	8.83	26.6	Yes
6589	3458.59	13.41	16.41	22.24	0.83	1.76	8.83	26.6	Yes
6490	3458.59	13.38	16.38	22.23	0.82	1.72	8.85	26.6	Yes
6390	3458.59	13.38	16.38	22.22	0.81	1.69	8.84	26.6	Yes
6289	3458.6	13.34	16.34	22.22	0.8	1.66	8.88	26.6	Yes
6189	3458.6	13.34	16.34	22.21	0.8	1.65	8.87	26.6	Yes
6089	3458.6	13.34	16.34	22.21	0.78	1.61	8.87	26.6	Yes
5989	3458.6	13.31	16.31	22.2	0.75	1.55	8.89	26.6	Yes
5889	3458.6	13.31	16.31	22.19	0.76	1.55	8.88	26.6	Yes
5789	3458.6	13.28	16.28	22.19	0.76	1.53	8.91	26.6	Yes
5690	3458.6	13.28	16.28	22.18	0.77	1.57	8.9	26.6	Yes
5589	3458.61	13.25	16.25	22.18	0.77	1.55	8.93	26.6	Yes
5489	3458.6	13.25	16.25	22.17	0.76	1.52	8.92	26.6	Yes
5389	3458.6	13.25	16.25	22.17	0.74	1.5	8.92	26.6	Yes
5189	3458.59	13.22	16.22	22.15	0.55	1.46	8.93	26.6	Yes
4989	3458.59	13.19	16.19	22.15	0.3	1.05	8.96	26.6	Yes
4789	3458.62	13.16	16.16	22.14	0.3	1.01	8.98	26.6	Yes
4589	3458.59	13.12	16.12	22.13	0.31	1.01	9.01	26.6	Yes
4391	3458.6	13.09	16.09	22.12	0.3	0.91	9.03	26.6	Yes
4191	3458.6	13.06	16.06	22.12	0.3	0.86	9.06	26.6	Yes
3990	3458.59	13.03	16.03	22.11	0.3	0.87	9.08	26.6	Yes
3789	3458.61	13.03	16.03	22.1	0.29	0.81	9.07	26.6	Yes
3489	3458.6	12.97	15.97	22.1	0.28	0.74	9.13	26.6	Yes
3189	3458.56	12.94	15.94	22.09	0.23	0.58	9.15	26.6	Yes
2589	3458.65	12.84	15.84	22.09	0.23	0.59	9.25	26.6	Yes
1991	3458.58	12.78	15.78	22.08	0.25	0.65	9.3	26.6	Yes
1389	3458.61	12.69	15.69	22.06	0.35	0.75	9.37	26.6	Yes
703	3458.59	12.59	15.59	22.03	0.61	1.28	9.44	26.6	Yes
89	3458.59	12.53	15.53	21.82	1.47	3.63	9.29	26.6	Yes

Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench:

Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 60 ft)

HEC-RAS Model Output
Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude #	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
D		1	1850 9JAN1990 240	1369.23	10	26.6		26.6	0.000005	0.46	2954.38	211.73	0.02	0.05	0.46	0.05
D		1	1820 9JAN1990 240	1369.23	23	26.5		26.6	0.000911	2.56	535.4	168.97	0.24		2.56	
D		1	1800	Culvert												
D		1	1750 9JAN1990 240	1369.23	22.75	25.98		26.11	0.0029	2.91	470.68	165.49	0.29		2.91	
D		1	1650 9JAN1990 240	1369.23	20.62	25.95		26.04	0.001273	2.43	563.42	121.85	0.2		2.43	
D		1	1550 9JAN1990 240	1369.23	20.41	25.83		25.92	0.001194	2.38	575.75	122.61	0.19		2.38	
D		1	1450 9JAN1990 240	1369.23	20.16	25.73		25.81	0.001059	2.25	607.79	128.46	0.18		2.25	

D	1	1350 9JAN1990 240	1369.23	19.91	25.63	25.7	0.000966	2.18	626.87	129.51	0.18		2.18	
D	1	1250 9JAN1990 240	1369.23	19.69	25.54	25.61	0.000887	2.12	645.02	130.48	0.17		2.12	
D	1	1150 9JAN1990 240	1369.23	19.44	25.46	25.53	0.000805	2.05	666.52	131.6	0.16		2.05	
D	1	1050 9JAN1990 240	1369.23	19.19	25.39	25.45	0.00073	1.99	688.16	132.52	0.15		1.99	
D	1	950 9JAN1990 240	1369.23	18.97	25.32	25.38	0.000665	1.93	711.29	134.14	0.15		1.93	
D	1	850 9JAN1990 240	1369.23	18.72	25.26	25.32	0.000599	1.86	735.93	135.03	0.14		1.86	
D	1	750 9JAN1990 240	1369.23	18.49	25.21	25.26	0.000549	1.81	756.75	135.57	0.14		1.81	
D	1	650 9JAN1990 240	1369.23	18.25	25.16	25.21	0.000494	1.74	785.26	137.35	0.13		1.74	
D	1	550 9JAN1990 240	1369.23	18	25.12	25.16	0.000446	1.68	812.92	138.77	0.12		1.68	
D	1	450 9JAN1990 240	1369.23	17.77	25.08	25.12	0.000407	1.63	839.9	140.34	0.12		1.63	
D	1	350 9JAN1990 240	1369.24	17.53	25.04	25.08	0.000368	1.58	866.98	141.03	0.11		1.58	
D	1	281 9JAN1990 240	1369.24	17.34	25.02	25.06	0.00034	1.53	893.69	143.11	0.11		1.53	
C	1	438 9JAN1990 240	3453.6	16.91	25.02	25.24	0.00186	3.74	924.58	138.77	0.26		3.74	
C	1	338 9JAN1990 240	3453.6	16.84	24.82	25.04	0.001955	3.8	908.13	137.81	0.26		3.8	
C	1	267 9JAN1990 240	3453.6	16.81	24.61	24.84	0.002121	3.91	883.43	136.77	0.27		3.91	
AB	1	9000 9JAN1990 240	3458.6	13.66	24.61	24.87	0.000729	4.69	1004.96	135.64	0.26	2.29	4.69	1.57
AB	1	8928 9JAN1990 240	3458.6	13.66	24.55	24.81	0.000745	4.72	997.14	135.29	0.26	2.3	4.72	1.58
AB	1	8810 9JAN1990 240	3458.6	13.66	24.37	24.65	0.000797	4.83	973.04	134.22	0.27	2.35	4.83	1.61
AB	1	5689 9JAN1990 240	3458.6	13.66	24.17	24.47	0.000858	4.94	946.49	132.97	0.28	2.4	4.94	1.69
AB	1	8589 9JAN1990 240	3458.6	13.62	23.98	24.29	0.000925	5.11	925.53	132.03	0.29	2.47	5.11	1.73
AB	1	8489 9JAN1990 240	3458.6	13.62	23.78	24.1	0.000992	5.19	899.54	130.81	0.3	2.52	5.19	1.68
AB	1	8389 9JAN1990 240	3458.6	13.62	23.55	23.9	0.001085	5.36	871.16	129.59	0.31	2.58	5.36	1.79
AB	1	8289 9JAN1990 240	3458.6	13.59	23.31	23.68	0.00119	5.52	842.78	128.18	0.32	2.66	5.52	1.85
AB	1	8189 9JAN1990 240	3458.6	13.59	23.03	23.43	0.001332	5.71	808.04	126.65	0.34	2.74	5.71	1.88
AB	1	8089 9JAN1990 240	3458.6	13.56	22.72	23.15	0.001522	5.98	771.4	124.8	0.36	2.85	5.98	2.04
AB	1	7990 9JAN1990 240	3458.6	13.56	22.4	22.84	0.001582	5.97	766.85	127.84	0.37	2.84	5.97	1.93
AB	1	7890 9JAN1990 240	3458.6	13.56	22.32	22.55	0.000946	4.61	1165.27	239.97	0.28	2.09	4.61	1.7
AB	1	7790 9JAN1990 240	3458.6	13.56	22.34	22.44	0.000491	3.33	1641.52	293.24	0.2	1.52	3.33	1.62
AB	1	7689 9JAN1990 240	3458.6	13.56	22.33	22.41	0.000388	2.95	1898.71	340.29	0.18	1.38	2.95	1.45
AB	1	7589 9JAN1990 240	3458.6	13.53	22.32	22.38	0.000326	2.72	2109.18	378.81	0.17	1.28	2.72	1.33
AB	1	7489 9JAN1990 240	3458.6	13.53	22.31	22.36	0.000286	2.54	2276.67	410.02	0.16	1.22	2.54	1.25
AB	1	7389 9JAN1990 240	3458.6	13.5	22.3	22.34	0.000255	2.39	2429.93	438.31	0.15	1.16	2.39	1.18
AB	1	7289 9JAN1990 240	3458.6	13.5	22.29	22.33	0.000231	2.28	2579.95	466.81	0.14	1.11	2.28	1.12
AB	1	7187 9JAN1990 240	3458.6	13.47	22.28	22.31	0.000211	2.18	2719.52	493.43	0.13	1.06	2.18	1.07
AB	1	7089 9JAN1990 240	3458.59	13.47	22.27	22.3	0.000194	2.09	2857.48	519.55	0.13	1.02	2.09	1.03
AB	1	6989 9JAN1990 240	3458.59	13.44	22.26	22.29	0.000175	2	3021.69	548.96	0.12	0.98	2	0.98
AB	1	6890 9JAN1990 240	3458.6	13.44	22.26	22.28	0.000153	1.87	3260.15	593.37	0.11	0.92	1.87	0.92
AB	1	6789 9JAN1990 240	3458.6	13.44	22.25	22.27	0.000137	1.76	3485.6	638.39	0.11	0.86	1.76	0.87
AB	1	6689 9JAN1990 240	3458.59	13.41	22.24	22.26	0.000139	1.77	3529.46	673.03	0.11	0.83	1.77	0.87
AB	1	6589 9JAN1990 240	3458.59	13.41	22.24	22.26	0.000136	1.76	3578.64	681.06	0.11	0.83	1.76	0.86
AB	1	6490 9JAN1990 240	3458.59	13.38	22.23	22.25	0.000131	1.72	3639.2	690.06	0.11	0.82	1.72	0.84
AB	1	6390 9JAN1990 240	3458.59	13.38	22.22	22.24	0.000125	1.69	3724.62	703.78	0.1	0.81	1.69	0.82
AB	1	6289 9JAN1990 240	3458.6	13.34	22.22	22.24	0.000122	1.66	3759.6	704.73	0.1	0.8	1.66	0.81
AB	1	6189 9JAN1990 240	3458.6	13.34	22.21	22.23	0.000119	1.65	3805.66	711.76	0.1	0.8	1.65	0.8
AB	1	6089 9JAN1990 240	3458.6	13.34	22.21	22.22	0.000113	1.61	3904.65	728.01	0.1	0.78	1.61	0.79
AB	1	5989 9JAN1990 240	3458.6	13.31	22.2	22.22	0.000105	1.55	4041.5	747.18	0.09	0.75	1.55	0.76
AB	1	5889 9JAN1990 240	3458.6	13.31	22.19	22.21	0.000105	1.55	4024.61	739.58	0.09	0.76	1.55	0.76
AB	1	5789 9JAN1990 240	3458.6	13.28	22.19	22.2	0.000105	1.53	4004.63	732.81	0.09	0.76	1.53	0.76
AB	1	5690 9JAN1990 240	3458.6	13.28	22.18	22.2	0.000107	1.57	3981.43	728.79	0.1	0.77	1.57	0.77
AB	1	5589 9JAN1990 240	3458.61	13.25	22.18	22.19	0.000105	1.55	4026.61	739.31	0.09	0.77	1.55	0.76
AB	1	5489 9JAN1990 240	3458.6	13.25	22.17	22.18	0.000102	1.52	4101.7	755.74	0.09	0.76	1.52	0.74
AB	1	5389 9JAN1990 240	3458.6	13.25	22.17	22.18	0.000098	1.5	4203.36	777.76	0.09	0.74	1.5	0.72
AB	1	5189 9JAN1990 240	3458.59	13.22	22.15	22.17	0.000092	1.46	4733.49	1032.91	0.09	0.55	1.46	0.7

AB	1	4989	9JAN1990 240	3458.59	13.19	22.15		22.15	0.000048	1.05	8421.57	2853.6	0.06	0.3	1.05	0.51
AB	1	4789	9JAN1990 240	3458.62	13.16	22.14		22.14	0.000046	1.01	8546.97	2826.91	0.06	0.3	1.01	0.5
AB	1	4589	9JAN1990 240	3458.59	13.12	22.13		22.13	0.000045	1.01	8575.02	2813.07	0.06	0.31	1.01	0.5
AB	1	4391	9JAN1990 240	3458.6	13.09	22.12		22.13	0.000036	0.91	9370.07	2789.5	0.06	0.3	0.91	0.45
AB	1	4191	9JAN1990 240	3458.6	13.06	22.12		22.12	0.000031	0.86	9882.02	2797.57	0.05	0.3	0.86	0.43
AB	1	3990	9JAN1990 240	3458.59	13.03	22.11		22.11	0.000032	0.87	9823.83	2812.69	0.05	0.3	0.87	0.43
AB	1	3789	9JAN1990 240	3458.61	13.03	22.1		22.11	0.000028	0.81	10312.86	2832.75	0.05	0.29	0.81	0.4
AB	1	3489	9JAN1990 240	3458.6	12.97	22.1		22.1	0.000023	0.74	12302.94	3851.81	0.04	0.28	0.74	0.2
AB	1	3189	9JAN1990 240	3458.56	12.94	22.09		22.09	0.000014	0.58	14916.35	4123.54	0.04	0.23	0.58	0.2
AB	1	2589	9JAN1990 240	3458.65	12.84	22.09		22.09	0.000014	0.59	15962.41	5005.89	0.04	0.23	0.59	0.18
AB	1	1991	9JAN1990 240	3458.58	12.78	22.08		22.08	0.000018	0.65	15036.97	5121.19	0.04	0.25	0.65	0.19
AB	1	1389	9JAN1990 240	3458.61	12.69	22.06		22.07	0.000023	0.75	12978.61	4758	0.04	0.35	0.75	0.2
AB	1	703	9JAN1990 240	3458.59	12.59	22.03		22.04	0.000066	1.28	8695.03	4502.87	0.08	0.61	1.28	0.27
AB	1	89	9JAN1990 240	3458.59	12.53	21.82	17.6	21.94	0.000538	3.63	3271.51	4368.04	0.22	1.47	3.63	0.38

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (cfs)
D		1850	9JAN1990 240	26.6	26.6	0	0.05		0.25	1368.73	0.25	211.73
D		1820	9JAN1990 240	26.6	26.5	0.1				1369.23		168.97
D		1800		Culvert								
D		1750	9JAN1990 240	26.11	25.98	0.13	0.06			1369.23		165.49
D		1650	9JAN1990 240	26.04	25.95	0.09	0.12			1369.23		121.85
C		2338	9JAN1990 240	26.61	26.6	0.01	0.02		0.32	2083.72	0.32	210
C		2308	9JAN1990 240	26.61	26.53	0.08				2084.37		181.66
C		2300		Culvert								
C		2238	9JAN1990 240	26.12	26.02	0.1	0.02			2084.37		178.6
C		2138	9JAN1990 240	26.09	26.02	0.08	0.07			2084.36		138.62

Culvert Only

Channel	Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	EG. IC (ft)	E.G. OC (ft)	Min El Weir Flow (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
C	2	1800 Culverts D	9JAN1990 240	26.58	26.5	26.04	26.58	31.81	1369.23		0.53	5.13	4.72
D	1	2300 Culverts C	9JAN1990 240	26.59	26.53	24.76	26.59	31.81	2084.37		0.51	4.94	4.75

AB-1 Channel Criterion Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Channel Velocity Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Water Depth at Bench (ft)	Reach Length (ft)	Water Surface Elevation in Sac. River (ft)	Channel Passage Logic	Bench Passage Logic	Length of Reach w/ Vel. >4 ft/s Logic	Length of Reach w/ Vel. >4 ft/s	Design Criterion Logic	Design Criterion Met
Headworks															
2338	688.39	10	N/A	23.2	N/A	0.3	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
2308	688.39	20	N/A	23.16	N/A	1.54	N/A	68.5	23.2	YES	N/A	0	0	TRUE	Yes
2300	Structure: 3 A Culverts, 3 B Culverts, and 10 C Culverts Open														
2238	688.39	19.75	N/A	23.08	N/A	1.54	N/A	31	23.2	YES	N/A	0	0	TRUE	Yes
C-2 Channel															
2138	688.39	17.91	N/A	23.08	N/A	1.26	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
2038	688.39	17.84	N/A	23.04	N/A	1.26	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1938	688.39	17.81	N/A	23.01	N/A	1.25	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1838	688.39	17.75	N/A	22.97	N/A	1.25	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1738	688.39	17.69	N/A	22.94	N/A	1.24	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1638	688.39	17.62	N/A	22.91	N/A	1.23	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1538	688.39	17.56	N/A	22.87	N/A	1.22	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1438	688.39	17.5	N/A	22.84	N/A	1.22	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1338	688.39	17.44	N/A	22.81	N/A	1.21	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1238	688.39	17.38	N/A	22.78	N/A	1.2	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1138	688.39	17.31	N/A	22.75	N/A	1.19	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
1038	688.39	17.25	N/A	22.72	N/A	1.18	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
938	688.39	17.22	N/A	22.69	N/A	1.18	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
838	688.39	17.16	N/A	22.66	N/A	1.17	N/A	128.13	23.2	YES	N/A	0	0	TRUE	Yes
710	688.39	17.06	N/A	22.63	N/A	1.16	N/A	271.87	23.2	YES	N/A	0	0	TRUE	Yes
C-1 Channel															
438	693.39	16.91	N/A	22.63	N/A	1.14	N/A	100	23.2	YES	N/A	0	0	TRUE	Yes
338	693.39	16.84	N/A	22.6	N/A	1.12	N/A	98.31	23.2	YES	N/A	0	0	TRUE	Yes
267	693.39	16.81	N/A	22.58	N/A	1.12	N/A	190.5	23.2	YES	N/A	0	0	TRUE	Yes
AB-1 Channel															
9000	1896.37	13.66	16.66	22.58	1.62	3.39	5.92	74.39	23.2	YES	N/A	0	0	TRUE	Yes
8928	1896.37	13.66	16.66	22.54	1.62	3.41	5.88	218.39	23.2	YES	N/A	0	0	TRUE	Yes
8810	1896.37	13.66	16.66	22.42	1.65	3.47	5.76	220.57	23.2	YES	N/A	0	0	TRUE	Yes
5689	1896.37	13.66	16.66	22.29	1.67	3.54	5.63	200	23.2	YES	N/A	0	0	TRUE	Yes
8589	1896.37	13.62	16.62	22.16	1.71	3.63	5.54	200	23.2	YES	N/A	0	0	TRUE	Yes
8489	1896.37	13.62	16.62	22.03	1.74	3.67	5.41	200	23.2	YES	N/A	0	0	TRUE	Yes
8389	1896.37	13.62	16.62	21.89	1.77	3.76	5.27	200	23.2	YES	N/A	0	0	TRUE	Yes
8289	1896.37	13.59	16.59	21.74	1.8	3.84	5.15	200	23.2	YES	N/A	0	0	TRUE	Yes
8189	1896.37	13.59	16.49	21.58	1.84	3.9	5.09	200.09	23.2	YES	N/A	0	0	TRUE	Yes
8089	1896.37	13.56	16.31	21.42	1.9	4	5.11	200.15	23.2	NO	YES	0	0	TRUE	Yes
7989	1896.37	13.56	15.81	21.25	2	4.02	5.44	199.1	23.2	NO	YES	0	0	TRUE	Yes
7890	1896.37	13.56	16.56	21.17	1.43	3.22	4.61	100.01	23.2	YES	N/A	0	0	TRUE	Yes
7790	1896.37	13.56	16.56	21.17	1.02	2.29	4.61	59.7	23.2	YES	N/A	0	0	TRUE	Yes
7690	1896.37	13.56	16.56	21.17	0.92	2.05	4.61	61.05	23.2	YES	N/A	0	0	TRUE	Yes
7589	1896.37	13.53	16.53	21.16	0.86	1.89	4.63	60.49	23.2	YES	N/A	0	0	TRUE	Yes
7489	1896.37	13.53	16.53	21.15	0.82	1.77	4.62	59.42	23.2	YES	N/A	0	0	TRUE	Yes
7389	1896.37	13.5	16.5	21.15	0.78	1.67	4.65	60	23.2	YES	N/A	0	0	TRUE	Yes
7289	1896.37	13.5	16.5	21.14	0.75	1.6	4.64	62.79	23.2	YES	N/A	0	0	TRUE	Yes
7187	1896.37	13.47	16.47	21.13	0.72	1.53	4.66	57.21	23.2	YES	N/A	0	0	TRUE	Yes
7089	1896.37	13.47	16.47	21.13	0.69	1.47	4.66	60	23.2	YES	N/A	0	0	TRUE	Yes
6989	1896.37	13.44	16.44	21.12	0.66	1.41	4.68	59.75	23.2	YES	N/A	0	0	TRUE	Yes
6890	1896.37	13.44	16.44	21.12	0.62	1.32	4.68	60.25	23.2	YES	N/A	0	0	TRUE	Yes
6789	1896.37	13.44	16.44	21.11	0.58	1.25	4.67	60.61	23.2	YES	N/A	0	0	TRUE	Yes
6689	1896.37	13.41	16.41	21.11	0.56	1.28	4.7	59.52	23.2	YES	N/A	0	0	TRUE	Yes
6589	1896.37	13.41	16.41	21.11	0.56	1.27	4.7	59.65	23.2	YES	N/A	0	0	TRUE	Yes
6490	1896.37	13.38	16.38	21.1	0.55	1.23	4.72	60.17	23.2	YES	N/A	0	0	TRUE	Yes
6390	1896.38	13.38	16.38	21.1	0.54	1.21	4.72	60.04	23.2	YES	N/A	0	0	TRUE	Yes
6289	1896.38	13.34	16.34	21.09	0.54	1.19	4.75	60	23.2	YES	N/A	0	0	TRUE	Yes

Max Velocity (Channel) (ft/s)	Max Velocity Bench (ft/s)
4.02	2.0

6189	1896.38	13.34	16.34	21.09	0.53	1.18	4.75	60	23.2	YES	N/A	0	0	TRUE	Yes
6089	1896.37	13.34	16.34	21.09	0.52	1.14	4.75	60	23.2	YES	N/A	0	0	TRUE	Yes
5989	1896.37	13.31	16.31	21.08	0.5	1.1	4.77	60.08	23.2	YES	N/A	0	0	TRUE	Yes
5889	1896.38	13.31	16.31	21.08	0.51	1.1	4.77	59.92	23.2	YES	N/A	0	0	TRUE	Yes
5789	1896.37	13.28	16.28	21.07	0.51	1.08	4.79	59.74	23.2	YES	N/A	0	0	TRUE	Yes
5690	1896.36	13.28	16.28	21.07	0.52	1.11	4.79	60.26	23.2	YES	N/A	0	0	TRUE	Yes
5589	1896.37	13.25	16.25	21.07	0.52	1.1	4.82	60	23.2	YES	N/A	0	0	TRUE	Yes
5489	1896.37	13.25	16.25	21.06	0.51	1.08	4.81	60	23.2	YES	N/A	0	0	TRUE	Yes
5389	1896.38	13.25	16.25	21.06	0.5	1.06	4.81	160	23.2	YES	N/A	0	0	TRUE	Yes
5189	1896.37	13.22	16.22	21.05	0.38	1.07	4.83	200	23.2	YES	N/A	0	0	TRUE	Yes
4989	1896.38	13.19	16.19	21.04	0.3	1.06	4.85	200	23.2	YES	N/A	0	0	TRUE	Yes
4789	1896.36	13.16	16.16	21.03	0.21	0.93	4.87	200	23.2	YES	N/A	0	0	TRUE	Yes
4589	1896.4	13.12	16.12	21.03	0.21	0.92	4.91	198.95	23.2	YES	N/A	0	0	TRUE	Yes
4391	1896.38	13.09	16.09	21.02	0.22	0.81	4.93	199.94	23.2	YES	N/A	0	0	TRUE	Yes
4191	1896.33	13.06	16.06	21.01	0.22	0.75	4.95	200.73	23.2	YES	N/A	0	0	TRUE	Yes
3990	1896.38	13.03	16.03	21.01	0.22	0.78	4.98	200.38	23.2	YES	N/A	0	0	TRUE	Yes
3789	1896.38	13.03	16.03	21	0.22	0.73	4.97	300	23.2	YES	N/A	0	0	TRUE	Yes
3489	1896.36	12.97	15.97	21	0.21	0.65	5.03	300	23.2	YES	N/A	0	0	TRUE	Yes
3189	1896.38	12.94	15.94	20.99	0.18	0.54	5.05	600	23.2	YES	N/A	0	0	TRUE	Yes
2589	1896.4	12.84	15.84	20.98	0.17	0.51	5.14	598.21	23.2	YES	N/A	0	0	TRUE	Yes
1991	1896.38	12.78	15.78	20.97	0.2	0.57	5.19	601.79	23.2	YES	N/A	0	0	TRUE	Yes
1389	1896.38	12.69	15.69	20.96	0.28	0.66	5.27	686.52	23.2	YES	N/A	0	0	TRUE	Yes
703	1896.39	12.59	15.59	20.94	0.4	0.89	5.35	613.48	23.2	YES	N/A	0	0	TRUE	Yes
89	1896.39	12.53	15.53	20.82	0.92	2.45	5.29	0	23.2	YES	N/A	0	0	TRUE	Yes

Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec

Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 60 ft)

HEC-RAS Model Output

Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
C	2	233816FEB1990 2400		688.39	10	23.2		23.2	0.000003	0.3	2270.4	194	0.02		0.3	
C	2	230816FEB1990 2400		688.39	20	23.16		23.2	0.000373	1.54	448.21	161.42	0.15		1.54	
C	2	2300		Culvert												
C	2	223816FEB1990 2400		688.39	19.75	23.08		23.12	0.000779	1.54	446.44	160.95	0.15		1.54	
C	2	213816FEB1990 2400		688.39	17.91	23.08		23.1	0.000357	1.26	544.66	120.99	0.11		1.26	
C	2	203816FEB1990 2400		688.39	17.84	23.04		23.07	0.000349	1.26	548.37	121.08	0.1		1.26	
C	2	193816FEB1990 2400		688.39	17.81	23.01		23.03	0.000349	1.25	548.95	121.36	0.1		1.25	
C	2	183816FEB1990 2400		688.39	17.75	22.97		23	0.000343	1.25	552.04	121.49	0.1		1.25	
C	2	173816FEB1990 2400		688.39	17.69	22.94		22.96	0.000337	1.24	555.19	121.58	0.1		1.24	
C	2	163816FEB1990 2400		688.39	17.62	22.91		22.93	0.000329	1.23	559.43	121.75	0.1		1.23	
C	2	153816FEB1990 2400		688.39	17.56	22.87		22.9	0.000323	1.22	562.8	121.96	0.1		1.22	
C	2	143816FEB1990 2400		688.39	17.5	22.84		22.87	0.000318	1.22	565.69	122.02	0.1		1.22	
C	2	133816FEB1990 2400		688.39	17.44	22.81		22.83	0.000312	1.21	569.52	122.23	0.1		1.21	
C	2	123816FEB1990 2400		688.39	17.38	22.78		22.8	0.000306	1.2	573.05	122.38	0.1		1.2	
C	2	113816FEB1990 2400		688.39	17.31	22.75		22.77	0.000299	1.19	577.67	122.64	0.1		1.19	
C	2	103816FEB1990 2400		688.39	17.25	22.72		22.74	0.000292	1.18	581.71	122.76	0.1		1.18	
C	2	93816FEB1990 2400		688.39	17.22	22.69		22.71	0.000292	1.18	582.33	122.87	0.1		1.18	
C	2	83816FEB1990 2400		688.39	17.16	22.66		22.69	0.000285	1.17	586.63	123.12	0.09		1.17	
C	2	71016FEB1990 2400		688.39	17.06	22.63		22.65	0.000275	1.16	594.09	123.43	0.09		1.16	
C	1	43816FEB1990 2400		693.39	16.91	22.63		22.65	0.000258	1.14	610.05	124.48	0.09		1.14	
C	1	33816FEB1990 2400		693.39	16.84	22.6		22.62	0.000248	1.12	617.47	124.54	0.09		1.12	
C	1	26716FEB1990 2400		693.39	16.81	22.58		22.6	0.000247	1.12	618.5	124.64	0.09		1.12	
AB	1	900016FEB1990 2400		1896.37	13.66	22.58		22.72	0.000509	3.39	742.29	123.54	0.21	1.62	3.39	1.07
AB	1	892816FEB1990 2400		1896.37	13.66	22.54		22.68	0.000518	3.41	737.42	123.3	0.21	1.62	3.41	1.07
AB	1	881016FEB1990 2400		1896.37	13.66	22.42		22.57	0.000548	3.47	722.51	122.58	0.21	1.65	3.47	1.09
AB	1	568916FEB1990 2400		1896.37	13.66	22.29		22.44	0.000582	3.54	706.44	121.64	0.22	1.67	3.54	1.15
AB	1	858916FEB1990 2400		1896.37	13.62	22.16		22.32	0.000615	3.63	695.26	121.11	0.23	1.71	3.63	1.17

AB	1	848916FEB1990 2400	1896.37	13.62	22.03		22.2	0.00065	3.67	680.09	120.37	0.23	1.74	3.67	1.11
AB	1	838916FEB1990 2400	1896.37	13.62	21.89		22.07	0.000695	3.76	663.84	119.63	0.24	1.77	3.76	1.19
AB	1	828916FEB1990 2400	1896.37	13.59	21.74		21.92	0.00074	3.84	649.16	118.8	0.25	1.8	3.84	1.22
AB	1	818916FEB1990 2400	1896.37	13.59	21.58		21.77	0.000789	3.9	634.88	117.97	0.25	1.84	3.9	1.22
AB	1	808916FEB1990 2400	1896.37	13.56	21.42		21.61	0.000837	4	624.69	117.02	0.26	1.9	4	1.3
AB	1	798916FEB1990 2400	1896.37	13.56	21.25		21.44	0.000862	4.02	623.96	115.74	0.26	2	4.02	1.23
AB	1	789016FEB1990 2400	1896.37	13.56	21.17		21.29	0.000563	3.22	895.99	227.59	0.21	1.43	3.22	1.04
AB	1	779016FEB1990 2400	1896.37	13.56	21.17		21.22	0.000285	2.29	1307.34	281.24	0.15	1.02	2.29	1.07
AB	1	769016FEB1990 2400	1896.37	13.56	21.17		21.21	0.000229	2.05	1509.55	328.53	0.14	0.92	2.05	0.96
AB	1	758916FEB1990 2400	1896.37	13.53	21.16		21.19	0.000193	1.89	1676.26	367.14	0.13	0.86	1.89	0.88
AB	1	748916FEB1990 2400	1896.37	13.53	21.15		21.18	0.000171	1.77	1809.02	398.43	0.12	0.82	1.77	0.83
AB	1	738916FEB1990 2400	1896.37	13.5	21.15		21.17	0.000153	1.67	1931.17	426.84	0.11	0.78	1.67	0.78
AB	1	728916FEB1990 2400	1896.37	13.5	21.14		21.16	0.000139	1.6	2050.06	455.28	0.11	0.75	1.6	0.75
AB	1	718716FEB1990 2400	1896.37	13.47	21.13		21.15	0.000127	1.53	2160.79	481.91	0.1	0.72	1.53	0.72
AB	1	708916FEB1990 2400	1896.37	13.47	21.13		21.14	0.000117	1.47	2271.16	508.07	0.1	0.69	1.47	0.69
AB	1	698916FEB1990 2400	1896.37	13.44	21.12		21.14	0.000106	1.41	2402.49	537.56	0.09	0.66	1.41	0.66
AB	1	689016FEB1990 2400	1896.37	13.44	21.12		21.13	0.000093	1.32	2591.53	581.95	0.09	0.62	1.32	0.62
AB	1	678916FEB1990 2400	1896.37	13.44	21.11		21.13	0.000084	1.25	2767.14	626.69	0.08	0.58	1.25	0.59
AB	1	668916FEB1990 2400	1896.37	13.41	21.11		21.12	0.000088	1.28	2773.48	661.53	0.08	0.56	1.28	0.6
AB	1	658916FEB1990 2400	1896.37	13.41	21.11		21.12	0.000085	1.27	2815.11	669.7	0.08	0.56	1.27	0.59
AB	1	649016FEB1990 2400	1896.37	13.38	21.1		21.11	0.000082	1.23	2867.17	678.65	0.08	0.55	1.23	0.58
AB	1	639016FEB1990 2400	1896.38	13.38	21.1		21.11	0.000078	1.21	2938.5	692.5	0.08	0.54	1.21	0.56
AB	1	628916FEB1990 2400	1896.38	13.34	21.09		21.1	0.000076	1.19	2974.12	693.39	0.08	0.54	1.19	0.56
AB	1	618916FEB1990 2400	1896.38	13.34	21.09		21.1	0.000074	1.18	3013.9	700.33	0.08	0.53	1.18	0.55
AB	1	608916FEB1990 2400	1896.37	13.34	21.09		21.09	0.00007	1.14	3096.08	716.5	0.08	0.52	1.14	0.54
AB	1	598916FEB1990 2400	1896.37	13.31	21.08		21.09	0.000064	1.1	3212.99	735.69	0.07	0.5	1.1	0.52
AB	1	588916FEB1990 2400	1896.38	13.31	21.08		21.09	0.000064	1.1	3206.48	728.33	0.07	0.51	1.1	0.52
AB	1	578916FEB1990 2400	1896.37	13.28	21.07		21.08	0.000064	1.08	3195.98	721.42	0.07	0.51	1.08	0.51
AB	1	569016FEB1990 2400	1896.36	13.28	21.07		21.08	0.000065	1.11	3178.9	717.51	0.07	0.52	1.11	0.51
AB	1	558916FEB1990 2400	1896.37	13.25	21.07		21.08	0.000063	1.1	3214.07	728.19	0.07	0.52	1.1	0.5
AB	1	548916FEB1990 2400	1896.37	13.25	21.06		21.07	0.000062	1.08	3272.43	744.46	0.07	0.51	1.08	0.5
AB	1	538916FEB1990 2400	1896.38	13.25	21.06		21.07	0.000059	1.06	3351	766.7	0.07	0.5	1.06	0.48
AB	1	518916FEB1990 2400	1896.37	13.22	21.05		21.06	0.00006	1.07	3615.17	974.74	0.07	0.38	1.07	0.49
AB	1	498916FEB1990 2400	1896.38	13.19	21.04		21.05	0.000059	1.06	3922.82	1288.36	0.07	0.3	1.06	0.48
AB	1	478916FEB1990 2400	1896.36	13.16	21.03		21.04	0.000046	0.93	5389.67	2749.34	0.06	0.21	0.93	0.43
AB	1	458916FEB1990 2400	1896.4	13.12	21.03		21.03	0.000046	0.92	5484.58	2789.61	0.06	0.21	0.92	0.44
AB	1	439116FEB1990 2400	1896.38	13.09	21.02		21.02	0.000034	0.81	6306.73	2764.9	0.05	0.22	0.81	0.38
AB	1	419116FEB1990 2400	1896.33	13.06	21.01		21.02	0.000029	0.75	6806.98	2779.22	0.05	0.22	0.75	0.35
AB	1	399016FEB1990 2400	1896.38	13.03	21.01		21.01	0.000031	0.78	6642.71	2785.72	0.05	0.22	0.78	0.37
AB	1	378916FEB1990 2400	1896.38	13.03	21		21	0.000028	0.73	6950.83	2805.65	0.05	0.22	0.73	0.34
AB	1	348916FEB1990 2400	1896.36	12.97	21		21	0.000022	0.65	8049.06	3194.58	0.04	0.21	0.65	0.22
AB	1	318916FEB1990 2400	1896.38	12.94	20.99		20.99	0.000015	0.54	9994.24	3974.12	0.03	0.18	0.54	0.15
AB	1	258916FEB1990 2400	1896.4	12.84	20.98		20.98	0.000013	0.51	10762.9	4281.81	0.03	0.17	0.51	0.15
AB	1	199116FEB1990 2400	1896.38	12.78	20.97		20.98	0.000017	0.57	9795.96	4251.6	0.04	0.2	0.57	0.16
AB	1	138916FEB1990 2400	1896.38	12.69	20.96		20.97	0.000021	0.66	8174.07	3703.28	0.04	0.28	0.66	0.16
AB	1	70316FEB1990 2400	1896.39	12.59	20.94		20.95	0.000038	0.89	4758.89	1347.99	0.06	0.4	0.89	0.32
AB	1	8916FEB1990 2400	1896.39	12.53	20.82	16.44	20.88	0.000287	2.45	1380.71	386.69	0.15	0.92	2.45	0.79

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (cfs)
C		1	233816FEB1990 2400	23.2	23.2	0	0.02			688.39		194
C		1	230816FEB1990 2400	23.2	23.16	0.04				688.39		161.42
C		1	2300	Culvert								
C		1	223816FEB1990 2400	23.12	23.08	0.04	0.02			688.39		160.95
C		1	213816FEB1990 2400	23.1	23.08	0.02	0.04			688.39		120.99
AB		2	1175016FEB1990 2400	23.2	23.2	0	0.01			1202.98		194
AB		2	1157516FEB1990 2400	23.21	23.16	0.05			306.14	896.84		134.55
AB		2	11550	Culvert								
AB		2	1152016FEB1990 2400	23.09	23.03	0.06	0.01		265.43	937.55		133.76

AB		2	11390	16FEB1990	2400	23.08	23.03	0.05	0.02		287.16	884.28	31.54	124.24	

Culvert Only

Channel	Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	EG. IC (ft)	E.G. OC (ft)	Min El Weir (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
C		1 2300 Culverts	16FEB1990 2400	23.2	23.16	21.79	23.2	31.81	688.39		0.08	2.23	2.07
AB		21550 Culverts	16FEB1990 2400	23.2	23.16	20.04	23.18	31.81	456.48		0.13	2.52	2.42
AB		21550 Culverts	16FEB1990 2400	23.2	23.16	18.22	23.21	31.81	746.5		0.13	2.75	2.68

AB-2 Channel Criterion Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Channel Velocity Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Water Depth at Bench (ft)	Reach Length (ft)	Water Surface Elevation in Sac. River (ft)	Channel Passage Logic	Bench Logic	Length of Reach w/ Vel. >4 ft/s Logic	Length of Reach w/ Vel. >4 ft/s	Design Criterion Logic	Design Criterion Met
Headworks															
11750	1464.09	10	N/A	25.5	N/A	0.54		100	25.5	YES	N/A	0	0	TRUE	Yes
11575	1464.09	14	N/A	25.37	N/A	4.44		68.5	25.5	YES	N/A	0	0	TRUE	Yes
11550	Structure: 3 B Culverts and 10 C Culverts Open														
11520	1464.09	13.75	N/A	24.41	N/A	7.02		31	25.5	NO	NO	31	31	FALSE	No*
AB-2 Channel															
11390	1464.09	13.97	16.97	24.59	1	2.05	7.62	99.65	25.5	YES	N/A	0	0	TRUE	Yes
11290	1464.1	13.97	16.97	24.58	1	2.05	7.61	99.47	25.5	YES	N/A	0	0	TRUE	Yes
11190	1464.1	13.97	16.97	24.57	1	2.05	7.6	101.86	25.5	YES	N/A	0	0	TRUE	Yes
11089	1464.1	13.94	16.94	24.55	1	2.05	7.61	98.96	25.5	YES	N/A	0	0	TRUE	Yes
10990	1464.1	13.94	16.94	24.53	1.02	2.1	7.59	98.43	25.5	YES	N/A	0	0	TRUE	Yes
10891	1464.1	13.94	16.94	24.52	1.01	2.08	7.58	101.46	25.5	YES	N/A	0	0	TRUE	Yes
10790	1464.1	13.91	16.91	24.5	1.01	2.08	7.59	99.62	25.5	YES	N/A	0	0	TRUE	Yes
10690	1464.1	13.91	16.91	24.49	1	2.07	7.58	100.86	25.5	YES	N/A	0	0	TRUE	Yes
10589	1464.1	13.88	16.88	24.47	1.01	2.08	7.59	99.86	25.5	YES	N/A	0	0	TRUE	Yes
10489	1464.09	13.88	16.88	24.46	1	2.07	7.58	99.24	25.5	YES	N/A	0	0	TRUE	Yes
10390	1464.1	13.88	16.88	24.45	1	2.07	7.57	101.16	25.5	YES	N/A	0	0	TRUE	Yes
10289	1464.1	13.84	16.84	24.43	1.01	2.08	7.59	99.84	25.5	YES	N/A	0	0	TRUE	Yes
10189	1464.1	13.84	16.84	24.42	1.01	2.09	7.58	100.25	25.5	YES	N/A	0	0	TRUE	Yes
10089	1464.09	13.81	16.81	24.4	1.01	2.07	7.59	98.83	25.5	YES	N/A	0	0	TRUE	Yes
9990	1464.09	13.81	16.81	24.39	1	2.07	7.58	100.05	25.5	YES	N/A	0	0	TRUE	Yes
9890	1464.09	13.81	16.81	24.37	1.01	2.09	7.56	100.91	25.5	YES	N/A	0	0	TRUE	Yes
9789	1464.09	13.78	16.78	24.36	1.07	2.02	7.58	99.49	25.5	YES	N/A	0	0	TRUE	Yes
9690	1464.09	13.78	16.78	24.34	1.03	2.06	7.56	101.72	25.5	YES	N/A	0	0	TRUE	Yes
9588	1464.1	13.75	16.75	24.32	1.02	2.1	7.57	99.82	25.5	YES	N/A	0	0	TRUE	Yes
9488	1464.09	13.75	16.75	24.31	1.01	2.09	7.56	99.95	25.5	YES	N/A	0	0	TRUE	Yes
9388	1464.09	13.75	16.75	24.29	1.01	2.07	7.54	100.43	25.5	YES	N/A	0	0	TRUE	Yes
9288	1464.09	13.72	16.72	24.28	1.05	2.06	7.56	113.25	25.5	YES	N/A	0	0	TRUE	Yes
9189	1464.09	13.72	16.72	24.26	1.01	2.07	7.54	172.5	25.5	YES	N/A	0	0	TRUE	Yes
AB-1 Channel															
9000	3140.51	13.66	16.66	24.26	2.16	4.45	7.6	74.39	25.5	NO	YES	0	0	TRUE	Yes
8928	3140.51	13.66	16.66	24.2	2.18	4.48	7.54	218.39	25.5	NO	YES	0	0	TRUE	Yes
8810	3140.51	13.66	16.66	24.04	2.22	4.58	7.38	220.57	25.5	NO	YES	0	0	TRUE	Yes
5689	3140.51	13.66	16.66	23.85	2.26	4.68	7.19	200	25.5	NO	YES	0	0	TRUE	Yes
8589	3140.51	13.62	16.62	23.68	2.33	4.83	7.06	200	25.5	NO	YES	0	0	TRUE	Yes
8489	3140.52	13.62	16.62	23.49	2.37	4.9	6.87	200	25.5	NO	YES	0	0	TRUE	Yes
8389	3140.52	13.62	16.62	23.28	2.43	5.05	6.66	200	25.5	NO	YES	0	0	TRUE	Yes
8289	3140.51	13.59	16.59	23.06	2.49	5.2	6.47	200	25.5	NO	YES	0	0	TRUE	Yes
8189	3140.51	13.59	16.49	22.81	2.56	5.35	6.32	200.09	25.5	NO	YES	0	0	TRUE	Yes
8089	3140.51	13.56	16.31	22.52	2.65	5.59	6.21	200.15	25.5	NO	YES	0	0	TRUE	Yes
7989	3140.51	13.56	15.81	22.25	2.63	5.55	6.44	199.1	25.5	NO	YES	0	0	TRUE	Yes
7890	3140.52	13.56	16.56	22.17	1.95	4.31	5.61	100.01	25.5	NO	YES	0	0	TRUE	Yes
7790	3140.52	13.56	16.56	22.18	1.41	3.11	5.62	59.7	25.5	YES	N/A	0	0	TRUE	Yes
7689	3140.51	13.56	16.56	22.18	1.28	2.76	5.62	61.05	25.5	YES	N/A	0	0	TRUE	Yes
7589	3140.52	13.53	16.53	22.17	1.19	2.54	5.64	60.49	25.5	YES	N/A	0	0	TRUE	Yes
7489	3140.52	13.53	16.53	22.16	1.13	2.37	5.63	59.42	25.5	YES	N/A	0	0	TRUE	Yes
7389	3140.52	13.5	16.5	22.15	1.08	2.23	5.65	60	25.5	YES	N/A	0	0	TRUE	Yes
7289	3140.52	13.5	16.5	22.14	1.03	2.13	5.64	62.79	25.5	YES	N/A	0	0	TRUE	Yes
7187	3140.52	13.47	16.47	22.13	0.99	2.04	5.66	57.21	25.5	YES	N/A	0	0	TRUE	Yes
7089	3140.52	13.47	16.47	22.12	0.95	1.95	5.65	60	25.5	YES	N/A	0	0	TRUE	Yes
6989	3140.52	13.44	16.44	22.11	0.91	1.87	5.67	59.75	25.5	YES	N/A	0	0	TRUE	Yes
6890	3140.52	13.44	16.44	22.11	0.85	1.75	5.67	60.25	25.5	YES	N/A	0	0	TRUE	Yes

Max Velocity (Channel) (ft/s)	Max Velocity (Bench) (ft/s)
7.02	2.65

6789	3140.52	13.44	16.44	22.1	0.8	1.65	5.66	60.61	25.5	YES	N/A	0	0	TRUE	Yes
6689	3140.51	13.41	16.41	22.09	0.78	1.66	5.68	59.52	25.5	YES	N/A	0	0	TRUE	Yes
6589	3140.51	13.41	16.41	22.09	0.78	1.65	5.68	59.65	25.5	YES	N/A	0	0	TRUE	Yes
6490	3140.51	13.38	16.38	22.08	0.77	1.61	5.7	60.17	25.5	YES	N/A	0	0	TRUE	Yes
6390	3140.51	13.38	16.38	22.08	0.75	1.58	5.7	60.04	25.5	YES	N/A	0	0	TRUE	Yes
6289	3140.52	13.34	16.34	22.07	0.75	1.56	5.73	60	25.5	YES	N/A	0	0	TRUE	Yes
6189	3140.52	13.34	16.34	22.07	0.74	1.54	5.73	60	25.5	YES	N/A	0	0	TRUE	Yes
6089	3140.52	13.34	16.34	22.06	0.72	1.5	5.72	60	25.5	YES	N/A	0	0	TRUE	Yes
5989	3140.51	13.31	16.31	22.06	0.7	1.45	5.75	60.08	25.5	YES	N/A	0	0	TRUE	Yes
5889	3140.51	13.31	16.31	22.05	0.71	1.45	5.74	59.92	25.5	YES	N/A	0	0	TRUE	Yes
5789	3140.51	13.28	16.28	22.04	0.71	1.44	5.76	59.74	25.5	YES	N/A	0	0	TRUE	Yes
5690	3140.51	13.28	16.28	22.04	0.72	1.47	5.76	60.26	25.5	YES	N/A	0	0	TRUE	Yes
5589	3140.51	13.25	16.25	22.03	0.71	1.45	5.78	60	25.5	YES	N/A	0	0	TRUE	Yes
5489	3140.52	13.25	16.25	22.03	0.7	1.43	5.78	60	25.5	YES	N/A	0	0	TRUE	Yes
5389	3140.52	13.25	16.25	22.03	0.69	1.4	5.78	160	25.5	YES	N/A	0	0	TRUE	Yes
5189	3140.52	13.22	16.22	22.01	0.51	1.37	5.79	200	25.5	YES	N/A	0	0	TRUE	Yes
4989	3140.52	13.19	16.19	22.01	0.28	1	5.82	200	25.5	YES	N/A	0	0	TRUE	Yes
4789	3140.51	13.16	16.16	22	0.28	0.98	5.84	200	25.5	YES	N/A	0	0	TRUE	Yes
4589	3140.51	13.12	16.12	21.99	0.29	0.97	5.87	198.95	25.5	YES	N/A	0	0	TRUE	Yes
4391	3140.51	13.09	16.09	21.98	0.29	0.87	5.89	199.94	25.5	YES	N/A	0	0	TRUE	Yes
4191	3140.5	13.06	16.06	21.98	0.28	0.82	5.92	200.73	25.5	YES	N/A	0	0	TRUE	Yes
3990	3140.49	13.03	16.03	21.97	0.28	0.84	5.94	200.38	25.5	YES	N/A	0	0	TRUE	Yes
3789	3140.51	13.03	16.03	21.97	0.28	0.8	5.94	300	25.5	YES	N/A	0	0	TRUE	Yes
3489	3140.53	12.97	15.97	21.96	0.27	0.73	5.99	300	25.5	YES	N/A	0	0	TRUE	Yes
3189	3140.52	12.94	15.94	21.96	0.22	0.58	6.02	600	25.5	YES	N/A	0	0	TRUE	Yes
2589	3140.51	12.84	15.84	21.95	0.22	0.57	6.11	598.21	25.5	YES	N/A	0	0	TRUE	Yes
1991	3140.52	12.78	15.78	21.94	0.24	0.63	6.16	601.79	25.5	YES	N/A	0	0	TRUE	Yes
1389	3140.49	12.69	15.69	21.93	0.34	0.73	6.24	686.52	25.5	YES	N/A	0	0	TRUE	Yes
703	3140.52	12.59	15.59	21.9	0.59	1.26	6.31	613.48	25.5	YES	N/A	0	0	TRUE	Yes
89	3140.52	12.53	15.53	21.66	1.51	3.78	6.13	0	25.5	YES	N/A	0	0	TRUE	Yes

Operation Criterion: Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec
Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec

Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum

*Notes: AB channel fails fish passage criteria at the gate at 25.5' Sac. R. WSE. This corresponds to the closing of the A gates. Fish passage is provided within the C-channel at this flow. Conditions in AB are passible below 25.5' when the A gates are open.

HEC-RAS Model Output
Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
AB		2	11750 05JAN1990 2400	1464.09	10	25.5		25.5	0.000007	0.54	2725.6	202.5	0.03	0.03	0.54	0.03
AB		2	11575 05JAN1990 2400	1464.09	14	25.37		25.57	0.000791	4.44	411.09	147.81	0.26	3.42	4.44	
AB		2	11550	Culvert												
AB		2	11520 05JAN1990 2400	1464.09	13.75	24.41		24.78	0.002351	7.02	306.25	142.07	0.45	4.66	7.02	
AB		2	11390 05JAN1990 2400	1464.09	13.97	24.59		24.65	0.000147	2.05	959.99	133.66	0.11	1	2.05	0.68
AB		2	11290 05JAN1990 2400	1464.1	13.97	24.58		24.63	0.000147	2.05	960.1	133.63	0.11	1	2.05	0.68
AB		2	11190 05JAN1990 2400	1464.1	13.97	24.57		24.62	0.000148	2.05	958.27	133.58	0.12	1	2.05	0.66
AB		2	11089 05JAN1990 2400	1464.1	13.94	24.55		24.6	0.000148	2.05	959.1	133.6	0.11	1	2.05	0.65
AB		2	10990 05JAN1990 2400	1464.1	13.94	24.53		24.59	0.000151	2.1	957.99	133.6	0.12	1.02	2.1	0.71
AB		2	10891 05JAN1990 2400	1464.1	13.94	24.52		24.57	0.00015	2.08	956.73	133.54	0.12	1.01	2.08	0.7
AB		2	10790 05JAN1990 2400	1464.1	13.91	24.5		24.56	0.000149	2.08	958.1	133.57	0.12	1.01	2.08	0.71
AB		2	10690 05JAN1990 2400	1464.1	13.91	24.49		24.54	0.000149	2.07	956.36	133.53	0.12	1	2.07	0.71
AB		2	10589 05JAN1990 2400	1464.1	13.88	24.47		24.53	0.00015	2.08	958.18	133.58	0.12	1.01	2.08	0.71
AB		2	10489 05JAN1990 2400	1464.09	13.88	24.46		24.51	0.000149	2.07	956.32	133.49	0.12	1	2.07	0.7
AB		2	10390 05JAN1990 2400	1464.1	13.88	24.45		24.5	0.00015	2.07	954.88	133.54	0.12	1	2.07	0.71
AB		2	10289 05JAN1990 2400	1464.1	13.84	24.43		24.48	0.00015	2.08	956.71	133.54	0.12	1.01	2.08	0.72

AB	2	10189	05JAN1990 2400	1464.1	13.84	24.42	24.47	0.000151	2.09	955.82	133.48	0.12	1.01	2.09	0.71
AB	2	10089	05JAN1990 2400	1464.09	13.81	24.4	24.45	0.000149	2.07	956.53	133.46	0.12	1.01	2.07	0.69
AB	2	9990	05JAN1990 2400	1464.09	13.81	24.39	24.44	0.00015	2.07	955.29	133.4	0.12	1	2.07	0.71
AB	2	9890	05JAN1990 2400	1464.09	13.81	24.37	24.42	0.000152	2.09	953.93	133.46	0.12	1.01	2.09	0.72
AB	2	9789	05JAN1990 2400	1464.09	13.78	24.36	24.4	0.000169	2.02	954.96	133.4	0.11	1.07	2.02	0.74
AB	2	9690	05JAN1990 2400	1464.09	13.78	24.34	24.39	0.000157	2.06	953.58	133.36	0.12	1.03	2.06	0.72
AB	2	9588	05JAN1990 2400	1464.1	13.75	24.32	24.37	0.000152	2.1	954.17	133.38	0.12	1.02	2.1	0.71
AB	2	9488	05JAN1990 2400	1464.09	13.75	24.31	24.36	0.000152	2.09	952.88	133.35	0.12	1.01	2.09	0.7
AB	2	9388	05JAN1990 2400	1464.09	13.75	24.29	24.34	0.00015	2.07	951.85	133.34	0.12	1.01	2.07	0.78
AB	2	9288	05JAN1990 2400	1464.09	13.72	24.28	24.33	0.000163	2.06	952.34	133.32	0.12	1.05	2.06	0.74
AB	2	9189	05JAN1990 2400	1464.09	13.72	24.26	24.31	0.000151	2.07	951.01	133.34	0.12	1.01	2.07	0.68
AB	1	9000	05JAN1990 2400	3140.51	13.66	24.26	24.49	0.000686	4.45	958.12	133.56	0.25	2.16	4.45	1.48
AB	1	8928	05JAN1990 2400	3140.51	13.66	24.2	24.44	0.000701	4.48	950.9	133.24	0.25	2.18	4.48	1.49
AB	1	8810	05JAN1990 2400	3140.51	13.66	24.04	24.29	0.000748	4.58	928.69	132.24	0.26	2.22	4.58	1.51
AB	1	5689	05JAN1990 2400	3140.51	13.66	23.85	24.12	0.000803	4.68	904.29	131.05	0.27	2.26	4.68	1.59
AB	1	8589	05JAN1990 2400	3140.51	13.62	23.68	23.95	0.000862	4.83	885.41	130.19	0.28	2.33	4.83	1.63
AB	1	8489	05JAN1990 2400	3140.52	13.62	23.49	23.78	0.000921	4.9	861.74	129.07	0.28	2.37	4.9	1.58
AB	1	8389	05JAN1990 2400	3140.52	13.62	23.28	23.59	0.001003	5.05	836	127.96	0.3	2.43	5.05	1.67
AB	1	8289	05JAN1990 2400	3140.51	13.59	23.06	23.38	0.001093	5.2	810.65	126.67	0.31	2.49	5.2	1.73
AB	1	8189	05JAN1990 2400	3140.51	13.59	22.81	23.16	0.001213	5.35	779.53	125.3	0.32	2.56	5.35	1.75
AB	1	8089	05JAN1990 2400	3140.51	13.56	22.52	22.9	0.00137	5.59	747.41	123.65	0.34	2.65	5.59	1.9
AB	1	7989	05JAN1990 2400	3140.51	13.56	22.25	22.63	0.001403	5.55	746.94	126.71	0.34	2.63	5.55	1.79
AB	1	7890	05JAN1990 2400	3140.52	13.56	22.17	22.37	0.000849	4.31	1128.6	238.32	0.27	1.95	4.31	1.57
AB	1	7790	05JAN1990 2400	3140.52	13.56	22.18	22.27	0.00044	3.11	1595.8	291.63	0.19	1.41	3.11	1.5
AB	1	7689	05JAN1990 2400	3140.51	13.56	22.18	22.24	0.000348	2.76	1845.7	338.71	0.17	1.28	2.76	1.35
AB	1	7589	05JAN1990 2400	3140.52	13.53	22.17	22.22	0.000292	2.54	2050.5	377.24	0.16	1.19	2.54	1.24
AB	1	7489	05JAN1990 2400	3140.52	13.53	22.16	22.2	0.000256	2.37	2213.5	408.45	0.15	1.13	2.37	1.16
AB	1	7389	05JAN1990 2400	3140.52	13.5	22.15	22.19	0.000229	2.23	2362.9	436.79	0.14	1.08	2.23	1.1
AB	1	7289	05JAN1990 2400	3140.52	13.5	22.14	22.17	0.000207	2.13	2509	465.28	0.13	1.03	2.13	1.04
AB	1	7187	05JAN1990 2400	3140.52	13.47	22.13	22.16	0.000189	2.04	2645	491.92	0.13	0.99	2.04	1
AB	1	7089	05JAN1990 2400	3140.52	13.47	22.12	22.15	0.000174	1.95	2779.4	518.03	0.12	0.95	1.95	0.96
AB	1	6989	05JAN1990 2400	3140.52	13.44	22.11	22.14	0.000157	1.87	2939.6	547.47	0.12	0.91	1.87	0.91
AB	1	6890	05JAN1990 2400	3140.52	13.44	22.11	22.13	0.000138	1.75	3171.7	591.87	0.11	0.85	1.75	0.85
AB	1	6789	05JAN1990 2400	3140.52	13.44	22.1	22.12	0.000123	1.65	3390.8	636.84	0.1	0.8	1.65	0.81
AB	1	6689	05JAN1990 2400	3140.51	13.41	22.09	22.11	0.000126	1.66	3430.1	671.53	0.1	0.78	1.66	0.82
AB	1	6589	05JAN1990 2400	3140.51	13.41	22.09	22.11	0.000122	1.65	3478.5	679.59	0.1	0.78	1.65	0.8
AB	1	6490	05JAN1990 2400	3140.51	13.38	22.08	22.1	0.000118	1.61	3538.2	688.56	0.1	0.77	1.61	0.78
AB	1	6390	05JAN1990 2400	3140.51	13.38	22.08	22.09	0.000113	1.58	3622	702.32	0.1	0.75	1.58	0.76
AB	1	6289	05JAN1990 2400	3140.52	13.34	22.07	22.09	0.000109	1.56	3657.3	703.25	0.1	0.75	1.56	0.75
AB	1	6189	05JAN1990 2400	3140.52	13.34	22.07	22.08	0.000107	1.54	3702.7	710.28	0.1	0.74	1.54	0.75
AB	1	6089	05JAN1990 2400	3140.52	13.34	22.06	22.08	0.000102	1.5	3799.8	726.55	0.09	0.72	1.5	0.74
AB	1	5989	05JAN1990 2400	3140.51	13.31	22.06	22.07	0.000094	1.45	3934.3	745.7	0.09	0.7	1.45	0.71
AB	1	5889	05JAN1990 2400	3140.51	13.31	22.05	22.06	0.000094	1.45	3919	738.14	0.09	0.71	1.45	0.71
AB	1	5789	05JAN1990 2400	3140.51	13.28	22.04	22.06	0.000094	1.44	3900.5	731.35	0.09	0.71	1.44	0.71
AB	1	5690	05JAN1990 2400	3140.51	13.28	22.04	22.05	0.000096	1.47	3878.3	727.36	0.09	0.72	1.47	0.71
AB	1	5589	05JAN1990 2400	3140.51	13.25	22.03	22.05	0.000094	1.45	3922.5	737.88	0.09	0.71	1.45	0.7
AB	1	5489	05JAN1990 2400	3140.52	13.25	22.03	22.04	0.000091	1.43	3995.6	754.3	0.09	0.7	1.43	0.69
AB	1	5389	05JAN1990 2400	3140.52	13.25	22.03	22.04	0.000087	1.4	4094.6	776.34	0.09	0.69	1.4	0.67
AB	1	5189	05JAN1990 2400	3140.52	13.22	22.01	22.03	0.000083	1.37	4590.1	1031.13	0.08	0.51	1.37	0.66
AB	1	4989	05JAN1990 2400	3140.52	13.19	22.01	22.01	0.000045	1	8021.5	2846.33	0.06	0.28	1	0.48
AB	1	4789	05JAN1990 2400	3140.51	13.16	22	22	0.000044	0.98	8100	2825.31	0.06	0.28	0.98	0.48
AB	1	4589	05JAN1990 2400	3140.51	13.12	21.99	22	0.000043	0.97	8187.4	2811.06	0.06	0.29	0.97	0.48
AB	1	4391	05JAN1990 2400	3140.51	13.09	21.98	21.99	0.000034	0.87	8987	2786.8	0.05	0.29	0.87	0.43
AB	1	4191	05JAN1990 2400	3140.5	13.06	21.98	21.98	0.000029	0.82	9498.9	2795.56	0.05	0.28	0.82	0.4
AB	1	3990	05JAN1990 2400	3140.49	13.03	21.97	21.98	0.000031	0.84	9346.4	2810.36	0.05	0.28	0.84	0.42
AB	1	3789	05JAN1990 2400	3140.51	13.03	21.97	21.97	0.000028	0.8	9673.8	2830.49	0.05	0.28	0.8	0.39
AB	1	3489	05JAN1990 2400	3140.53	12.97	21.96	21.96	0.000023	0.73	11627	3849.37	0.04	0.27	0.73	0.19
AB	1	3189	05JAN1990 2400	3140.52	12.94	21.96	21.96	0.000015	0.58	13934	4122.45	0.04	0.22	0.58	0.19
AB	1	2589	05JAN1990 2400	3140.51	12.84	21.95	21.95	0.000014	0.57	15279	5004.27	0.03	0.22	0.57	0.17
AB	1	1991	05JAN1990 2400	3140.52	12.78	21.94	21.94	0.000017	0.63	14341	5119.92	0.04	0.24	0.63	0.18

AB	1	1389	05JAN1990 2400	3140.49	12.69	21.93		21.93	0.000022	0.73	12334	4757.11	0.04	0.34	0.73	0.19
AB	1	703	05JAN1990 2400	3140.52	12.59	21.9		21.9	0.000065	1.26	8087.8	4501.87	0.08	0.59	1.26	0.26
AB	1	89	05JAN1990 2400	3140.52	12.53	21.66	17.4	21.8	0.000597	3.78	2578.4	4365.94	0.23	1.51	3.78	0.32

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss	C & E Los (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (cfs)
C	2	2338	05JAN1990 2400	25.51	25.5	0.01	0.02		0.01	1671.39	0.01	203.13
C	2	2308	05JAN1990 2400	25.51	25.44	0.07				1671.42		175.07
C	2	2300		Culvert								
C	2	2238	05JAN1990 2400	25.35	25.27	0.08	0.02			1671.42		174.06
C	2	2138	05JAN1990 2400	25.32	25.26	0.06	0.06			1671.42		134.08
AB	2	11750	05JAN1990 2400	25.5	25.5	0	0.04		0.01	1464.08	0.01	202.5
AB	2	11575	05JAN1990 2400	25.57	25.37	0.2			1205.85	258.25		147.81
Ab	2	11550		Culvert								
AB	2	11520	05JAN1990 2400	24.78	24.41	0.37	0.04		1355.81	108.29		142.07
AB	2	11390	05JAN1990 2400	24.65	24.59	0.05	0.01		378.73	1032.34	53.03	133.66

Culvert Only

Channel	Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	EG. IC (ft)	E.G. OC (ft)	Min El W (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta W (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
C	2	2300 Culverts	05JAN1990 2400	25.5	25.44	23.24	25.5	31.81	1671.42		0.17	3.17	3.03
AB	2	11550 Culverts	05JAN1990 2400	25.43	25.37	23.61	25.43	31.81	1464.09		0.96	6.58	6.37

C-2 Channel Criterion Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Channel Velocity Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Water Depth at Bench (ft)	Reach Length (ft)	Water Surface Elevation in Sac. River (ft)	Channel Passage Logic	Bench Passage Logic	Length of Reach w/ Vel. >4 ft/s Logic	Length of Reach w/ Vel. >4 ft/s	Design Criterion Logic	Design Criterion Met
Headworks															
2338	1399.96	10	N/A	27	N/A	0.46	N/A	100	27	YES	N/A	0	0	TRUE	Yes
2308	1399.96	20	N/A	26.86	N/A	4.17	N/A	68.5	27	YES	N/A	0	0	TRUE	Yes
2300	Structure: 3 A Culverts, 3 B Culverts, and 10 C Culverts Open														
2238	1399.96	19.75	N/A	25.06	N/A	6.59	N/A	31	27	NO	NO	31	31	FALSE	No*
C-2 Channel															
2138	1399.96	17.91	N/A	25.35	N/A	1.68	N/A	100	27	YES	N/A	0	0	TRUE	Yes
2038	1399.96	17.84	N/A	25.31	N/A	1.67	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1938	1399.96	17.81	N/A	25.27	N/A	1.67	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1838	1399.96	17.75	N/A	25.23	N/A	1.67	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1738	1399.96	17.69	N/A	25.19	N/A	1.66	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1638	1399.95	17.62	N/A	25.15	N/A	1.65	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1538	1399.96	17.56	N/A	25.11	N/A	1.65	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1438	1399.96	17.5	N/A	25.07	N/A	1.64	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1338	1399.96	17.44	N/A	25.03	N/A	1.64	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1238	1399.96	17.38	N/A	24.99	N/A	1.63	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1138	1399.96	17.31	N/A	24.95	N/A	1.62	N/A	100	27	YES	N/A	0	0	TRUE	Yes
1038	1399.96	17.25	N/A	24.92	N/A	1.62	N/A	100	27	YES	N/A	0	0	TRUE	Yes
938	1399.96	17.22	N/A	24.88	N/A	1.62	N/A	100	27	YES	N/A	0	0	TRUE	Yes
838	1399.96	17.16	N/A	24.84	N/A	1.61	N/A	128.13	27	YES	N/A	0	0	TRUE	Yes
710	1399.96	17.06	N/A	24.8	N/A	1.6	N/A	271.87	27	YES	N/A	0	0	TRUE	Yes
C-1 Channel															
438	3258.57	16.91	N/A	24.8	N/A	3.64	N/A	100	27	YES	N/A	0	0	TRUE	Yes
338	3258.57	16.84	N/A	24.6	N/A	3.71	N/A	98.31	27	YES	N/A	0	0	TRUE	Yes
267	3258.58	16.81	N/A	24.4	N/A	3.81	N/A	190.5	27	YES	N/A	0	0	TRUE	Yes
	AB-1 Channel														
9000	3263.57	13.66	16.66	24.4	2.21	4.54	7.74	74.39	27	NO	YES	0	0	TRUE	Yes
8928	3263.57	13.66	16.66	24.34	2.23	4.58	7.68	218.39	27	NO	YES	0	0	TRUE	Yes
8810	3263.58	13.66	16.66	24.17	2.27	4.68	7.51	220.57	27	NO	YES	0	0	TRUE	Yes
5689	3263.58	13.66	16.66	23.98	2.31	4.78	7.32	200	27	NO	YES	0	0	TRUE	Yes
8589	3263.57	13.62	16.62	23.8	2.38	4.94	7.18	200	27	NO	YES	0	0	TRUE	Yes
8489	3263.57	13.62	16.62	23.6	2.43	5.01	6.98	200	27	NO	YES	0	0	TRUE	Yes
8389	3263.57	13.62	16.62	23.39	2.49	5.17	6.77	200	27	NO	YES	0	0	TRUE	Yes
8289	3263.57	13.59	16.59	23.16	2.56	5.32	6.57	200	27	NO	YES	0	0	TRUE	Yes
8189	3263.57	13.59	16.49	22.9	2.63	5.49	6.41	200.09	27	NO	YES	0	0	TRUE	Yes
8089	3263.58	13.56	16.31	22.6	2.73	5.75	6.29	200.15	27	NO	YES	0	0	TRUE	Yes
7989	3263.57	13.56	15.81	22.31	2.71	5.71	6.5	199.1	27	NO	YES	0	0	TRUE	Yes
7890	3263.57	13.56	16.56	22.23	2.01	4.43	5.67	100.01	27	NO	YES	0	0	TRUE	Yes
7790	3263.58	13.56	16.56	22.24	1.46	3.19	5.68	59.7	27	YES	N/A	0	0	TRUE	Yes
7690	3263.58	13.56	16.56	22.24	1.32	2.84	5.68	61.05	27	YES	N/A	0	0	TRUE	Yes
7589	3263.58	13.53	16.53	22.23	1.23	2.61	5.7	60.49	27	YES	N/A	0	0	TRUE	Yes
7489	3263.58	13.53	16.53	22.22	1.17	2.44	5.69	59.42	27	YES	N/A	0	0	TRUE	Yes
7389	3263.57	13.5	16.5	22.21	1.11	2.29	5.71	60	27	YES	N/A	0	0	TRUE	Yes
7289	3263.57	13.5	16.5	22.2	1.06	2.19	5.7	62.79	27	YES	N/A	0	0	TRUE	Yes
7187	3263.58	13.47	16.47	22.19	1.02	2.1	5.72	57.21	27	YES	N/A	0	0	TRUE	Yes
7089	3263.58	13.47	16.47	22.18	0.98	2	5.71	60	27	YES	N/A	0	0	TRUE	Yes
6989	3263.58	13.44	16.44	22.17	0.94	1.92	5.73	59.75	27	YES	N/A	0	0	TRUE	Yes
6890	3263.58	13.44	16.44	22.17	0.88	1.8	5.73	60.25	27	YES	N/A	0	0	TRUE	Yes
6789	3263.58	13.44	16.44	22.16	0.83	1.69	5.72	60.61	27	YES	N/A	0	0	TRUE	Yes
6689	3263.58	13.41	16.41	22.15	0.8	1.71	5.74	59.52	27	YES	N/A	0	0	TRUE	Yes
6589	3263.58	13.41	16.41	22.15	0.8	1.69	5.74	59.65	27	YES	N/A	0	0	TRUE	Yes

Max Velocity (Channel) (ft/s)

6.59

6490	3263.57	13.38	16.38	22.14	0.79	1.65	5.76	60.17	27	YES	N/A	0	0	TRUE	Yes
6390	3263.57	13.38	16.38	22.13	0.78	1.63	5.75	60.04	27	YES	N/A	0	0	TRUE	Yes
6289	3263.57	13.34	16.34	22.13	0.77	1.6	5.79	60	27	YES	N/A	0	0	TRUE	Yes
6189	3263.58	13.34	16.34	22.12	0.76	1.58	5.78	60	27	YES	N/A	0	0	TRUE	Yes
6089	3263.58	13.34	16.34	22.12	0.74	1.54	5.78	60	27	YES	N/A	0	0	TRUE	Yes
5989	3263.57	13.31	16.31	22.11	0.72	1.49	5.8	60.08	27	YES	N/A	0	0	TRUE	Yes
5889	3263.57	13.31	16.31	22.11	0.73	1.49	5.8	59.92	27	YES	N/A	0	0	TRUE	Yes
5789	3263.57	13.28	16.28	22.1	0.73	1.47	5.82	59.74	27	YES	N/A	0	0	TRUE	Yes
5690	3263.57	13.28	16.28	22.1	0.74	1.51	5.82	60.26	27	YES	N/A	0	0	TRUE	Yes
5589	3263.58	13.25	16.25	22.09	0.73	1.49	5.84	60	27	YES	N/A	0	0	TRUE	Yes
5489	3263.58	13.25	16.25	22.09	0.72	1.46	5.84	60	27	YES	N/A	0	0	TRUE	Yes
5389	3263.58	13.25	16.25	22.08	0.71	1.44	5.83	160	27	YES	N/A	0	0	TRUE	Yes
5189	3263.57	13.22	16.22	22.07	0.53	1.41	5.85	200	27	YES	N/A	0	0	TRUE	Yes
4989	3263.57	13.19	16.19	22.06	0.29	1.02	5.87	200	27	YES	N/A	0	0	TRUE	Yes
4789	3263.56	13.16	16.16	22.05	0.29	1	5.89	200	27	YES	N/A	0	0	TRUE	Yes
4589	3263.57	13.12	16.12	22.05	0.29	0.98	5.93	198.95	27	YES	N/A	0	0	TRUE	Yes
4391	3263.58	13.09	16.09	22.04	0.29	0.88	5.95	199.94	27	YES	N/A	0	0	TRUE	Yes
4191	3263.56	13.06	16.06	22.03	0.29	0.83	5.97	200.73	27	YES	N/A	0	0	TRUE	Yes
3990	3263.58	13.03	16.03	22.03	0.29	0.86	6	200.38	27	YES	N/A	0	0	TRUE	Yes
3789	3263.58	13.03	16.03	22.02	0.29	0.81	5.99	300	27	YES	N/A	0	0	TRUE	Yes
3489	3263.58	12.97	15.97	22.01	0.27	0.74	6.04	300	27	YES	N/A	0	0	TRUE	Yes
3189	3263.6	12.94	15.94	22.01	0.23	0.59	6.07	600	27	YES	N/A	0	0	TRUE	Yes
2589	3263.54	12.84	15.84	22	0.22	0.58	6.16	598.21	27	YES	N/A	0	0	TRUE	Yes
1991	3263.59	12.78	15.78	21.99	0.25	0.64	6.21	601.79	27	YES	N/A	0	0	TRUE	Yes
1389	3263.6	12.69	15.69	21.98	0.34	0.74	6.29	686.52	27	YES	N/A	0	0	TRUE	Yes
703	3263.57	12.59	15.59	21.95	0.6	1.27	6.36	613.48	27	YES	N/A	0	0	TRUE	Yes
89	3263.58	12.53	15.53	21.72	1.5	3.73	6.19	0	27	YES	N/A	0	0	TRUE	Yes

Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec
Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec
Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4 ft/sec (maximum velocity can be exceeded for a maximum length of 60 ft)

*Notes:

C channel fails fish passage criteria at the gate at 27' Sac. R. WSE. This corresponds to the closing of the 7 of the 10 C gates. Fish passage is provided within the D-channel at this stage. Conditions in C channel are passible below 27' when all C gates are open.

HEC-RAS Model Output
Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
C	2	2338	09JAN1990 2400	1399.96	10	27		27	0.000004	0.46	3037.5	212.5	0.02	0.06	0.46	0.06
C	2	2308	09JAN1990 2400	1399.96	20	26.86		27.13	0.000966	4.17	335.94	183.6	0.28		4.17	
C	2	2300		Culvert												
C	2	2238	09JAN1990 2400	1399.96	19.75	25.06		25.74	0.007629	6.59	212.54	172.84	0.5		6.59	
C	2	2138	09JAN1990 2400	1399.96	17.91	25.35		25.39	0.000412	1.68	834.64	134.61	0.12		1.68	
C	2	2038	09JAN1990 2400	1399.96	17.84	25.31		25.35	0.000407	1.67	837.83	134.69	0.12		1.67	
C	2	1938	09JAN1990 2400	1399.96	17.81	25.27		25.31	0.000408	1.67	838.21	134.94	0.12		1.67	
C	2	1838	09JAN1990 2400	1399.96	17.75	25.23		25.27	0.000404	1.67	840.77	134.97	0.12		1.67	
C	2	1738	09JAN1990 2400	1399.96	17.69	25.19		25.23	0.0004	1.66	843.26	135.04	0.12		1.66	
C	2	1638	09JAN1990 2400	1399.95	17.62	25.15		25.19	0.000395	1.65	847.05	135.19	0.12		1.65	
C	2	1538	09JAN1990 2400	1399.96	17.56	25.11		25.15	0.000391	1.65	849.93	135.35	0.12		1.65	
C	2	1438	09JAN1990 2400	1399.96	17.5	25.07		25.11	0.000388	1.64	852.11	135.42	0.12		1.64	
C	2	1338	09JAN1990 2400	1399.96	17.44	25.03		25.07	0.000383	1.64	855.46	135.56	0.11		1.64	
C	2	1238	09JAN1990 2400	1399.96	17.38	24.99		25.03	0.000379	1.63	858.28	135.64	0.11		1.63	
C	2	1138	09JAN1990 2400	1399.96	17.31	24.95		25	0.000374	1.62	862.39	135.81	0.11		1.62	
C	2	1038	09JAN1990 2400	1399.96	17.25	24.92		24.96	0.00037	1.62	865.75	135.93	0.11		1.62	
C	2	938	09JAN1990 2400	1399.96	17.22	24.88		24.92	0.00037	1.62	865.63	136.04	0.11		1.62	
C	2	838	09JAN1990 2400	1399.96	17.16	24.84		24.88	0.000366	1.61	869.33	136.21	0.11		1.61	

C	2	71009JAN1990 2400	1399.96	17.06	24.8		24.84	0.000358	1.6	876.03	136.47	0.11		1.6	
C	1	43809JAN1990 2400	3258.57	16.91	24.8		25.01	0.001827	3.64	894.21	137.45	0.25		3.64	
C	1	33809JAN1990 2400	3258.57	16.84	24.6		24.82	0.001919	3.71	878.5	136.51	0.26		3.71	
C	1	26709JAN1990 2400	3258.58	16.81	24.4		24.62	0.002082	3.81	854.62	135.49	0.27		3.81	
AB	1	900009JAN1990 2400	3263.57	13.66	24.4		24.64	0.000703	4.54	976.39	134.37	0.25	2.21	4.54	1.52
AB	1	892809JAN1990 2400	3263.57	13.66	24.34		24.59	0.000718	4.58	968.94	134.04	0.25	2.23	4.58	1.53
AB	1	881009JAN1990 2400	3263.58	13.66	24.17		24.43	0.000767	4.68	945.99	133.02	0.26	2.27	4.68	1.55
AB	1	568909JAN1990 2400	3263.58	13.66	23.98		24.25	0.000825	4.78	920.75	131.8	0.27	2.31	4.78	1.63
AB	1	858909JAN1990 2400	3263.57	13.62	23.8		24.08	0.000887	4.94	901.06	130.91	0.28	2.38	4.94	1.67
AB	1	848909JAN1990 2400	3263.57	13.62	23.6		23.9	0.000949	5.01	876.48	129.75	0.29	2.43	5.01	1.62
AB	1	838909JAN1990 2400	3263.57	13.62	23.39		23.71	0.001036	5.17	849.71	128.6	0.3	2.49	5.17	1.72
AB	1	828909JAN1990 2400	3263.57	13.59	23.16		23.5	0.001131	5.32	823.18	127.26	0.31	2.56	5.32	1.77
AB	1	818909JAN1990 2400	3263.57	13.59	22.9		23.26	0.00126	5.49	790.66	125.83	0.33	2.63	5.49	1.8
AB	1	808909JAN1990 2400	3263.58	13.56	22.6		23	0.001429	5.75	756.8	124.1	0.35	2.73	5.75	1.95
AB	1	798909JAN1990 2400	3263.57	13.56	22.31		22.71	0.001472	5.71	754.78	127.13	0.35	2.71	5.71	1.85
AB	1	789009JAN1990 2400	3263.57	13.56	22.23		22.44	0.000887	4.43	1142.99	238.97	0.27	2.01	4.43	1.62
AB	1	779009JAN1990 2400	3263.58	13.56	22.24		22.34	0.00046	3.19	1613.79	292.27	0.2	1.46	3.19	1.55
AB	1	769009JAN1990 2400	3263.58	13.56	22.24		22.31	0.000363	2.84	1866.54	339.34	0.18	1.32	2.84	1.39
AB	1	758909JAN1990 2400	3263.58	13.53	22.23		22.28	0.000305	2.61	2073.54	377.85	0.16	1.23	2.61	1.27
AB	1	748909JAN1990 2400	3263.58	13.53	22.22		22.27	0.000268	2.44	2238.35	409.06	0.15	1.17	2.44	1.19
AB	1	738909JAN1990 2400	3263.57	13.5	22.21		22.25	0.000239	2.29	2389.25	437.39	0.14	1.11	2.29	1.13
AB	1	728909JAN1990 2400	3263.57	13.5	22.2		22.23	0.000216	2.19	2536.9	465.89	0.14	1.06	2.19	1.07
AB	1	718709JAN1990 2400	3263.58	13.47	22.19		22.22	0.000198	2.1	2674.31	492.52	0.13	1.02	2.1	1.03
AB	1	708909JAN1990 2400	3263.58	13.47	22.18		22.21	0.000182	2	2810.13	518.63	0.12	0.98	2	0.98
AB	1	698909JAN1990 2400	3263.58	13.44	22.17		22.2	0.000164	1.92	2971.9	548.06	0.12	0.94	1.92	0.94
AB	1	689009JAN1990 2400	3263.58	13.44	22.17		22.19	0.000144	1.8	3206.54	592.46	0.11	0.88	1.8	0.88
AB	1	678909JAN1990 2400	3263.58	13.44	22.16		22.18	0.000128	1.69	3428.12	637.46	0.1	0.83	1.69	0.83
AB	1	668909JAN1990 2400	3263.58	13.41	22.15		22.17	0.000131	1.71	3469.19	672.12	0.11	0.8	1.71	0.84
AB	1	658909JAN1990 2400	3263.58	13.41	22.15		22.17	0.000128	1.69	3517.93	680.17	0.1	0.8	1.69	0.82
AB	1	649009JAN1990 2400	3263.57	13.38	22.14		22.16	0.000123	1.65	3577.95	689.15	0.1	0.79	1.65	0.8
AB	1	639009JAN1990 2400	3263.57	13.38	22.13		22.15	0.000118	1.63	3662.41	702.9	0.1	0.78	1.63	0.78
AB	1	628909JAN1990 2400	3263.57	13.34	22.13		22.15	0.000114	1.6	3697.58	703.84	0.1	0.77	1.6	0.77
AB	1	618909JAN1990 2400	3263.58	13.34	22.12		22.14	0.000112	1.58	3743.28	710.87	0.1	0.76	1.58	0.77
AB	1	608909JAN1990 2400	3263.58	13.34	22.12		22.13	0.000106	1.54	3841.08	727.13	0.09	0.74	1.54	0.76
AB	1	598909JAN1990 2400	3263.57	13.31	22.11		22.13	0.000099	1.49	3976.51	746.28	0.09	0.72	1.49	0.73
AB	1	588909JAN1990 2400	3263.57	13.31	22.11		22.12	0.000099	1.49	3960.61	738.7	0.09	0.73	1.49	0.73
AB	1	578909JAN1990 2400	3263.57	13.28	22.1		22.12	0.000099	1.47	3941.53	731.92	0.09	0.73	1.47	0.73
AB	1	569009JAN1990 2400	3263.57	13.28	22.1		22.11	0.0001	1.51	3918.96	727.92	0.09	0.74	1.51	0.73
AB	1	558909JAN1990 2400	3263.58	13.25	22.09		22.1	0.000098	1.49	3963.52	738.44	0.09	0.73	1.49	0.72
AB	1	548909JAN1990 2400	3263.58	13.25	22.09		22.1	0.000095	1.46	4037.44	754.87	0.09	0.72	1.46	0.71
AB	1	538909JAN1990 2400	3263.58	13.25	22.08		22.09	0.000091	1.44	4137.45	776.9	0.09	0.71	1.44	0.69
AB	1	518909JAN1990 2400	3263.57	13.22	22.07		22.08	0.000087	1.41	4646.62	1031.83	0.09	0.53	1.41	0.67
AB	1	498909JAN1990 2400	3263.57	13.19	22.06		22.07	0.000046	1.02	8177.33	2847.4	0.06	0.29	1.02	0.49
AB	1	478909JAN1990 2400	3263.56	13.16	22.05		22.06	0.000045	1	8254.07	2825.94	0.06	0.29	1	0.49
AB	1	458909JAN1990 2400	3263.57	13.12	22.05		22.05	0.000044	0.98	8340.14	2812.14	0.06	0.29	0.98	0.49
AB	1	439109JAN1990 2400	3263.58	13.09	22.04		22.04	0.000035	0.88	9137.95	2787.87	0.05	0.29	0.88	0.44
AB	1	419109JAN1990 2400	3263.56	13.06	22.03		22.04	0.00003	0.83	9649.9	2796.35	0.05	0.29	0.83	0.41
AB	1	399009JAN1990 2400	3263.58	13.03	22.03		22.03	0.000032	0.86	9497.69	2811.28	0.05	0.29	0.86	0.42
AB	1	378909JAN1990 2400	3263.58	13.03	22.02		22.02	0.000029	0.81	9825.73	2831.38	0.05	0.29	0.81	0.4
AB	1	348909JAN1990 2400	3263.58	12.97	22.01		22.02	0.000023	0.74	11832.8	3850.33	0.04	0.27	0.74	0.2
AB	1	318909JAN1990 2400	3263.6	12.94	22.01		22.01	0.000015	0.59	14154.7	4122.88	0.04	0.23	0.59	0.19
AB	1	258909JAN1990 2400	3263.54	12.84	22		22	0.000014	0.58	15545.8	5004.9	0.03	0.22	0.58	0.17
AB	1	199109JAN1990 2400	3263.59	12.78	21.99		21.99	0.000017	0.64	14612.1	5120.41	0.04	0.25	0.64	0.18
AB	1	138909JAN1990 2400	3263.6	12.69	21.98		21.98	0.000022	0.74	12585.5	4757.45	0.04	0.34	0.74	0.19
AB	1	70309JAN1990 2400	3263.57	12.59	21.95		21.96	0.000066	1.27	8324.34	4502.26	0.08	0.6	1.27	0.26
AB	1	8909JAN1990 2400	3263.58	12.53	21.72	17.48	21.85	0.000576	3.73	2846.51	4366.93	0.22	1.5	3.73	0.35

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (cfs)
D		1 1850	09JAN1990 2400	27.01	27	0.01	0.06		0.59	1857.44	0.59	214.66
D		1 1820	09JAN1990 2400	27.01	26.86	0.15				1858.62		171.16
D		1 1800		Culvert								
D		1 1750	09JAN1990 2400	26.61	26.42	0.19	0.08			1858.62		168.45
D		1 1650	09JAN1990 2400	26.53	26.39	0.14	0.18			1858.62		124.49
C		2 2338	09JAN1990 2400	27	27	0	0.05		0.38	1399.2	0.38	212.5
C		2 2308	09JAN1990 2400	27.13	26.86	0.27				1399.96		183.6
C		2 2300		Culvert								
C		2 2238	09JAN1990 2400	25.74	25.06	0.67	0.12			1399.96		172.84
C		2 2138	09JAN1990 2400	25.39	25.35	0.04	0.04			1399.96		134.61

						Culvert Only						
Channel	Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	EG. IC (ft)	E.G. OC (ft)	Min El Weir (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
D		1 1800 Culverts	09JAN1990 2400	26.99	26.86	26.26	26.99	31.81	1858.62		0.44	4.95	4.6
C		2 2300 Culverts	09JAN1990 2400	27.04	26.86	26.42	27.04	31.81	1399.96		1.79	9.23	8.78

D-1 Channel Criterion Evaluation

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Channel Velocity Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Water Depth at Bench (ft)	Reach Length (ft)	Water Surface Elevation in Sac. River (ft)	Channel Passage Logic	Bench Passage Logic	Length of Reach w/ Vel. >4 ft/s Logic	Length of Reach w/ Vel. >4 ft/s	Design Criterion Logic	Design Criterion Met	Max Velocity (Channel) (ft/s)
Headworks																
2338	3180.12	10	N/A	28.7	N/A	0.94	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	4.27
2308	3180.12	23	N/A	28.52	N/A	3.75	N/A	68.5	28.7	YES	N/A	0	0	TRUE	Yes	
2300	Structure: 3 A Culverts, 3 B Culverts, and 10 C Culverts Open															
2238	3180.12	22.75	N/A	27.86	N/A	4.27	N/A	31	28.7	YES	N/A	0	0	TRUE	Yes	
D-1 Channel																
2138	3180.12	20.62	N/A	27.8	N/A	3.98	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
2038	3180.11	20.41	N/A	27.56	N/A	3.99	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1938	3180.12	20.16	N/A	27.34	N/A	3.86	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1838	3180.12	19.91	N/A	27.11	N/A	3.85	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1738	3180.11	19.69	N/A	26.87	N/A	3.85	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1638	3180.12	19.44	N/A	26.64	N/A	3.85	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1538	3180.12	19.19	N/A	26.42	N/A	3.84	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1438	3180.11	18.97	N/A	26.19	N/A	3.83	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1338	3180.11	18.72	N/A	25.96	N/A	3.82	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1238	3180.12	18.49	N/A	25.74	N/A	3.84	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1138	3180.11	18.25	N/A	25.52	N/A	3.81	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
1038	3180.11	18	N/A	25.29	N/A	3.8	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
938	3180.12	17.77	N/A	25.08	N/A	3.79	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
838	3180.12	17.53	N/A	24.86	N/A	3.78	N/A	128.13	28.7	YES	N/A	0	0	TRUE	Yes	
710	3180.11	17.34	N/A	24.71	N/A	3.74	N/A	271.87	28.7	YES	N/A	0	0	TRUE	Yes	
C-1 Channel																
438	3185.11	16.91	N/A	24.71	N/A	3.61	N/A	100	28.7	YES	N/A	0	0	TRUE	Yes	
338	3185.12	16.84	N/A	24.52	N/A	3.67	N/A	98.31	28.7	YES	N/A	0	0	TRUE	Yes	
267	3185.12	16.81	N/A	24.31	N/A	3.78	N/A	190.5	28.7	YES	N/A	0	0	TRUE	Yes	
AB-1 Channel																
9000	3190.12	13.66	16.66	24.31	2.18	4.49	7.65	74.39	28.7	NO	YES	0	0	TRUE	Yes	
8928	3190.12	13.66	16.66	24.26	2.2	4.52	7.6	218.39	28.7	NO	YES	0	0	TRUE	Yes	
8810	3190.11	13.66	16.66	24.09	2.24	4.62	7.43	220.57	28.7	NO	YES	0	0	TRUE	Yes	
5689	3190.12	13.66	16.66	23.9	2.28	4.72	7.24	200	28.7	NO	YES	0	0	TRUE	Yes	
8589	3190.12	13.62	16.62	23.72	2.35	4.87	7.1	200	28.7	NO	YES	0	0	TRUE	Yes	
8489	3190.11	13.62	16.62	23.53	2.4	4.94	6.91	200	28.7	NO	YES	0	0	TRUE	Yes	
8389	3190.11	13.62	16.62	23.32	2.45	5.1	6.7	200	28.7	NO	YES	0	0	TRUE	Yes	
8289	3190.12	13.59	16.59	23.1	2.52	5.25	6.51	200	28.7	NO	YES	0	0	TRUE	Yes	
8189	3190.11	13.59	16.49	22.84	2.59	5.41	6.35	200.09	28.7	NO	YES	0	0	TRUE	Yes	
8089	3190.11	13.56	16.31	22.55	2.68	5.65	6.24	200.15	28.7	NO	YES	0	0	TRUE	Yes	
7989	3190.12	13.56	15.81	22.27	2.66	5.61	6.46	199.1	28.7	NO	YES	0	0	TRUE	Yes	
7890	3190.12	13.56	16.56	22.19	1.98	4.36	5.63	100.01	28.7	NO	YES	0	0	TRUE	Yes	
7790	3190.12	13.56	16.56	22.21	1.43	3.14	5.65	59.7	28.7	YES	N/A	0	0	TRUE	Yes	
7690	3190.12	13.56	16.56	22.2	1.3	2.79	5.64	61.05	28.7	YES	N/A	0	0	TRUE	Yes	
7589	3190.12	13.53	16.53	22.19	1.21	2.57	5.66	60.49	28.7	YES	N/A	0	0	TRUE	Yes	
7489	3190.12	13.53	16.53	22.18	1.15	2.4	5.65	59.42	28.7	YES	N/A	0	0	TRUE	Yes	
7389	3190.12	13.5	16.5	22.17	1.09	2.26	5.67	60	28.7	YES	N/A	0	0	TRUE	Yes	
7289	3190.12	13.5	16.5	22.16	1.04	2.15	5.66	62.79	28.7	YES	N/A	0	0	TRUE	Yes	
7187	3190.11	13.47	16.47	22.15	1	2.06	5.68	57.21	28.7	YES	N/A	0	0	TRUE	Yes	
7089	3190.11	13.47	16.47	22.14	0.96	1.97	5.67	60	28.7	YES	N/A	0	0	TRUE	Yes	
6989	3190.11	13.44	16.44	22.14	0.92	1.89	5.7	59.75	28.7	YES	N/A	0	0	TRUE	Yes	
6890	3190.11	13.44	16.44	22.13	0.86	1.77	5.69	60.25	28.7	YES	N/A	0	0	TRUE	Yes	
6789	3190.11	13.44	16.44	22.13	0.81	1.67	5.69	60.61	28.7	YES	N/A	0	0	TRUE	Yes	
6689	3190.12	13.41	16.41	22.12	0.79	1.68	5.71	59.52	28.7	YES	N/A	0	0	TRUE	Yes	
6589	3190.12	13.41	16.41	22.11	0.78	1.67	5.7	59.65	28.7	YES	N/A	0	0	TRUE	Yes	

6490	3190.12	13.38	16.38	22.11	0.78	1.63	5.73	60.17	28.7	YES	N/A	0	0	TRUE	Yes
6390	3190.11	13.38	16.38	22.1	0.76	1.6	5.72	60.04	28.7	YES	N/A	0	0	TRUE	Yes
6289	3190.11	13.34	16.34	22.1	0.76	1.58	5.76	60	28.7	YES	N/A	0	0	TRUE	Yes
6189	3190.12	13.34	16.34	22.09	0.75	1.56	5.75	60	28.7	YES	N/A	0	0	TRUE	Yes
6089	3190.12	13.34	16.34	22.08	0.73	1.52	5.74	60	28.7	YES	N/A	0	0	TRUE	Yes
5989	3190.12	13.31	16.31	22.08	0.71	1.47	5.77	60.08	28.7	YES	N/A	0	0	TRUE	Yes
5889	3190.12	13.31	16.31	22.07	0.71	1.47	5.76	59.92	28.7	YES	N/A	0	0	TRUE	Yes
5789	3190.11	13.28	16.28	22.07	0.72	1.45	5.79	59.74	28.7	YES	N/A	0	0	TRUE	Yes
5690	3190.11	13.28	16.28	22.06	0.73	1.49	5.78	60.26	28.7	YES	N/A	0	0	TRUE	Yes
5589	3190.11	13.25	16.25	22.06	0.72	1.47	5.81	60	28.7	YES	N/A	0	0	TRUE	Yes
5489	3190.11	13.25	16.25	22.05	0.71	1.44	5.8	60	28.7	YES	N/A	0	0	TRUE	Yes
5389	3190.11	13.25	16.25	22.05	0.7	1.41	5.8	160	28.7	YES	N/A	0	0	TRUE	Yes
5189	3190.11	13.22	16.22	22.04	0.52	1.39	5.82	200	28.7	YES	N/A	0	0	TRUE	Yes
4989	3190.1	13.19	16.19	22.03	0.28	1.01	5.84	200	28.7	YES	N/A	0	0	TRUE	Yes
4789	3190.13	13.16	16.16	22.02	0.28	0.99	5.86	200	28.7	YES	N/A	0	0	TRUE	Yes
4589	3190.14	13.12	16.12	22.01	0.29	0.97	5.89	198.95	28.7	YES	N/A	0	0	TRUE	Yes
4391	3190.09	13.09	16.09	22.01	0.29	0.88	5.92	199.94	28.7	YES	N/A	0	0	TRUE	Yes
4191	3190.12	13.06	16.06	22	0.28	0.82	5.94	200.73	28.7	YES	N/A	0	0	TRUE	Yes
3990	3190.13	13.03	16.03	22	0.29	0.85	5.97	200.38	28.7	YES	N/A	0	0	TRUE	Yes
3789	3190.09	13.03	16.03	21.99	0.28	0.8	5.96	300	28.7	YES	N/A	0	0	TRUE	Yes
3489	3190.1	12.97	15.97	21.98	0.27	0.73	6.01	300	28.7	YES	N/A	0	0	TRUE	Yes
3189	3190.14	12.94	15.94	21.98	0.23	0.59	6.04	600	28.7	YES	N/A	0	0	TRUE	Yes
2589	3190.11	12.84	15.84	21.97	0.22	0.57	6.13	598.21	28.7	YES	N/A	0	0	TRUE	Yes
1991	3190.09	12.78	15.78	21.96	0.24	0.63	6.18	601.79	28.7	YES	N/A	0	0	TRUE	Yes
1389	3190.12	12.69	15.69	21.95	0.34	0.73	6.26	686.52	28.7	YES	N/A	0	0	TRUE	Yes
703	3190.11	12.59	15.59	21.92	0.59	1.27	6.33	613.48	28.7	YES	N/A	0	0	TRUE	Yes
89	3190.12	12.53	15.53	21.68	1.51	3.76	6.15	0	28.7	YES	N/A	0	0	TRUE	Yes

Operation Criterion:

Headworks: Minimum Depth 3 ft, Maximum Velocity 6 ft/sec
Channel: Minimum Depth 5 ft, Maximum Velocity 4 ft/sec
Bench: Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4

HEC-RAS Model Output
Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
D	1	2338	09JAN1990 2400	3180.12	10	28.7		28.71	0.000016	0.94	3415.18	227.13	0.04	0.17	0.94	0.17
D	1	2308	09JAN1990 2400	3180.12	23	28.52		28.73	0.001064	3.75	847.32	181.07	0.28		3.75	
D	1	2300		Culvert												
D	1	2238	09JAN1990 2400	3180.12	22.75	27.86		28.14	0.00338	4.27	745.29	177.1	0.33		4.27	
D	1	2138	09JAN1990 2400	3180.12	20.62	27.8		28.05	0.002414	3.98	799.65	133.06	0.29		3.98	
D	1	2038	09JAN1990 2400	3180.11	20.41	27.56		27.81	0.002443	3.99	796.63	133.01	0.29		3.99	
D	1	1938	09JAN1990 2400	3180.12	20.16	27.34		27.57	0.002326	3.86	823.44	139.61	0.28		3.86	
D	1	1838	09JAN1990 2400	3180.12	19.91	27.11		27.34	0.002309	3.85	825.38	139.68	0.28		3.85	
D	1	1738	09JAN1990 2400	3180.11	19.69	26.87		27.11	0.002315	3.85	825.05	139.78	0.28		3.85	
D	1	1638	09JAN1990 2400	3180.12	19.44	26.64		26.87	0.002297	3.85	827.03	139.8	0.28		3.85	
D	1	1538	09JAN1990 2400	3180.12	19.19	26.42		26.65	0.002284	3.84	827.88	139.57	0.28		3.84	
D	1	1438	09JAN1990 2400	3180.11	18.97	26.19		26.42	0.002275	3.83	830.04	140.06	0.28		3.83	
D	1	1338	09JAN1990 2400	3180.11	18.72	25.96		26.19	0.002252	3.82	832.21	139.89	0.28		3.82	
D	1	1238	09JAN1990 2400	3180.12	18.49	25.74		25.97	0.002264	3.84	829.2	139.17	0.28		3.84	
D	1	1138	09JAN1990 2400	3180.11	18.25	25.52		25.74	0.002232	3.81	834.32	139.81	0.28		3.81	
D	1	1038	09JAN1990 2400	3180.11	18	25.29		25.52	0.002206	3.8	837.71	140.01	0.27		3.8	
D	1	938	09JAN1990 2400	3180.12	17.77	25.08		25.3	0.002194	3.79	839.74	140.33	0.27		3.79	
D	1	838	09JAN1990 2400	3180.12	17.53	24.86		25.08	0.00217	3.78	841.38	139.8	0.27		3.78	
D	1	710	09JAN1990 2400	3180.11	17.34	24.71		24.93	0.002118	3.74	850.46	141.04	0.27		3.74	
C	1	438	09JAN1990 2400	3185.11	16.91	24.71		24.92	0.001813	3.61	882.63	136.95	0.25		3.61	
C	1	338	09JAN1990 2400	3185.12	16.84	24.52		24.73	0.001905	3.67	867.22	136.02	0.26		3.67	
C	1	267	09JAN1990 2400	3185.12	16.81	24.31		24.54	0.002066	3.78	843.65	135.01	0.27		3.78	
AB	1	9000	09JAN1990 2400	3190.12	13.66	24.31		24.55	0.000693	4.49	965.51	133.89	0.25	2.18	4.49	1.5

AB		1	8928	09JAN1990 2400	3190.12	13.66	24.26		24.5	0.000708	4.52	958.2	133.56	0.25	2.2	4.52	1.5
AB		1	8810	09JAN1990 2400	3190.11	13.66	24.09		24.34	0.000756	4.62	935.69	132.55	0.26	2.24	4.62	1.53
AB		1	5689	09JAN1990 2400	3190.12	13.66	23.9		24.17	0.000812	4.72	910.96	131.35	0.27	2.28	4.72	1.6
AB		1	8589	09JAN1990 2400	3190.12	13.62	23.72		24.01	0.000872	4.87	891.75	130.48	0.28	2.35	4.87	1.65
AB		1	8489	09JAN1990 2400	3190.11	13.62	23.53		23.83	0.000932	4.94	867.71	129.35	0.29	2.4	4.94	1.59
AB		1	8389	09JAN1990 2400	3190.11	13.62	23.32		23.64	0.001016	5.1	841.56	128.22	0.3	2.45	5.1	1.69
AB		1	8289	09JAN1990 2400	3190.12	13.59	23.1		23.43	0.001109	5.25	815.73	126.91	0.31	2.52	5.25	1.74
AB		1	8189	09JAN1990 2400	3190.11	13.59	22.84		23.2	0.001232	5.41	784.05	125.52	0.33	2.59	5.41	1.77
AB		1	8089	09JAN1990 2400	3190.11	13.56	22.55		22.94	0.001394	5.65	751.24	123.83	0.34	2.68	5.65	1.92
AB		1	7989	09JAN1990 2400	3190.12	13.56	22.27		22.66	0.001431	5.61	750.15	126.88	0.35	2.66	5.61	1.82
AB		1	7890	09JAN1990 2400	3190.12	13.56	22.19		22.4	0.000864	4.36	1134.47	238.59	0.27	1.98	4.36	1.59
AB		1	7790	09JAN1990 2400	3190.12	13.56	22.21		22.3	0.000448	3.14	1603.19	291.89	0.19	1.43	3.14	1.52
AB		1	7690	09JAN1990 2400	3190.12	13.56	22.2		22.27	0.000354	2.79	1854.22	338.97	0.17	1.3	2.79	1.36
AB		1	7589	09JAN1990 2400	3190.12	13.53	22.19		22.25	0.000297	2.57	2059.9	377.49	0.16	1.21	2.57	1.25
AB		1	7489	09JAN1990 2400	3190.12	13.53	22.18		22.23	0.000261	2.4	2223.69	408.7	0.15	1.15	2.4	1.17
AB		1	7389	09JAN1990 2400	3190.12	13.5	22.17		22.21	0.000233	2.26	2373.68	437.03	0.14	1.09	2.26	1.11
AB		1	7289	09JAN1990 2400	3190.12	13.5	22.16		22.2	0.000211	2.15	2520.41	465.53	0.13	1.04	2.15	1.06
AB		1	7187	09JAN1990 2400	3190.11	13.47	22.15		22.18	0.000193	2.06	2657	492.17	0.13	1	2.06	1.01
AB		1	7089	09JAN1990 2400	3190.11	13.47	22.14		22.17	0.000177	1.97	2791.99	518.28	0.12	0.96	1.97	0.97
AB		1	6989	09JAN1990 2400	3190.11	13.44	22.14		22.16	0.00016	1.89	2952.84	547.71	0.12	0.92	1.89	0.92
AB		1	6890	09JAN1990 2400	3190.11	13.44	22.13		22.15	0.00014	1.77	3186	592.11	0.11	0.86	1.77	0.86
AB		1	6789	09JAN1990 2400	3190.11	13.44	22.13		22.14	0.000125	1.67	3406.11	637.1	0.1	0.81	1.67	0.82
AB		1	6689	09JAN1990 2400	3190.12	13.41	22.12		22.14	0.000128	1.68	3446.11	671.77	0.1	0.79	1.68	0.82
AB		1	6589	09JAN1990 2400	3190.12	13.41	22.11		22.13	0.000125	1.67	3494.67	679.83	0.1	0.78	1.67	0.81
AB		1	6490	09JAN1990 2400	3190.12	13.38	22.11		22.12	0.00012	1.63	3554.49	688.8	0.1	0.78	1.63	0.79
AB		1	6390	09JAN1990 2400	3190.11	13.38	22.1		22.12	0.000115	1.6	3638.56	702.56	0.1	0.76	1.6	0.77
AB		1	6289	09JAN1990 2400	3190.11	13.34	22.1		22.11	0.000111	1.58	3673.81	703.49	0.1	0.76	1.58	0.76
AB		1	6189	09JAN1990 2400	3190.12	13.34	22.09		22.11	0.000109	1.56	3719.38	710.52	0.1	0.75	1.56	0.76
AB		1	6089	09JAN1990 2400	3190.12	13.34	22.08		22.1	0.000103	1.52	3816.72	726.79	0.09	0.73	1.52	0.75
AB		1	5989	09JAN1990 2400	3190.12	13.31	22.08		22.09	0.000096	1.47	3951.59	745.94	0.09	0.71	1.47	0.72
AB		1	5889	09JAN1990 2400	3190.12	13.31	22.07		22.09	0.000096	1.47	3936.08	738.37	0.09	0.71	1.47	0.72
AB		1	5789	09JAN1990 2400	3190.11	13.28	22.07		22.08	0.000096	1.45	3917.34	731.59	0.09	0.72	1.45	0.72
AB		1	5690	09JAN1990 2400	3190.11	13.28	22.06		22.08	0.000097	1.49	3895	727.59	0.09	0.73	1.49	0.72
AB		1	5589	09JAN1990 2400	3190.11	13.25	22.06		22.07	0.000096	1.47	3939.32	738.11	0.09	0.72	1.47	0.71
AB		1	5489	09JAN1990 2400	3190.11	13.25	22.05		22.07	0.000093	1.44	4012.8	754.54	0.09	0.71	1.44	0.7
AB		1	5389	09JAN1990 2400	3190.11	13.25	22.05		22.06	0.000089	1.41	4112.17	776.57	0.09	0.7	1.41	0.68
AB		1	5189	09JAN1990 2400	3190.11	13.22	22.04		22.05	0.000085	1.39	4613.3	1031.42	0.08	0.52	1.39	0.66
AB		1	4989	09JAN1990 2400	3190.1	13.19	22.03		22.03	0.000045	1.01	8085.57	2846.77	0.06	0.28	1.01	0.49
AB		1	4789	09JAN1990 2400	3190.13	13.16	22.02		22.03	0.000044	0.99	8163.31	2825.57	0.06	0.28	0.99	0.48
AB		1	4589	09JAN1990 2400	3190.14	13.12	22.01		22.02	0.000043	0.97	8250.16	2811.58	0.06	0.29	0.97	0.48
AB		1	4391	09JAN1990 2400	3190.09	13.09	22.01		22.01	0.000034	0.88	9049.05	2787.24	0.05	0.29	0.88	0.43
AB		1	4191	09JAN1990 2400	3190.12	13.06	22		22	0.00003	0.82	9561.01	2795.88	0.05	0.28	0.82	0.41
AB		1	3990	09JAN1990 2400	3190.13	13.03	22		22	0.000031	0.85	9408.61	2810.74	0.05	0.29	0.85	0.42
AB		1	3789	09JAN1990 2400	3190.09	13.03	21.99		21.99	0.000029	0.8	9736.27	2830.86	0.05	0.28	0.8	0.39
AB		1	3489	09JAN1990 2400	3190.1	12.97	21.98		21.99	0.000023	0.73	11711.5	3849.76	0.04	0.27	0.73	0.19
AB		1	3189	09JAN1990 2400	3190.14	12.94	21.98		21.98	0.000015	0.59	14025.1	4122.62	0.04	0.23	0.59	0.19
AB		1	2589	09JAN1990 2400	3190.11	12.84	21.97		21.97	0.000014	0.57	15389	5004.53	0.03	0.22	0.57	0.17
AB		1	1991	09JAN1990 2400	3190.09	12.78	21.96		21.96	0.000017	0.63	14452.4	5120.12	0.04	0.24	0.63	0.18
AB		1	1389	09JAN1990 2400	3190.12	12.69	21.95		21.95	0.000022	0.73	12437.7	4757.25	0.04	0.34	0.73	0.19
AB		1	703	09JAN1990 2400	3190.11	12.59	21.92		21.93	0.000065	1.27	8185.22	4502.03	0.08	0.59	1.27	0.26
AB		1	89	09JAN1990 2400	3190.12	12.53	21.68	17.43	21.82	0.000589	3.76	2686.42	4366.34	0.23	1.51	3.76	0.33

Four XS Culvert

Channel	Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (cfs)
D		1	2338 09JAN1990 2400	28.71	28.7	0.01	0.05		4.36	3171.4	4.36	227.13
D		1	2308 09JAN1990 2400	28.73	28.52	0.22				3180.12		181.07
D		1	2300	Culvert								

D		1	2238	09JAN1990 2400	28.14	27.86	0.28	0.09			3180.12		177.1
D		1	2138	09JAN1990 2400	28.05	27.8	0.25	0.24			3180.12		133.06

							Culvert Only								
Channel	Reach	River Sta	Profile	E.G. US.	W.S. US.	EG. IC	E.G. OC	Min El Weir	Q Culv Group	Q Weir	Delta WS	Culv Vel US	Culv Vel DS		
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)		
C		2 2300	Culverts 09JAN1990 2400	28.68	28.52	27.66	28.68	31.81	3180.12		0.66	5.96	5.66		

System Capacity Evalualtion (Max stage 31.7', ~3900 cfs)

Multiple Channel Alternative with Gated Culverts

Operational Range of Sacramento River Stage Meeting Fish Passage Criterion* 19.61 ft to 28.7 ft

HEC-RAS XS #	Flow to Achieve Bench Criterion in System (cfs)	Channel Invert Elevation (ft)	Bench Invert Elevation (ft)	Water Surface Elevation (ft)	Velocity Bench (ft/s)	Velocity Channel (ft/s)	Water Depth at Bench (ft)	Reach Length (ft)	Water Surface Elevation in Sac. River (ft)	Channel Passage Logic	Bench Logic	Length of Reach w/ Vel. >4 ft/s Logic	Length of Reach w/ Vel. >4 ft/s	Design Criterion Logic	Design Criterion Met	Max Velocity (channel) (ft/s)	*Max Velocity (Bench) (ft/s)
Headworks																	
1850	3863	10.00	N/A	31.70	N/A	0.97	N/A	100	31.7	YES	N/A	0	0	TRUE	Yes	8.00	3.09
1820	3863	23.00	N/A	31.47	N/A	4.8	N/A	68.5	31.7	YES	N/A	0	0	TRUE	Yes	*Bench never exceeds 4 ft/s	
1800	Structure: 6 D Culverts Open																
1750	3863	22.75	N/A	28.37	N/A	8.0	N/A	31	31.7	NO	NO	31	131	FALSE	No		
D-1 Channel																	
1650	3863	20.62	N/A	28.61	N/A	4.25	N/A	100	31.7	NO	NO	100	231	FALSE	No		
1550	3863	20.41	N/A	28.37	N/A	4.26	N/A	100	31.7	NO	NO	100	300	FALSE	No		
1450	3863	20.16	N/A	28.15	N/A	4.12	N/A	100	31.7	NO	NO	100	300	FALSE	No		
1350	3863	19.91	N/A	27.91	N/A	4.11	N/A	100	31.7	NO	NO	100	300	FALSE	No		
1250	3863	19.69	N/A	27.68	N/A	4.11	N/A	100	31.7	NO	NO	100	300	FALSE	No		
1150	3863	19.44	N/A	27.45	N/A	4.10	N/A	100	31.7	NO	NO	100	300	FALSE	No		
1050	3863	19.19	N/A	27.22	N/A	4.10	N/A	100	31.7	NO	NO	100	300	FALSE	No		
950	3863	18.97	N/A	26.99	N/A	4.09	N/A	100	31.7	NO	NO	100	300	FALSE	No		
850	3863	18.72	N/A	26.76	N/A	4.09	N/A	100	31.7	NO	NO	100	300	FALSE	No		
750	3863	18.49	N/A	26.52	N/A	4.11	N/A	100	31.7	NO	NO	100	300	FALSE	No		
650	3863	18.25	N/A	26.30	N/A	4.08	N/A	100	31.7	NO	NO	100	300	FALSE	No		
550	3863	18.00	N/A	26.07	N/A	4.07	N/A	100	31.7	NO	NO	100	300	FALSE	No		
450	3863	17.77	N/A	25.85	N/A	4.07	N/A	100	31.7	NO	NO	100	270	FALSE	No		
350	3863	17.53	N/A	25.62	N/A	4.07	N/A	70	31.7	NO	NO	70	450	FALSE	No		
281	3863	17.34	N/A	25.47	N/A	4.03	N/A	281	31.7	NO	NO	281	350	FALSE	No		
C-1 Channel																	
438	3868	16.91	N/A	25.47	N/A	3.92	N/A	100	31.7	YES	N/A	0	0	TRUE	Yes		
338	3868	16.84	N/A	25.27	N/A	3.99	N/A	98	31.7	YES	N/A	0	0	TRUE	Yes		
267	3868	16.81	N/A	25.04	N/A	4.10	N/A	191	31.7	NO	NO	191	191	FALSE	No		
AB-1 Channel																	
9000	3873	13.66	16.66	25.04	2.44	4.99	8.38	74	31.7	NO	YES	0	0	TRUE	Yes		
8928	3873	13.66	16.66	24.98	2.46	5.02	8.32	218	31.7	NO	YES	0	0	TRUE	Yes		
8810	3873	13.66	16.66	24.79	2.51	5.14	8.13	221	31.7	NO	YES	0	0	TRUE	Yes		
5689	3873	13.66	16.66	24.58	2.56	5.27	7.92	200	31.7	NO	YES	0	0	TRUE	Yes		
8589	3873	13.62	16.62	24.37	2.64	5.45	7.75	200	31.7	NO	YES	0	0	TRUE	Yes		
8489	3873	13.62	16.62	24.15	2.7	5.54	7.53	200	31.7	NO	YES	0	0	TRUE	Yes		
8389	3873	13.62	16.62	23.90	2.77	5.73	7.28	200	31.7	NO	YES	0	0	TRUE	Yes		
8289	3873	13.59	16.59	23.63	2.86	5.92	7.04	200	31.7	NO	YES	0	0	TRUE	Yes		
8189	3873	13.59	16.49	23.33	2.95	6.13	6.84	200	31.7	NO	YES	0	0	TRUE	Yes		
8089	3873	13.56	16.31	22.97	3.08	6.46	6.66	200	31.7	NO	YES	0	0	TRUE	Yes		
7989	3873	13.56	15.81	22.61	3.09	6.48	6.80	199	31.7	NO	YES	0	0	TRUE	Yes		
7890	3873	13.56	16.56	22.52	2.26	4.97	5.96	100	31.7	NO	YES	0	0	TRUE	Yes		
7790	3873	13.56	16.56	22.54	1.65	3.60	5.98	60	31.7	YES	N/A	0	0	TRUE	Yes		
7689	3873	13.56	16.56	22.54	1.49	3.19	5.98	61	31.7	YES	N/A	0	0	TRUE	Yes		
7589	3873	13.53	16.53	22.52	1.39	2.93	5.99	60	31.7	YES	N/A	0	0	TRUE	Yes		
7489	3873	13.53	16.53	22.51	1.32	2.74	5.98	59	31.7	YES	N/A	0	0	TRUE	Yes		
7389	3873	13.50	16.50	22.50	1.26	2.57	6.00	60	31.7	YES	N/A	0	0	TRUE	Yes		
7289	3873	13.50	16.50	22.49	1.2	2.46	5.99	63	31.7	YES	N/A	0	0	TRUE	Yes		
7187	3873	13.47	16.47	22.48	1.15	2.35	6.01	57	31.7	YES	N/A	0	0	TRUE	Yes		
7089	3873	13.47	16.47	22.47	1.1	2.25	6.00	60	31.7	YES	N/A	0	0	TRUE	Yes		
6989	3873	13.44	16.44	22.46	1.06	2.15	6.02	60	31.7	YES	N/A	0	0	TRUE	Yes		
6890	3873	13.44	16.44	22.45	1	2.01	6.01	60	31.7	YES	N/A	0	0	TRUE	Yes		
6789	3873	13.44	16.44	22.45	0.94	1.90	6.01	61	31.7	YES	N/A	0	0	TRUE	Yes		

6689	3873	13.41	16.41	22.44	0.91	1.91	6.03	60	31.7	YES	N/A	0	0	TRUE	Yes			
6589	3873	13.41	16.41	22.43	0.9	1.89	6.02	60	31.7	YES	N/A	0	0	TRUE	Yes			
6490	3873	13.38	16.38	22.42	0.89	1.85	6.04	60	31.7	YES	N/A	0	0	TRUE	Yes			
6390	3873	13.38	16.38	22.41	0.88	1.82	6.03	60	31.7	YES	N/A	0	0	TRUE	Yes			
6289	3873	13.34	16.34	22.41	0.87	1.79	6.07	60	31.7	YES	N/A	0	0	TRUE	Yes			
6189	3873	13.34	16.34	22.40	0.86	1.77	6.06	60	31.7	YES	N/A	0	0	TRUE	Yes			
6089	3873	13.34	16.34	22.39	0.84	1.73	6.05	60	31.7	YES	N/A	0	0	TRUE	Yes			
5989	3873	13.31	16.31	22.39	0.82	1.67	6.08	60	31.7	YES	N/A	0	0	TRUE	Yes			
5889	3873	13.31	16.31	22.38	0.82	1.67	6.07	60	31.7	YES	N/A	0	0	TRUE	Yes			
5789	3873	13.28	16.28	22.37	0.83	1.66	6.09	60	31.7	YES	N/A	0	0	TRUE	Yes			
5690	3873	13.28	16.28	22.37	0.84	1.70	6.09	60	31.7	YES	N/A	0	0	TRUE	Yes			
5589	3873	13.25	16.25	22.36	0.83	1.67	6.11	60	31.7	YES	N/A	0	0	TRUE	Yes			
5489	3873	13.25	16.25	22.35	0.82	1.64	6.10	60	31.7	YES	N/A	0	0	TRUE	Yes			
5389	3873	13.25	16.25	22.35	0.8	1.61	6.10	160	31.7	YES	N/A	0	0	TRUE	Yes			
5189	3874	13.22	16.22	22.34	0.6	1.56	6.12	200	31.7	YES	N/A	0	0	TRUE	Yes			
4989	3873	13.19	16.19	22.33	0.32	1.09	6.14	201	31.7	YES	N/A	0	0	TRUE	Yes			
4789	3874	13.16	16.16	22.32	0.32	1.07	6.16	202	31.7	YES	N/A	0	0	TRUE	Yes			
4589	3874	13.12	16.12	22.31	0.33	1.05	6.19	203	31.7	YES	N/A	0	0	TRUE	Yes			
4391	3874	13.09	16.09	22.30	0.33	0.95	6.21	204	31.7	YES	N/A	0	0	TRUE	Yes			
4191	3873	13.06	16.06	22.30	0.32	0.90	6.24	205	31.7	YES	N/A	0	0	TRUE	Yes			
3990	3874	13.03	16.03	22.29	0.33	0.93	6.26	206	31.7	YES	N/A	0	0	TRUE	Yes			
3789	3873	13.03	16.03	22.28	0.32	0.88	6.25	207	31.7	YES	N/A	0	0	TRUE	Yes			
3489	3874	12.97	15.97	22.28	0.3	0.79	6.31	208	31.7	YES	N/A	0	0	TRUE	Yes			
3189	3873	12.94	15.94	22.27	0.25	0.64	6.33	209	31.7	YES	N/A	0	0	TRUE	Yes			
2589	3873	12.84	15.84	22.26	0.24	0.62	6.42	210	31.7	YES	N/A	0	0	TRUE	Yes			
1991	3874	12.78	15.78	22.25	0.27	0.67	6.47	211	31.7	YES	N/A	0	0	TRUE	Yes			
1389	3874	12.69	15.69	22.24	0.37	0.78	6.55	212	31.7	YES	N/A	0	0	TRUE	Yes			
703	3873	12.59	15.59	22.21	0.62	1.30	6.62	213	31.7	YES	N/A	0	0	TRUE	Yes			
89	3874	12.53	15.53	22.02	1.39	3.39	6.49	214	31.7	YES	N/A	0	0	TRUE	Yes			

	Operation Criterion:		Headworks:	Minimum Depth 3 ft, Maximum Velocity 6 ft/sec
			Channel:	Minimum Depth 5 ft, Maximum Velocity 4 ft/sec
			Bench:	Minimum Depth 5 ft (when channel velocity of 4 ft/sec is exceeded), Maximum Velocity 4

HEC-RAS Model Output

Standard Table 1

Channel	Reach	XS #	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Are	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)
D	1	1850	01JAN1990 240	3863.49	10	31.7		31.71	0.000013	0.97	4108.5	242.84	0.04	0.24	0.97	0.24
D	1	1820	01JAN1990 240	3863.49	23	31.47		31.82	0.000969	4.8	804.29	253.94	0.29		4.8	
D	1	1800		Culvert												
D	1	1750	01JAN1990 240	3863.49	22.75	28.37		29.36	0.010456	8	482.92	180.16	0.6		8	
D	1	1650	01JAN1990 240	3863.49	20.62	28.61		28.89	0.002437	4.25	909.51	137.91	0.29		4.25	
D	1	1550	01JAN1990 240	3863.49	20.41	28.37		28.65	0.00247	4.26	906.1	138	0.29		4.26	
D	1	1450	01JAN1990 240	3863.49	20.16	28.15		28.41	0.002341	4.12	938.68	145.22	0.29		4.12	
D	1	1350	01JAN1990 240	3863.49	19.91	27.91		28.18	0.002328	4.11	940.4	145.27	0.28		4.11	
D	1	1250	01JAN1990 240	3863.49	19.69	27.68		27.94	0.002335	4.11	939.84	145.38	0.29		4.11	
D	1	1150	01JAN1990 240	3863.49	19.44	27.45		27.71	0.00232	4.1	941.46	145.29	0.28		4.1	
D	1	1050	01JAN1990 240	3863.49	19.19	27.22		27.48	0.002315	4.1	941.71	145.12	0.28		4.1	
D	1	950	01JAN1990 240	3863.49	18.97	26.99		27.25	0.002308	4.09	943.81	145.63	0.28		4.09	
D	1	850	01JAN1990 240	3863.49	18.72	26.76		27.02	0.002291	4.09	945.23	145.36	0.28		4.09	
D	1	750	01JAN1990 240	3863.49	18.49	26.52		26.79	0.00231	4.11	940.93	144.57	0.28		4.11	
D	1	650	01JAN1990 240	3863.49	18.25	26.3		26.56	0.002283	4.08	945.84	145.19	0.28		4.08	
D	1	550	01JAN1990 240	3863.49	18	26.07		26.33	0.002266	4.07	948.55	145.44	0.28		4.07	
D	1	450	01JAN1990 240	3863.49	17.77	25.85		26.1	0.00226	4.07	949.81	145.62	0.28		4.07	

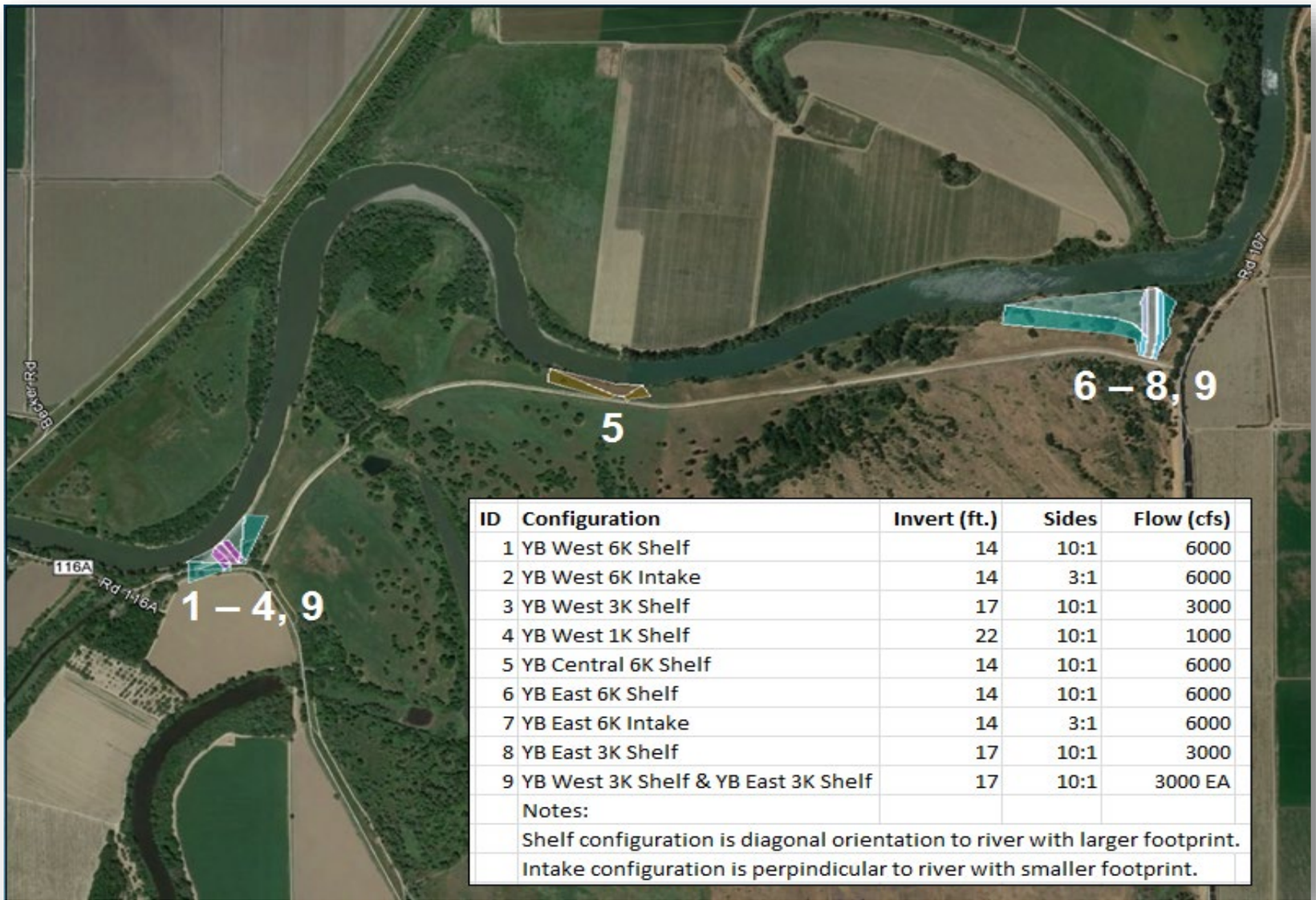
D	1	350	01JAN1990 240	3863.49	17.53	25.62		25.88	0.002247	4.07	949.84	144.95	0.28		4.07			
D	1	281	01JAN1990 240	3863.49	17.34	25.47		25.72	0.002199	4.03	959.1	146.19	0.28		4.03			
C	1	438	01JAN1990 240	3868.49	16.91	25.47		25.71	0.001921	3.92	987.94	141.47	0.26		3.92			
C	1	338	01JAN1990 240	3868.49	16.84	25.27		25.51	0.002022	3.99	970.04	140.47	0.27		3.99			
C	1	267	01JAN1990 240	3868.49	16.81	25.04		25.31	0.002192	4.1	943.8	139.42	0.28		4.1			
AB	1	9000	01JAN1990 240	3873.49	13.66	25.04		25.34	0.000779	4.99	1064.8	138.25	0.27	2.44	4.99	1.69		
AB	1	8928	01JAN1990 240	3873.49	13.66	24.98		25.28	0.000797	5.02	1056.3	137.88	0.27	2.46	5.02	1.7		
AB	1	8810	01JAN1990 240	3873.49	13.66	24.79		25.1	0.000855	5.14	1029.9	136.73	0.28	2.51	5.14	1.73		
AB	1	5689	01JAN1990 240	3873.49	13.66	24.58		24.91	0.000923	5.27	1000.7	135.4	0.29	2.56	5.27	1.81		
AB	1	8589	01JAN1990 240	3873.49	13.62	24.37		24.72	0.000998	5.45	977.2	134.35	0.3	2.64	5.45	1.87		
AB	1	8489	01JAN1990 240	3873.49	13.62	24.15		24.51	0.001074	5.54	948.38	133.04	0.31	2.7	5.54	1.82		
AB	1	8389	01JAN1990 240	3873.49	13.62	23.9		24.29	0.001182	5.73	916.8	131.68	0.32	2.77	5.73	1.93		
AB	1	8289	01JAN1990 240	3873.49	13.59	23.63		24.05	0.001305	5.92	884.71	130.15	0.34	2.86	5.92	1.99		
AB	1	8189	01JAN1990 240	3873.49	13.59	23.33		23.78	0.001472	6.13	845.56	128.41	0.36	2.95	6.13	2.04		
AB	1	8089	01JAN1990 240	3873.49	13.56	22.97		23.48	0.001705	6.46	803.4	126.34	0.38	3.08	6.46	2.22		
AB	1	7989	01JAN1990 240	3873.49	13.56	22.61		23.13	0.001804	6.48	793.74	129.58	0.39	3.09	6.48	2.08		
AB	1	7890	01JAN1990 240	3873.49	13.56	22.52		22.78	0.001065	4.97	1213.6	242.13	0.3	2.26	4.97	1.86		
AB	1	7790	01JAN1990 240	3873.49	13.56	22.54		22.66	0.000556	3.6	1701.3	295.33	0.22	1.65	3.6	1.76		
AB	1	7689	01JAN1990 240	3873.49	13.56	22.54		22.62	0.000438	3.19	1968.1	342.35	0.19	1.49	3.19	1.57		
AB	1	7589	01JAN1990 240	3873.49	13.53	22.52		22.6	0.000367	2.93	2186	380.85	0.18	1.39	2.93	1.45		
AB	1	7489	01JAN1990 240	3873.49	13.53	22.51		22.57	0.000322	2.74	2359.3	412.07	0.17	1.32	2.74	1.35		
AB	1	7389	01JAN1990 240	3873.49	13.5	22.5		22.55	0.000287	2.57	2517.7	440.29	0.16	1.26	2.57	1.28		
AB	1	7289	01JAN1990 240	3873.49	13.5	22.49		22.53	0.00026	2.46	2672.9	468.81	0.15	1.2	2.46	1.22		
AB	1	7187	01JAN1990 240	3873.49	13.47	22.48		22.52	0.000238	2.35	2817.1	495.4	0.14	1.15	2.35	1.16		
AB	1	7089	01JAN1990 240	3873.49	13.47	22.47		22.5	0.000219	2.25	2959.8	521.52	0.14	1.1	2.25	1.12		
AB	1	6989	01JAN1990 240	3873.49	13.44	22.46		22.49	0.000198	2.15	3129.2	550.94	0.13	1.06	2.15	1.06		
AB	1	6890	01JAN1990 240	3873.49	13.44	22.45		22.48	0.000173	2.01	3376	595.36	0.12	1	2.01	1		
AB	1	6789	01JAN1990 240	3873.49	13.44	22.45		22.47	0.000154	1.9	3609.8	640.39	0.11	0.94	1.9	0.94		
AB	1	6689	01JAN1990 240	3873.49	13.41	22.44		22.46	0.000156	1.91	3659.7	674.99	0.12	0.91	1.91	0.95		
AB	1	6589	01JAN1990 240	3873.49	13.41	22.43		22.45	0.000153	1.89	3709.9	682.99	0.11	0.9	1.89	0.93		
AB	1	6490	01JAN1990 240	3873.49	13.38	22.42		22.44	0.000147	1.85	3771.7	692.01	0.11	0.89	1.85	0.9		
AB	1	6390	01JAN1990 240	3873.49	13.38	22.41		22.44	0.000141	1.82	3859.2	705.7	0.11	0.88	1.82	0.88		
AB	1	6289	01JAN1990 240	3873.49	13.34	22.41		22.43	0.000137	1.79	3893.8	706.63	0.11	0.87	1.79	0.87		
AB	1	6189	01JAN1990 240	3873.49	13.34	22.4		22.42	0.000134	1.77	3940.7	713.69	0.11	0.86	1.77	0.87		
AB	1	6089	01JAN1990 240	3873.49	13.34	22.39		22.41	0.000128	1.73	4042.3	729.91	0.1	0.84	1.73	0.86		
AB	1	5989	01JAN1990 240	3873.48	13.31	22.39		22.41	0.000119	1.67	4182.3	749.11	0.1	0.82	1.67	0.83		
AB	1	5889	01JAN1990 240	3873.48	13.31	22.38		22.4	0.000119	1.67	4163.3	741.49	0.1	0.82	1.67	0.83		
AB	1	5789	01JAN1990 240	3873.48	13.28	22.37		22.39	0.000119	1.66	4141.4	734.71	0.1	0.83	1.66	0.83		
AB	1	5690	01JAN1990 240	3873.48	13.28	22.37		22.39	0.000121	1.7	4116.9	730.67	0.1	0.84	1.7	0.83		
AB	1	5589	01JAN1990 240	3873.49	13.25	22.36		22.38	0.000119	1.67	4163.5	741.19	0.1	0.83	1.67	0.82		
AB	1	5489	01JAN1990 240	3873.49	13.25	22.35		22.37	0.000115	1.64	4241.1	757.62	0.1	0.82	1.64	0.81		
AB	1	5389	01JAN1990 240	3873.49	13.25	22.35		22.37	0.00011	1.61	4346.4	779.63	0.1	0.8	1.61	0.79		
AB	1	5189	01JAN1990 240	3873.5	13.22	22.34		22.35	0.000103	1.56	4922.2	1035.34	0.09	0.6	1.56	0.76		
AB	1	4989	01JAN1990 240	3873.49	13.19	22.33		22.33	0.00005	1.09	8936.4	2852.92	0.07	0.32	1.09	0.53		
AB	1	4789	01JAN1990 240	3873.5	13.16	22.32		22.32	0.000049	1.07	9004.9	2829.02	0.06	0.32	1.07	0.53		
AB	1	4589	01JAN1990 240	3873.52	13.12	22.31		22.32	0.000048	1.05	9084.9	2815.1	0.06	0.33	1.05	0.53		
AB	1	4391	01JAN1990 240	3873.51	13.09	22.3		22.31	0.000039	0.95	9874.5	2793.05	0.06	0.33	0.95	0.48		
AB	1	4191	01JAN1990 240	3873.49	13.06	22.3		22.3	0.000034	0.9	10387	2800.22	0.05	0.32	0.9	0.45		
AB	1	3990	01JAN1990 240	3873.5	13.03	22.29		22.29	0.000036	0.93	10236	2815.75	0.06	0.33	0.93	0.46		
AB	1	3789	01JAN1990 240	3873.49	13.03	22.28		22.29	0.000033	0.88	10568	2835.7	0.05	0.32	0.88	0.44		
AB	1	3489	01JAN1990 240	3873.5	12.97	22.28		22.28	0.000026	0.79	12839	3854.99	0.05	0.3	0.79	0.22		
AB	1	3189	01JAN1990 240	3873.48	12.94	22.27		22.27	0.000017	0.64	15230	4124.96	0.04	0.25	0.64	0.22		
AB	1	2589	01JAN1990 240	3873.49	12.84	22.26		22.26	0.000015	0.62	16847	5009.81	0.04	0.24	0.62	0.19		
AB	1	1991	01JAN1990 240	3873.52	12.78	22.25		22.25	0.000018	0.67	15939	5122.83	0.04	0.27	0.67	0.2		
AB	1	1389	01JAN1990 240	3873.5	12.69	22.24		22.24	0.000024	0.78	13814	4759.15	0.05	0.37	0.78	0.22		
AB	1	703	01JAN1990 240	3873.49	12.59	22.21		22.21	0.000066	1.3	9484.4	4504.38	0.08	0.62	1.3	0.29		
AB	1	89	01JAN1990 240	3873.51	12.53	22.02	17.83	22.11	0.000456	3.39	4176.1	4369.94	0.2	1.39	3.39	0.44		

Four XS Culvert																		
Channel	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width						
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(cfs)						
D	1	1850	01JAN1990 240	31.71	31.7	0.01	0.05		16.88	3829.73	16.88	242.84						
D	1	1820	01JAN1990 240	31.82	31.47	0.36				3863.49		253.94						
D	1	1800		Culvert														
D	1	1750	01JAN1990 240	29.36	28.37	0.99	0.2			3863.49		180.16						
D	1	1650	01JAN1990 240	28.89	28.61	0.28	0.25			3863.49		137.91						
Culvert Only																		
Channel	Reach	River Sta	Profile	E.G. US.	W.S. US.	EG. IC	E.G. OC	Min El W	Q Culv Group	Q Weir	Delta W	Culv Vel US	Culv Vel DS					
				(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)					
D	1	1800 Culverts C	01JAN1990 240	31.72	31.47	30.96	31.72	31.81	3863.49		3.1	12.01	11.47					

Appendix A
Gate Sizing and Headworks Flow
Appendix A9

Fish Behavior Input Data

Provided by DWR to USACE on 4/20/2016



ID	Configuration	Invert (ft.)	Sides	Flow (cfs)
1	YB West 6K Shelf	14	10:1	6000
2	YB West 6K Intake	14	3:1	6000
3	YB West 3K Shelf	17	10:1	3000
4	YB West 1K Shelf	22	10:1	1000
5	YB Central 6K Shelf	14	10:1	6000
6	YB East 6K Shelf	14	10:1	6000
7	YB East 6K Intake	14	3:1	6000
8	YB East 3K Shelf	17	10:1	3000
9	YB West 3K Shelf & YB East 3K Shelf	17	10:1	3000 EA
	Notes:			
	Shelf configuration is diagonal orientation to river with larger footprint.			
	Intake configuration is perpindicular to river with smaller footprint.			

STAGE-FLOW RATING CURVE

Stage (ft)	Invert at 14' Discharge (ft^3/sec)
14.5	10
15	22
16	45
17	115
18	179
19	354
20	560
21	860
22	1269
23	1769
24	2376
25	3080
26	3888
27	4798
28	5793
28.9	**6000**

* Run using HEC RAS [2016 0405 East_Alignment with modified opening to match a 36-ft opening from inv 14-ft to 29-ft and 46-ft opening from inv 20-ft to 29-ft]

STAGE-FLOW RATING CURVE

Stage (ft)	Invert at 14' Discharge (ft^3/sec)
17	1
18	19
19	68
20	152
21	275
22	441
23	657
24	927
25	1255
26	1645
27	2102
28	2630
29	3232

*Values provided by open channel flow calculator on www.engineering.com using criteria:
Slope 0.0016, Channel Bottom Width 10', Channel Top Width 100', Channel Height 15', n value 0.035

STAGE-FLOW RATING CURVE

Stage (ft)	Invert at 22' Discharge (ft^3/sec)
23.5	16
24	37
25	93
26	179
27	291
28	416
29	590
30	823
31	974

*This rating curve was derived from the HEC RAS 5.0 (non-beta version)model "v2 RAS_YB_Passive_Intake_FPO_feb_19_2016" performed by HDR. {10' [h] x 15' [w] opening @ inv. 22}

Appendix B

Assessments of Seepage and Landside Slope Stability Analyses Results of the Existing Yolo Bypass East Levee, Yolo Bypass Salmonid Habitat Restoration and Fish Passage (Big Notch) Project

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

[i]**State of California** **California Natural Resources Agency**

M e m o r a n d u m

Date: January 27, 2022

To: Maninder Bahia, Project Manager
Supervising Engineer, W.R.
State Water Project Ecosystem Improvements Branch
Division of Integrated Science and Engineering

Youssef Awad, Senior Engineer, W.R.
Geotechnical Engineering Section
Division of Engineering

From: **Department of Water Resources**

Subject: Assessments of Seepage and Landside Slope Stability Analyses Results of the Existing Yolo Bypass East Levee, Yolo Bypass Salmonid Habitat Restoration and Fish Passage (Big Notch) Project.

1. Project Description

The Department of Water Resources (DWR) Division of Integrated Science and Engineering (DISE), State Water Project Ecosystem Improvements Branch requested the Division of Engineering (DOE), Geotechnical Engineering Section to assess potential seepage and stability impacts on the existing Yolo Bypass East Levee (East Levee) because of implementing the Yolo Bypass Salmonid Habitat Restoration and Fish Passage (Big Notch) Project.

The Big Notch Project will allow increased flow from Sacramento River to enter the Yolo Bypass through a 0.2-mile-long excavated channel (Intake Channel) and a proposed gated headworks control structure (Headworks Structure) constructed along the east end of Fremont Weir. The new gated structure will connect to the northern end of existing Tule Pond with a 0.5-mile-long excavated channel (Transport Channel) that parallels the waterside of East Levee.

From the southern end of Tule Pond, the project will connect to the existing Tule Canal with a 0.7-mile-long excavated channel (Tule Channel) that generally parallels the existing East Levee. The proposed alignment of the proposed Intake Channel is approximately 300 feet to 500 feet away from the Yolo Bypass East Levee centerline with an invert elevation at about 12.5 feet. The proposed alignment of the Transport Channel is approximately 200 feet to 300 feet away from the East Levee centerline with an invert elevation at approximately 12.5 feet.

SURNAME DWR 155 (Rev 11/04)	Author: Gopalan Vishnan, P.E., G.E. REG. C.E. No. 71918	Co-Author: Matthew Havey, P.E. REG. C.E. No. 92315	Checked: Youssef Awad, P.E. REG. C.E. No. 62322	Section Manger: Tim Wehling, P.E. REG. C.E. No. 65001
	Gopalan Vishnan 1/27/2022	Matthew Havey 1/27/2022	 1/27/2022	Tim Wehling 1/27/2022

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

The Tule Channel centerline is approximately 300 to 600 feet away from the East Levee centerline with an invert elevation of 10 feet. The bottom of the channel will have a one-foot-thick riprap erosion protection underlain by a one-foot-thick sand bedding. Intake Channel and Transport Channel will have side slopes of 3H:1V (horizontal:vertical) on both sides, with a one-foot thick riprap layer for side slope protection underlain by geotextile fabric. The Tule Channel will have a 3H:1V side slope on the west side only; the east side of the channel will generally maintain the existing slope configuration. It will have the same riprap side slope protection and underlayment as other channels.

Figure 1 shows the proposed components of the project. The project will allow flows of up to approximately 6,000 cubic feet per second (cfs) from Sacramento River through the gated structure to provide an open channel flow for adult fish passage, juvenile emigration, and floodplain inundation. The project will also include a new Supplemental Fish Passage Channel and Headworks on the west end of Fremont Weir, improvements to Agricultural Road Crossing 1, which is located south of Tule Channel, and a Pedestrian Bridge Crossing across the Transport Channel, approximately 2,000 feet south of Headworks Structure. The Supplemental Fish Passage Channel will exist approximately 1.45 miles west of the East Levee and DOE does not expect it to impact the seepage and stability of the East Levee.

The project area is located within Yolo County, California, which includes a portion of the lower Sacramento River basin, Fremont Weir, Yolo Bypass, Tule Pond, Tule Canal, and the Yolo Bypass East Levee adjacent to Reclamation District 1600 (Figure 1). It also includes the Yolo Bypass, a designated floodway, which receives floodwater during periods of elevated stage from Sacramento River and tributaries.

2. Scope of Work

Our scope of work focuses on using available geotechnical data to assess potential seepage and stability impacts on the existing East Levee because of the construction of the proposed gated headworks structure and channels. To meet the scope, we have performed the following tasks.

- Reviewed available exploration data (soil borings, CPTs, and geophysical survey data), geotechnical reports, and previous construction plans within the site vicinity.
- Performed geotechnical explorations within the vicinity of the East Levee. These included seven CPT soundings and 16 soil borings.
- Carried out Laboratory testing on selected soil samples obtained from the soil borings.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

- Identified critical cross section locations capturing the geotechnical, geological, and geometric factors. We created cross sections at six critical locations along the East Levee to complete the steady state seepage and static landside slope stability analyses (see Figures 2 and 3).
- Performed steady state seepage and slope stability analyses to assess the potential impact of proposed channel construction on the performance of the existing East Levee.

3. Exploration Data

Previous Geotechnical Explorations and Geophysical Survey within the Study Area

Three, 50-foot-deep soil borings were drilled as part of the Fremont Weir Adult Fish Passage Modification Project geotechnical investigation in May 2017 (DWR, 2017). Figures 2 and 3 show the three boring locations (Borings FW-DH-01, FW-DH-08, and FW-DH-11.

Figures 2 and 3 show four, 100-foot-deep CPT soundings that were pushed into the ground as part of the Big Notch project groundwater study in 2019. CPT locations (CPTs YBHC1B, YBHC1C, YBHC2B, and YBHC2C).

A towed Transient Electro Magnetics (tTEM) geophysical survey was performed along the East Levee alignment. Ramboll (Ramboll, 2020) performed the survey in 2020. The survey provides subsurface lithology to a depth of about 150 feet using the tTEM geophysical survey technique.

Five borings were drilled as part of the 1963 USACE levee degradation and reconstruction project for 1,600 feet of East Levee south of Fremont Weir. The boring depths ranged between 7 and 17 feet. Figure 2 shows the five boring locations (Borings 2F-61-1, 2F-61-2, 2B-61-1, 2B-61-2, and 4F-49H-1).

URS Corporation conducted a Regional Geomorphic study as a part of Geotechnical Assessment Report for the DWR North NULE Study Area (URS, 2011) to study the surficial geology of the East levee site.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Recent Explorations

DOE's Project Geology section performed 16 borings and seven CPT soundings in the vicinity of East Levee, within the study area, between October and November 2020. Figures 2 and 3 show the Boring and CPT locations. Project Geology advanced triple explorations (waterside, levee crest, and landside) at approximate average spacing of 1200 feet. The Engineering Geology Report by DOE's Project Geology section (DWR, 2021) presents details of these explorations. Table 1 presents a summary of the recent explorations performed. Appendix B contains the recent borings. Appendix C summarizes the laboratory testing results on the recent explorations.

Table 1: Recent Exploration Details

Exploration ID	Exploration Type	Exploration Depth below Existing Grade (Feet)	Exploration Location
FW-103B	Boring	126.5	Levee Waterside
FW-104B	Boring	126.5	Levee Waterside
FW-105B	Boring	126.5	Levee Waterside
FW-106B	Boring	126.5	Levee Waterside
FW-107C	Seismic CPT	145	Levee Crest
FW-108B	Boring	101.5	Levee Crest
FW-111B	Boring	126.5	Levee Waterside
FW-112C	CPT	125	Levee Crest
FW-113B	Boring	51.5	Levee Landside Toe
FW-114C	CPT	60	Levee Waterside Toe
FW-115B	Boring	103	Levee Crest
FW-116B	Boring	61.5	Levee Waterside Toe
FW-117C	Seismic CPT	135	Levee Crest
FW-118B	Boring	61.5	Levee Waterside Toe
FW-119B	Boring	101.5	Levee Crest
FW-120B	Boring	61.5	Levee Landside Toe
FW-121B	Boring	61.5	Levee Waterside Toe
FW-122C	Seismic CPT	125	Levee Crest
FW-126B	Boring	61.5	Landside Far Field
FW-127C	CPT	70	Landside Far Field
FW-128B	Boring	61.5	Landside Far Field
FW-129B	Boring	61.5	Landside Far Field
FW-130C	CPT	60	Landside Far Field

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Levee Embankment Soils

As shown in Table 1, a total of seven explorations, three soil borings (Borings FW-108B, FW-115B, and FW-119B), and four CPT soundings were advanced through the crest of the existing East Levee embankment. The explorations were spaced about 1300 feet apart with Boring FW-108B located towards the northern end and Boring FW-119B towards the southern end (as shown in Figures 2 and 3) of the project area. Explorations indicated the embankment consisted of mostly lean clay with varying amounts of sand. Project Geology noted interbedded layers of silts and clayey sands in Boring FW-108B. Borings FW-115B and 2F-61-1 encountered a few interbedded thin layers of silty sand within the embankment. Boring FW-119B did not appear to have encountered interbedded layers of silts or sands within the embankment. The boring logs in Appendix B and the laboratory results in Appendix C provide more details on the levee embankment materials.

Foundation Soils

The recent and historical explorations indicated the upper 20 to 40 feet of foundation soils mostly consisted of a low permeability (blanket) soil layer. The blanket layer is comprised of lean clay and/or fat clay with varying amounts of sand. However, the geophysical survey performed along the northern portion of the project area indicated the upper five to eight feet of foundation soils have relatively permeable soil layers, which coincided with the shallow silty sand layer encountered in Boring FW-126B. Borings FW-111B and FW-129B also indicated that approximately a two-foot-thick silty sand layer in the near surface foundation layers existed. Boring FW-103B showed cobbles in the upper three feet of subsurface, which we understand the contractor placed to control erosion in the area. Except for the conditions in the above-mentioned borings, all other explorations indicated relatively low permeability soils in the upper foundation soil layers.

The low permeability blanket layer is underlain by an approximately 15- to 40-foot-thick relatively permeable soil (aquifer) layer. The aquifer layer generally consisted of poorly graded sand with silt and/or silty sand layers. An approximately 5- to 25-foot-thick low permeability lean clay and/or fat clay (aquiclude) layer was found beneath the aquifer layer, which was also underlain by relatively permeable silty sand and poorly graded sand with silt layers to the maximum depths of exploration.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Crevasse Splay Deposits

The regional geomorphic map (DWR, 2011) presented in Figure 4 (map resolution 1:24,000), shows the presence of several crevasse splay deposits within Yolo Bypass. These crevasse splays consist of sedimentary fluvial deposits, which form when nearby streams break the adjacent natural or artificial levees and deposit sediment on the Yolo Basin floodplain. The splays appear to cross diagonally beneath (northwest to southeast) the existing East Levee alignment at several locations. The sediments deposited within the lower portions of the splays are considered relatively more permeable compared to the surrounding foundation soils and would likely encourage seepage flow.

We oriented Cross Section C-C' in the direction of the suspected splay orientation to evaluate the effect of proposed channel construction on the existing East Levee. Generally, the performed explorations were not targeted along the possible alignment of these splays to determine depth of sediment deposits. For the analysis, we have conservatively assumed the bottom of the potential splay deposits was at Elevation 20 feet based on a historic Fremont Weir Site Survey and Test Borings Report (USADEO, 1920) from the United States Army San Francisco District Engineer Office.

4. Past Performance and Construction History

We obtained the following past performance and construction history information from the Geotechnical Assessment Report for the DWR North Non-Urban Levee Evaluation (NULE) Study Area (URS, 2011).

- In 1931, USACE improved East Levee by raising the levee approximately 4 feet and widening the crown to 20 feet. The slopes were conformed to 2H:1V and 3H:1V for the landside and waterside, respectively.
- In 1963, USACE proposed levee degradation and reconstruction of approximately 1,600 feet of East Levee from the north end of the levee adjacent to Sacramento River, which includes flattening the waterside slope to 4H:1V and landside slope to 3H:1V. No as-built documentation of this improvement work exists to our knowledge.
- In the 1990s, an approximately one-mile long East Levee segment from Fremont Weir to the south was improved by backfilling the landside toe ditch and placing a three- to five-foot-high toe berm. Before making this improvement, the area reportedly suffered from several seepage and stability problems. This reported distress matched with the areas of high piping potential and historic channels mapped in the Level-2-II geomorphology map (URS, 2011). During a 2009 interview, a DWR levee maintenance person stated that no incidents were reported after these improvements.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

California Levee Database (CLD) identifies a breach approximately 0.38 miles south of Fremont Weir on East Levee. The CLD provided no further description (no date of occurrence and no reconstruction detail). CLD also reported a landside rotational failure approximately 1.17 miles south of Fremont Weir that occurred during the 1997 flood event, resulting in a one- to two-foot-high vertical cut along the levee crown.

5. Geotechnical Evaluations Methodology

Analysis Cross Sections

We selected a total of six cross sections for the seepage and slope stability analyses—one cross section across the proposed Intake Channel, two cross sections across Transport Channel, two cross sections across Tule Channel, and one cross section in the direction of the crevasse splays within Transport Channel. Figures 2 and 3 show the selected cross section locations. Table 2 provides the rationale we used for cross section selection and cross section station locations.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Table 2: Summary of Analyses at Selected Cross Sections

Analyses Cross Section	Cross Section Location	Rationale for Cross Section Selection
Cross Section A – A'	Sta 998+00	This cross section is located just north of the Headwork Structure (near south end of the proposed Intake Channel). The cross section was selected to study the effects of Intake Channel construction on the existing East Levee and influence of seepage flow from Sacramento River. As shown in Figure 2, four waterside borings, one crest CPT sounding, and one landside boring were available for analyses. The explorations indicated the presence of an approximately 25- to 35-foot-thick blanket layer condition. The landside far field exploration (Boring FW-126B, drilled about 650 feet from the levee centerline) has about 5-foot-thick silty sand layer at the ground surface.
Cross Section B – B'	Sta 1005+70	This cross section is located about 600 feet south of the proposed Headworks Structure. The cross section was selected to study the impact of the Intake Channel construction on East Levee without the influence from Sacramento River. As shown in Figure 2, one crest boring, one landside far field boring, and two landside far field CPT soundings were used for the analyses. An approximately 30- to 40-foot-thick blanket layer condition is noted in the explorations. The landside far field exploration (Boring FW-126B, drilled about 650 feet from the levee centerline) has about 5-foot-thick silty sand layer at the ground surface.
Cross Section C – C'	Sta 1009+00	This cross section is located approximately 950 feet south of the proposed Headworks Structure. The cross section was selected to study the impact of the crevasse splay deposits (Figure 4) on both East Levee and Transport Channel. The cross section is parallel to the crevasse splay deposits in a northwest to southeast direction. One crest boring, one landside far field boring, and two landside far field CPT soundings were available for the analyses.
Cross Section D – D'	Sta 1019+50	This cross section is located near the proposed Pedestrian Bridge Crossing. The cross section was selected to study the impact of the proposed Transport Channel excavation construction on East Levee. This location has one crest boring, one landside toe boring, and two waterside toe borings available for analyses. The explorations indicate the presence of about an 18- to 20-foot-thick blanket layer condition.
Cross Section E – E'	Sta 1064+00	This cross section is located near the north end of the proposed Tule Channel. The cross section was selected to study the impact of the proposed Tule Channel excavation construction on East Levee. This location has one waterside toe boring, one crest boring, one landside toe boring, and one landside far field boring. About a 30- to 38-foot-thick blanket layer condition is noted in the explorations.
Cross Section F – F'	Sta 1080+70	The cross section is located near the south end of the proposed Tule Channel. The cross section was selected to study the impact of the proposed Tule Channel excavation construction on East Levee. This location has one waterside toe boring, one crest CPT sounding, and one landside toe CPT sounding. The explorations indicate the presence of about a 30- to 40-foot-thick blanket layer condition.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Seepage and Slope Stability Analyses

We performed seepage and steady state seepage landside slope stability analyses on the six selected cross sections to evaluate the potential impact of the proposed channel construction on the East Levee. For comparison, we conducted two sets of analyses on each cross section, one existing condition without the proposed channels and one including the proposed channels.

We performed the analyses using Version 2019-R2 of the Geostudio Software, including the finite element analysis computer program SEEP/W (seepage) and the limit equilibrium analysis computer program SLOPE/W (slope stability). We used boundary conditions for the seepage/underseepage models as shown in Figure 5.

We obtained the Water Surface Elevations (WSE) for the analyses from the project Hydraulic Impact Analysis Report (Table 12, HDR, 2020). The estimated WSE measures approximately 40.2 feet at Fremont Weir and 37.4 feet at Agricultural Road Crossing 1. We have linearly interpolated the WSE at our cross-section locations. Table 8 presents the WSE estimated at each cross section.

Table 3 below and the Transverse Cross Sections in Appendix A present the Presumptive Hydraulic Conductivity Values we used in the analyses. Table 4 below and the Transverse Cross Sections in Appendix A present the soil strength parameters. We estimated the parameters using the soil index properties from recent subsurface investigations coupled with values presented in the "*Department of Water Resources Urban Levee Evaluation (ULE) Program Guidance Document*" (URS, 2015). Additionally, we checked the hydraulic conductivity values used in the analyses by comparing them to values used in other projects with a similar geologic setting in the Yolo Bypass site region.

DOE did not perform waterside rapid drawdown analyses because the proposed channels are located 200 feet to 600 feet from the East Levee centerline. The proposed hydraulic structures' operations do not result in a rapid drawdown condition. Therefore, the proposed channels excavation and hydraulic structures operation will not impact the East Levee waterside stability and does not warrant rapid drawdown analysis.

Seepage Sensitivity Analysis for Cross Section A-A'

We provided an additional sensitivity analysis for Cross Section A-A' to account for the variable waterside blanket layer thickness indicated by Boring FW-DH-01. The contractor drilled this boring as part of the Fremont Weir Adult Fish Passage Modification Project geotechnical investigation in May 2017 (DWR, 2017). Boring FW-DH-01 shows a blanket layer thickness of about 18 feet, whereas the four adjacent recent borings (Borings FW-103B though FW-106B) show a blanket layer thickness exceeding about 25 feet.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

For the sensitivity model, we configured the proposed channel bottom to penetrate through the blanket layer and connect into the underlaying aquifer layer. We modeled the shallow sand layer in Boring FW-DH-01 as a discontinuous sand seam in Cross Section A-A'.

Erosion and Piping Potential for Cross Sections C-C' and D-D'

The foundation material beneath the levee embankment for Cross Sections C-C' and D-D' contains sand with silt and non-plastic silt. We evaluated the cross sections for creep ratio, hydraulic gradient through the top one foot of material beneath the levee toe, and severity of seepage through the non-plastic foundation layer. We evaluated the severity of seepage using criteria shown in Table 6. Table 7 lists the minimum safe creep ratios for different soil types. We have sourced both tables from Evaluation of Potential Erosion in Levees and Levee Foundations (Duncan, 2011).

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Table 3: Presumptive Hydraulic Conductivity Values used for the Big Notch Project

Material Type	Soil Description	Range of vertical hydraulic conductivity[1] (cm/sec)	Kv[1] (cm/sec)	Kv/Kh	Kh (cm/sec)	Layer Color
Clay (CL/CH)	Existing Embankment (CL)	5.0E-08 to 5.0E-06	2.5E-06	0.25	1.0E-05	Indigo
	Foundation: Lean/Fat Clay (CL/CH)	5.0E-08 to 5.0E-06	1.0E-06	0.25	4.0E-06	
Silt (ML)	Silt, Sandy Silt, or Plastic Silt with PI ≥ 8	5.0E-08 to 5.0E-06	1.0E-05	0.25	4.0E-05	Blue
	Silt, Sandy Silt with PI < 4 *For PI between 4 and 8, and fc >70% use judgement and adjust the k values*	1.0E-05 to 3.0E-04	1.0E-04	0.25	4.0E-04	
Clayey Sand (SC)	26-49% fines content	5.0E-07 to 3.0E-05	2.5E-05	0.25	1.0E-04	Brown
	13-25% fines content	1.0E-05 to 1.0E-04	5.0E-05	0.25	2.0E-04	
Silty Sand (SM)	26-49% fines content (Non-Plastic Fines) *If the fines are plastic based on field logging and/or PI information is available use judgment to adjust the K values*	1.0E-05 to 5.0E-04	2.0E-04	0.25	8.0E-04	Green
	13-25% fines content	1.0E-04 to 2.0E-03	5.0E-04	0.25	2.0E-03	
Sand (SP, SW, SP-SM, SW-SM)	6-12% fines content	5.0E-04 to 1.0E-02	5.0E-03	0.5	1.0E-02	Yellow
	0-5% fines content	5.0E-03 to 3.0E-02	2.0E-02	1	2.0E-02	
Sand (SP-SC, SW-SC)	6-12% fines content	4.0E-05 to 5.0E-04	2.0E-04	0.5	4.0E-04	

Notes:

1. *The range of Vertical Hydraulic Conductivity based on DWR Guidance Document*
2. *The parameters are selected based on geomorphic maps, DWR Guidance Document, boring logs, and parameters used for the other projects in the same geomorphic region. The parameters were also compared to other projects in the site region including Lower Elkhorn Basin Levee Setback, Natomas Levee Improvement Program, and other projects in Central Valley.*

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Table 4: Soil Strength Parameter Values used for East Levee

Location	Soil Classification	Soil Drained Strength Parameters	
		Phi' (degrees)	C' (psf)
Embankment	CL	30	50
	ML	30	0
	SM	32	0
Foundation	CL	30	100
	ML	30	0
	CH	30	100
	SM	32	0
	SP-SM	34	0
	SP	34	0

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

We performed the seepage and stability analyses in general accordance with "*US Army Corps of Engineers (USACE) Engineering Manual 1110-2-1913"* (USACE, 2000*)*. Table 5 below presents the USACE analyses criteria for seepage and stability.

Table 5: USACE Analyses Criteria for Seepage and Stability

Evaluation	Analysis Condition	Analysis Case	Criteria
Seepage	Through Seepage	WSE[1]	Potential for internal erosion and piping of the embankment material when phreatic surface for a cross section daylights above the landside levee toe. Embankments consisting of plastic fines are not susceptible to erosion or piping. For details refer ULE Guidance Document (URS, 2015).
	Underseepage – Blanket Layer Condition	WSE[1]	Average vertical exit gradient at landside levee toe ≤ 0.5.
			Average vertical exit gradient at landside levee toe ditch or depression ≤ 0.5 increasing to ≤ 0.8 at a distance of 150 feet from levee toe. Linear interpolation within the allowable gradients between these two locations.
	Shallow Underseepage – "Leaking" Condition	WSE[1]	Potential for piping of permeable (leaker) foundation was evaluated using Bligh's Creep Ratio method, and Duncan's[3] (Duncan, Michael, J., (2011)) seepage severity and localized exit gradient methods.
Landside Stability	Slope Stability under Steady-State Seepage	WSE[1]	Factor of safety ≥ 1.4

Notes:
[1] Analysis WSEs were provided in the Hydraulic Impact Analyses Report (HDR, 2020).
[2] Creep ratio is the length of the seepage path along the line of creep divided by the maximum hydraulic head that could occur. The allowable creep ratios are based on guidelines from Bligh's Creep Ratio method. The calculated creep ratio should be greater than 15.0 for fine to medium sand.
[3] Based on Duncan method, localized exit gradient and seepage severity were calculated at the levee toe within the permeable (leaker) layer. The localized exit gradients were compared with USACE criteria for underseepage presented in the Table 6. The seepage severity was compared to the criteria presented in Table 6.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Table 6: Proposed Categories of Seepage Severity [1]

Q_s / H (gpm per foot of head per 100 feet of levee)	Q_s / H (cfs per foot of head per foot of levee)[2]	Severity of Seepage	Seepage Remediation Needed
>10	$> 2.2 \times 10^{-4}$	Heavy	Yes
5 to 10	1.1×10^{-4} to 2.2×10^{-4}	Medium	Possible
1 to 5	2.2×10^{-5} to 1.1×10^{-4}	Light	Marginal
<1	$< 2.2 \times 10^{-5}$	Negligible	Not Needed

[1] Modified after Section 140 of TM3-424 (1956)
[2] 1 cfs/ft of head/ft of levee = 44883 gpm/ft of head/100 ft of levee

Table 7: Minimum Safe Creep Ratio Factors

Foundation Soil Type	Minimum Safe Creep Ratio	
	Lane CR_W	Bligh CR
Very Fine Sand or Silt	8.5	18.0
Fine Sand	7.0	15.0
Medium Sand	6.0	---
Coarse Sand	5.0	12.0
Fine Gravel	4.0	---
Medium Gravel	3.5	---
Gravel and Sand	---	9.0
Coarse Gravel with Cobbles	3.0	---
Boulders with some Cobbles and Gravel	2.5	---
Boulders, Gravel, and Sand	---	4.0 to 6.0
Soft Clay	3.0	---
Medium Clay	2.0	---
Hard Clay	1.8	---
Very Hard Clay or Hardpan	1.6	---

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

6. Analyses Results and Conclusions

Appendix A presents our analysis results, and Tables 8 and 9 summarize them. When we compare the analysis results for the “without the proposed channels” and “with the proposed channels” conditions, the proposed channel construction appears to have an insignificant effect on the performance of the East Levee embankment. It introduces negligible changes on the underseepage exit gradient and slope stability factor of safety (FOS). The proposed channels neither change the underseepage severity for permeable (leaker) foundation soil conditions nor the existing through seepage conditions.

The sensitivity analysis result of Cross Section A-A’ (Table 8) shows a slight increase in underseepage exit gradient (increase from 0.08 to 0.14) across the blanket layer at the landside levee toe and a slight decrease in landside slope stability FOS (reduced from FOS 2.04 to 2.01). However, we should note we based this sensitivity run on a conservative depiction of a continuous sand deposit into the aquifer layer. As we only encountered this condition in one historical boring (Boring FW-DH-01) and not in any of the recent explorations, the silt layer below the shallow sand layer likely appears consistent with the base of blanket layer detected from surrounding borings. Because of the modeled relatively thin blanket layer condition in Boring FW-DH-01, the proposed channel bottom potentially penetrates the underlaying aquifer layer. Consequently, the applied flood water loading may hydraulically connect to the aquifer layer, which increases the exit gradient across the blanket layer at the landside levee toe. This increase in calculated exit gradient is very small and well below the USACE underseepage criteria (less than 0.5). It is our opinion that this sensitivity model condition does not likely exist in the actual embankment foundation, and we only presented in this memorandum to show a worst-case scenario.

The resulting underseepage exit gradients and FOSs appeared similar in all other cross sections, with and without the proposed channel excavations, because of the presence of the intact waterside blanket layer beneath the channel bottom (see Appendix A). The intact blanket layer at the channel bottom resists seepage flow into the aquifer layer; therefore, it would not significantly increase the seepage pressure beneath the blanket layer.

Based on recent explorations, the foundation layer beneath the levee in Cross Section D-D appears to be a non-plastic silt. According to Bligh’s creep ratio criteria, the silt layer has the potential for piping failure because of concentrated seepage flow through the layer. However, Duncan’s method for determining seepage severity using quantity of seepage underneath the embankment per foot of head indicated the potential for piping failure appears negligible (see Tables 6 and 8). Based on Bligh’s creep ratio criteria, we used a minimum safe creep ratio of 18.0 for this potential piping evaluation. As shown in Table 9, the calculated creep ratio (11.7) using Bligh’s method in Cross Section D-D’ is lower than the allowable creep ratio (18.0). This risk indicated by creep ratio exists for both cases with and without the proposed Transport Channel when the

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

water surface reaches the elevation shown in Table 8. When the water surface is contained within Intake Channel, this condition does not exist.

In Cross Sections A-A' and D-D' (see Appendix A), the phreatic surface breakout is two and four feet above the landside levee toe. We assumed the East Levee embankment material to consist of comprised of silt, which we consider susceptible for erosion because of seepage flow. Therefore, the likelihood of internal erosion or piping of soil occurring within the levee embankment appears relatively high. The phreatic surface breakout is above the levee toe for Cross Sections B-B', E-E', and F-F', but the embankments for these cross sections consist of clayey soils. According to ULE Guidance Document, embankments consisting of plastic fines are not considered susceptible to erosion or piping (URS, 2015). The models show the phreatic surface breakout is above the levee toe with and without the proposed channels when the water surface is at the elevations shown in Table 8. When the water surface is contained within the proposed channels, this condition does not exist.

7. Recommendations

Our analysis results show the East Levee meets USACE criteria for underseepage and landside slope stability before and after excavating the channels for the Project. However, our results show the East Levee potentially does not meet USACE criteria for through seepage and a permeable (leaker) foundation soil condition. This condition exists with or without the Project when the water surface reaches the elevations listed in Table 8 and is consistent with previous findings of the NULE program for this reach of East Levee. The construction of the project channels does not change the performance of the East Levee. Therefore, we do not recommend making modifications to the existing Yolo Bypass East Levee as we understand that USACE would not require mitigation of this pre-existing condition as a part of this project.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Table 8: Seepage and Slope Stability Analyses Results of Yolo Bypass East Levee with and without the Proposed Channels

Analyses Cross Sections	Cross Section Location	Analysis WSE, feet (NAVD 88)	Analysis Results without Proposed Channels (Before Construction)				Analysis Results with the Proposed Channels (After Construction)			
			Seepage Results			Landside Slope Stability Results	Seepage Results			Landside Slope Stability Results
			Under seepage Exit Gradient	Through Seepage (Feet above Levee Toe)	Permeable Foundation Soil Condition	Factor of Safety	Under seepage Exit Gradient	Through Seepage (Feet above Levee Toe)	Permeable Foundation Soil Condition	Factor of Safety
Cross Section A-A'	Sta 998+00	40.2	0.07	2	NA	2.05	0.07	2	NA	2.04
Cross Section A-A' Sensitivity	Sta 998+00	40.2	0.08	2	NA	2.05	0.14	2	NA	2.01
Cross Section B-B'	Sta 1005+70	39.8	NO POSITIVE GRADIENT	2*	NA	2.04	NO POSITIVE GRADIENT	2 *	NA	2.02
Cross Section C-C'	Sta 1009+00	39.8	0.21	At Toe	SEE TABLE 9	1.92	0.21	At Toe	SEE TABLE 9	1.92
Cross Section D-D'	Sta 1019+50	39.4	0.39	4	SEE TABLE 9	1.45	0.39	4	SEE TABLE 9	1.45
Cross Section E-E'	Sta 1064+00	38.1	0.19	1*	NA	1.99	0.19	1*	NA	1.98
Cross Section F-F'	Sta 1080+70	37.5	0.41	4*	NA	1.61	0.41	4*	NA	1.61

* Embankments consisting of plastic fines are not considered susceptible to erosion or piping. For details refer ULE Guidance Document (URS, 2015).

.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Table 9: Permeable Foundation Soil Condition Evaluation

Cross Section	Channel Configuration (Before and After Construction)	Permeable (Leaker) Layer Material Classification	Vertical Permeability k_v, of Permeable (Leaker) Layer (cm/sec)	Horizontal Permeability k_h, of Permeable (Leaker) Layer (cm/sec)	Exit Gradient Within Top 1 Foot of Permeable (Leaker) Layer Beneath Levee Toe	Volumetric Flow per Foot of Levee, Qs (cfs/ft)	Change in Total Head H (ft)	Qs/H (cfs per Foot of Head per Foot of Levee)	Qs/H (gpm per Foot of Head per 100 Feet of Levee)	Severity of Seepage	Seepage Remediation Needed	Bligh Creep Ratio	Lane Weighted Creep Ratio
C-C'	Without Channels (Before)	SP-SM	5.00E-03	1.00E-02	0.21	2.13E-04	6.8	3.14E-05	1.41	Light	Marginal	15.6*	5.2*
	With Channels (After)				0.21	2.13E-04	6.8	3.14E-05	1.41	Light	Marginal	15.6*	5.2*
D-D'	Without Channels (Before)	ML	1.00E-05	4.00E-05	0.08	1.06E-06	13.56	7.82E-08	3.51E-03	Negligible	Not Needed	11.7**	2.6**
	With Channels (After)				0.08	1.08E-06	13.56	7.99E-08	3.5E-03	Negligible	Not Needed	11.7**	2.6**

* Minimum safe Bligh's Creep Ratio and Lane's Weighted Creep ratio for coarse sand are 12.0 and 5.0, respectively

** Minimum safe Bligh's Creep Ratio and Lane's Weighted Creep ratio for silt are 18.0 and 8.5, respectively

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

8. Limitations

We used limited, available data and inferred soil parameters from literature along with experience from nearby project sites and similar soil types to conduct the analyses and develop the recommendations presented in this memorandum. Therefore, a degree of uncertainty and inherent risk exist when using the results presented herein. GES shared these risks and uncertainties with the project design team and client (DISE). Both the design team and client have accepted and agreed to these uncertainties and associated risks for this project.

9. References

DWR, 2017, Fremont Weir Adult Fish Passage Modification Project, Engineering Geology Report, Project Geology Report 90-00-71. May 2017.

DWR, 2011, Final Geomorphology Technical Memoranda and Maps, North Non-Urban Levee Evaluations (NULE) Area Geomorphic Assessments, January 2011. Prepared by URS Corporation and Fugro.

Duncan, Michael, J., (2011), Evaluation of Potential Erosion in Levees and Levee Foundations. February 2011.

HDR, 2020, Hydraulics Impact Analyses (HIA) Report for the Yolo Bypass Salmonid Habitat and Fish Passage (Big Notch) Project, 35 Percent Design Submittal, July 24, 2020.

Ramboll, 2020, Yolo Bypass Shallow Hydrogeologic Assessment, tTEM-Geophysics, Performed by Ramboll, January 2020.

URS, 2011, Geotechnical Assessment Report, North NULE Study Area, Non-Urban Levee Evaluations (NULE) Project, Appendix F, Segment 171. April 30, 2011.

URS, 2015, Guidance Document for Geotechnical Analyses, Urban Levee Evaluation (ULE) Project, URS Corporation. April 2015.

United States Army Corps of Engineers. 2000. Engineering Manual 1110-2-1913, *Engineering and Design – Design and Construction of Levees*.
http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/entire.pdf

United States Army District Engineer Office. Fremont Weir Site Survey and Test Borings. January 1920.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Attachments

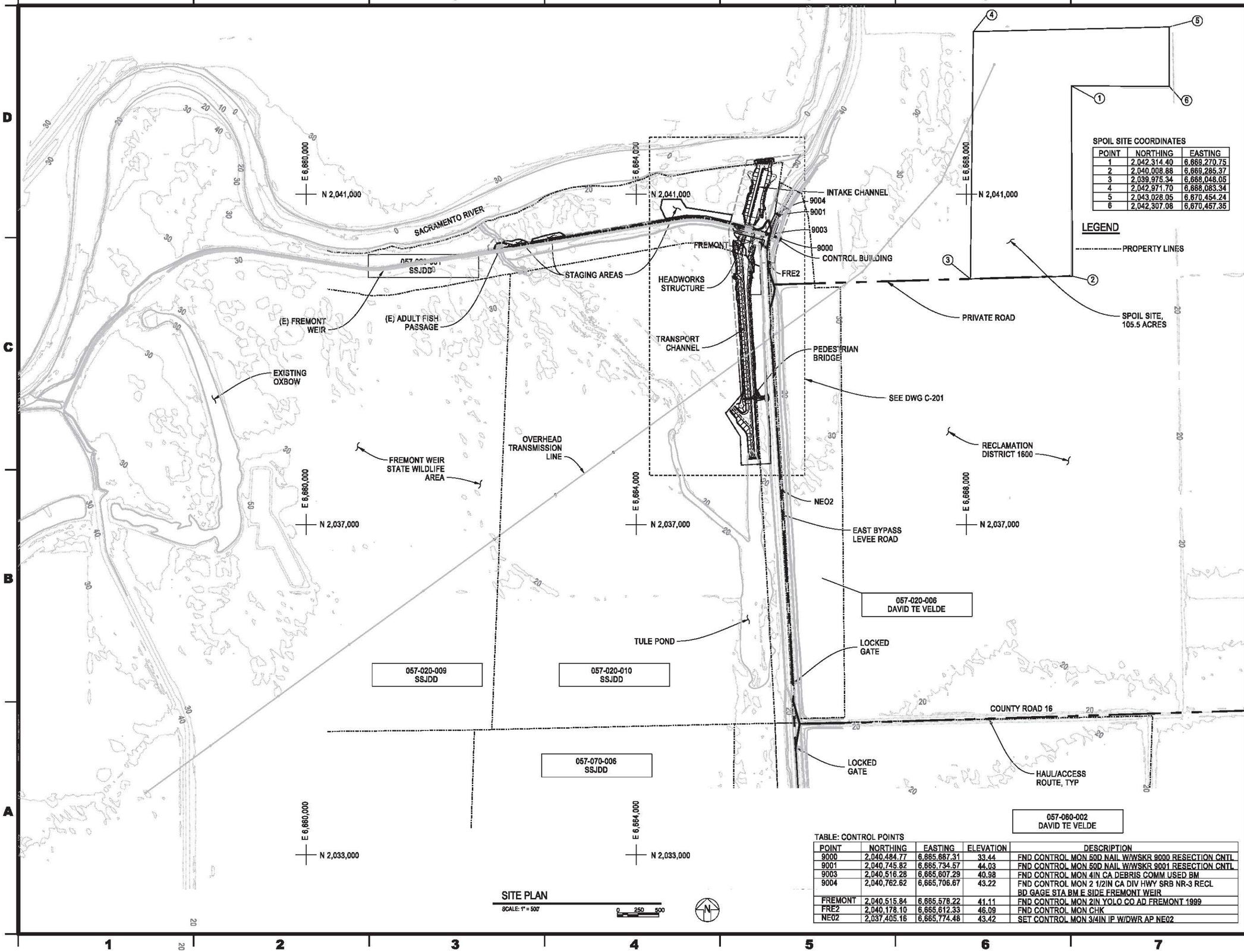
Figures

Figure 1 -	Site Plan
Figure 2 -	Explorations and Cross Sections Location Map - Intake and Transport Channel
Figure 3 -	Explorations and Cross Sections Location Map - Tule Channel
Figure 4 -	Regional Geomorphic and Underseepage Susceptibility Map
Figure 5 -	Typical SEEP/W Model with Boundary Conditions

Appendices

Appendix A -	Seepage and Slope Stability Analyses Results
Appendix B -	Recent and Historical Geotechnical Explorations
Appendix C -	Laboratory Test Results

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



SPOIL SITE COORDINATES

POINT	NORTHING	EASTING
1	2,042,314.40	6,669,270.75
2	2,040,008.88	6,669,285.37
3	2,039,975.34	6,668,048.05
4	2,042,971.70	6,668,083.34
5	2,043,028.05	6,670,454.24
6	2,042,307.08	6,670,457.35

LEGEND

PROPERTY LINES

SITE PLAN

SCALE: 1" = 500'

0 250 500

TABLE: CONTROL POINTS

POINT	NORTHING	EASTING	ELEVATION	DESCRIPTION
9000	2,040,484.77	6,665,687.31	33.44	FND CONTROL MON 50D NAIL W/WSKR 9000 RESECTION CNTL
9001	2,040,745.82	6,665,734.57	44.03	FND CONTROL MON 50D NAIL W/WSKR 9001 RESECTION CNTL
9003	2,040,516.28	6,665,607.29	40.98	FND CONTROL MON 4IN CA DEBRIS COMM USED BM
9004	2,040,762.62	6,665,706.67	43.22	FND CONTROL MON 2 1/2IN CA DIV HWY SRB NR-3 RECL BD GAGE STA BM E SIDE FREMONT WEIR
FREMONT	2,040,515.84	6,665,578.22	41.11	FND CONTROL MON 2IN YOLO CO AD FREMONT 1999
FRE2	2,040,178.10	6,665,612.33	46.09	FND CONTROL MON CHK
NE02	2,037,405.16	6,665,774.48	43.42	SET CONTROL MON 3/4IN IP W/DWR AP NE02

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

STATE WATER FACILITIES
DIVISION OF ENGINEERING
DEPARTMENT OF WATER RESOURCES
CALIFORNIA NATURAL RESOURCES AGENCY
STATE OF CALIFORNIA

REV.	DESCRIPTION	SUB.	APP.

LICENSED LAND SURVEYOR · STATE OF CALIFORNIA

REGISTERED PROFESSIONAL ENGINEER · BAO-DUY T. TA · No. 78298 · Exp. 6-30-23 · CIVIL · STATE OF CALIFORNIA

DESIGNED: FANNIE NG REG. C.E. No. 83906	CHECKED: SALENDAR SINGH REG. C.E. No. 76717
DRAWN: FANNIE NG REG. C.E. No. 83906	REVIEWED: BAO-DUY TA REG. C.E. No. 78298
SUBMITTED: BAO-DUY TA REG. C.E. No. 78298	

APPROVAL RECOMMENDED: DATE:

MANAGER, CIVIL II SECTION, REG. C.E. No. 67642

APPROVED: DATE:

MANAGER, CIVIL ENGINEERING BRANCH, REG. C.E. No. 85263

THINK SAFETY - ACT SAFELY

STATE WATER FACILITIES
DIV. OF INTEGRATED SCIENCE & ENGINEERING

FREMONT WEIR - YOLO BYPASS

SALMONID HABITAT RESTORATION AND FISH PASSAGE - BIG NOTCH

PROJECT OVERVIEW AND SITE CONTROLS

SITE PLAN

Figure No. 1

V:\ Print Styles 22x34.PEN
12/22/2021

Explorations

- Boring
- CPT
- CPT - Seismic

Other Features

- Cross Section Line
- Station Alignment
- Topographic Elevation Contour (Major)
- Topographic Elevation Contour (Minor)

A'
B'
C'
D'
A
B
C
D

985+00
990+00
995+00
1000+00
1005+00
1010+00
1015+00
1020+00
1025+00
1030+00
1035+00
1+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00

Intake Channel
Control Building
Headwork Structure
Transport Channel
Existing Fremont Weir
Tule Pond
Sacramento River

YBHC1C
FW-126B
YBHC1B
FW-127C
FW-107C
FW-106B
FW-108B
2F-61-1
2F-61-2
FW-113B
FW-112C
FW-115B
FW-114C
FW-DH-01
FW-105B
4F-49H-1
FW-111B
FW-104B
FW-103B
2B-61-1
2B-61-2

Sacramento R.
Fremont Weir
Map Area

N
0
400
Feet

Department of Water Resources Division of Engineering Geotechnical Engineering Section	**PREPARED FOR**	**PREPARED BY** Matthew Havey	Salmonid Habitat Restoration and Fish Passage - Big Notch	**Explorations and Cross Sections Location Map**
	DATE January 2022	**CHECKED BY** Vishnan Gopalan, PE, GE		FIGURE **2**

Explorations
- Boring
- CPT
- CPT - Seismic

Other Features
- Cross Section Line
- Station Alignment
- Topographic Elevation Contour (Major)
- Topographic Elevation Contour (Minor)

E

F

Sacramento R.

Fremont Weir

Map Area

FW-129B

YBHC2C

YBHC2B

040+

045+00

050+00

055+00

060+00

065+00

070+00

075+00

080+00

085+00

090+00

095+00

FW-128B

FW-117C

FW-116B

FW-120B

FW-119B

FW-118B

FW-130C

FW-122C

FW-121B

FW-DH-08

FW-DH-11

Tule Pond

Tule Channel

Agricultural Crossing 1

N

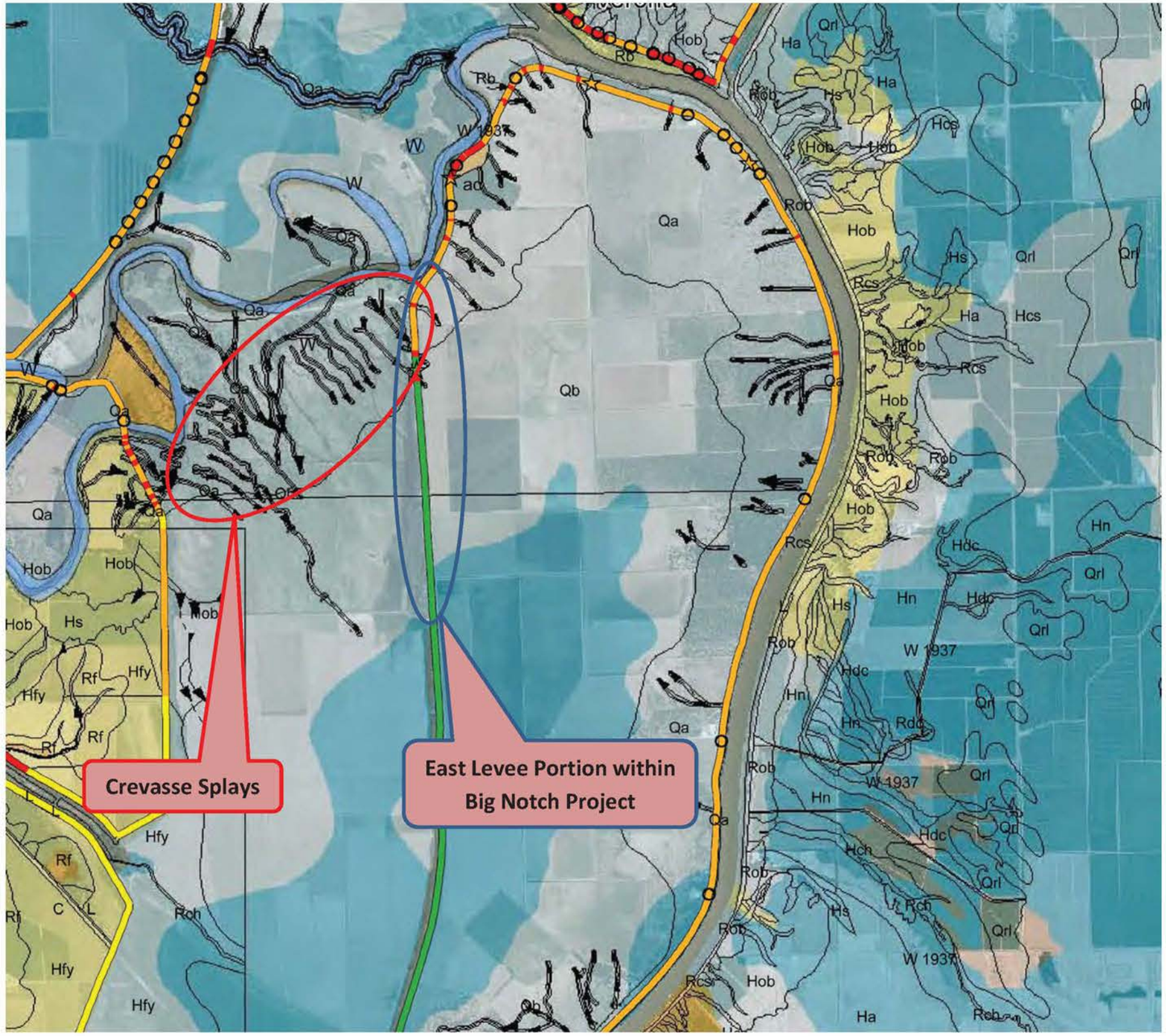
0

400

Feet

Department of Water Resources Division of Engineering Geotechnical Engineering Section	**PREPARED FOR**	**PREPARED BY** Matthew Havey	Salmonid Habitat Restoration and Fish Passage - Big Notch	**Explorations and Cross Sections Location Map - Tule Channel**
	DATE January 2022	**CHECKED BY** Vishnan Gopalan, PE, GE		FIGURE **3**

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qll — Intemittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Department of Water Resources

Division of Engineering

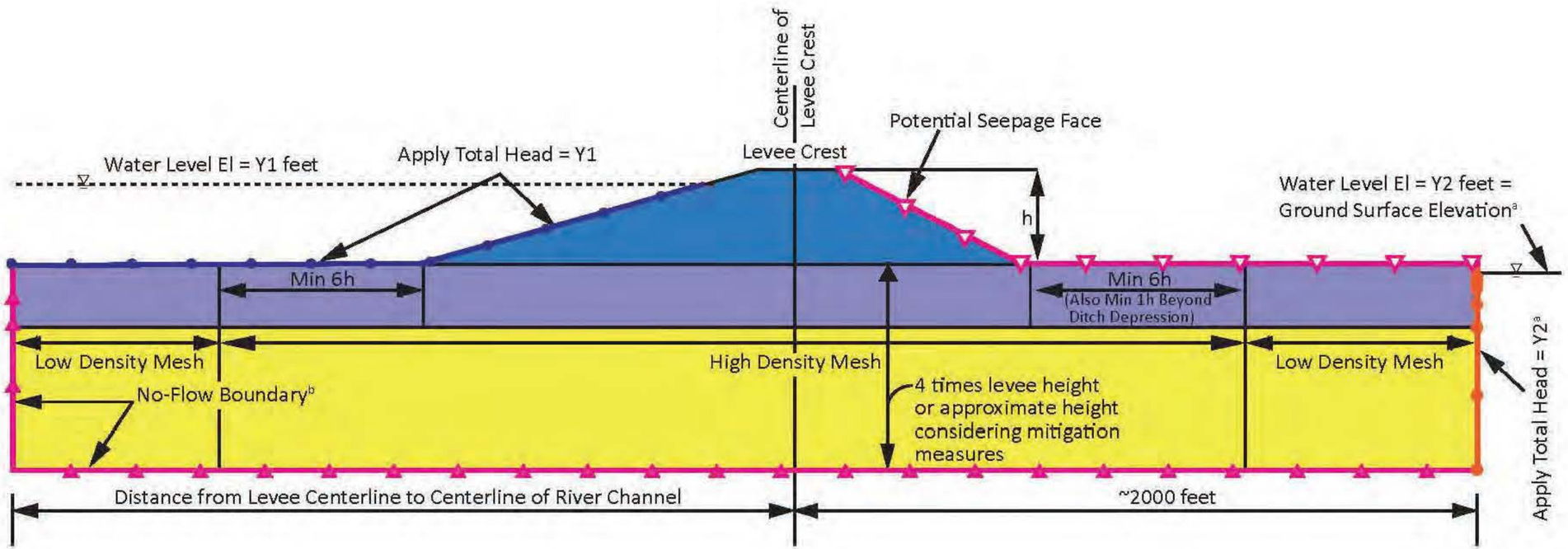
Geotechnical Engineering Section

REGIONAL GEOMORPHIC AND UNDERSEEPAGE SUSCEPTIBILITY MAP

Big Notch Project

Figure 4

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: GVISHNAN – Mar 20, 2020 – 8:28:06am
DRAWING: C:\Users\gvishnan\Desktop\Fremont Weir Adult Fish Passage Modification\Drawings\g-ba0000.DWG

Department of Water Resources Division of Engineering Dams and Canals Section	PREPARED FOR	PREPARED BY VISHNAN GOPALAN, PE, GE	BIG NOTCH PROJECT	**Typical Seep/W Model with Boundary Conditions** Seepage and Slope Stability Analyses	FIGURE 5
	DATE JANUARY 2022021	CHECKED BY YOUSSEF AWAD, PE.			

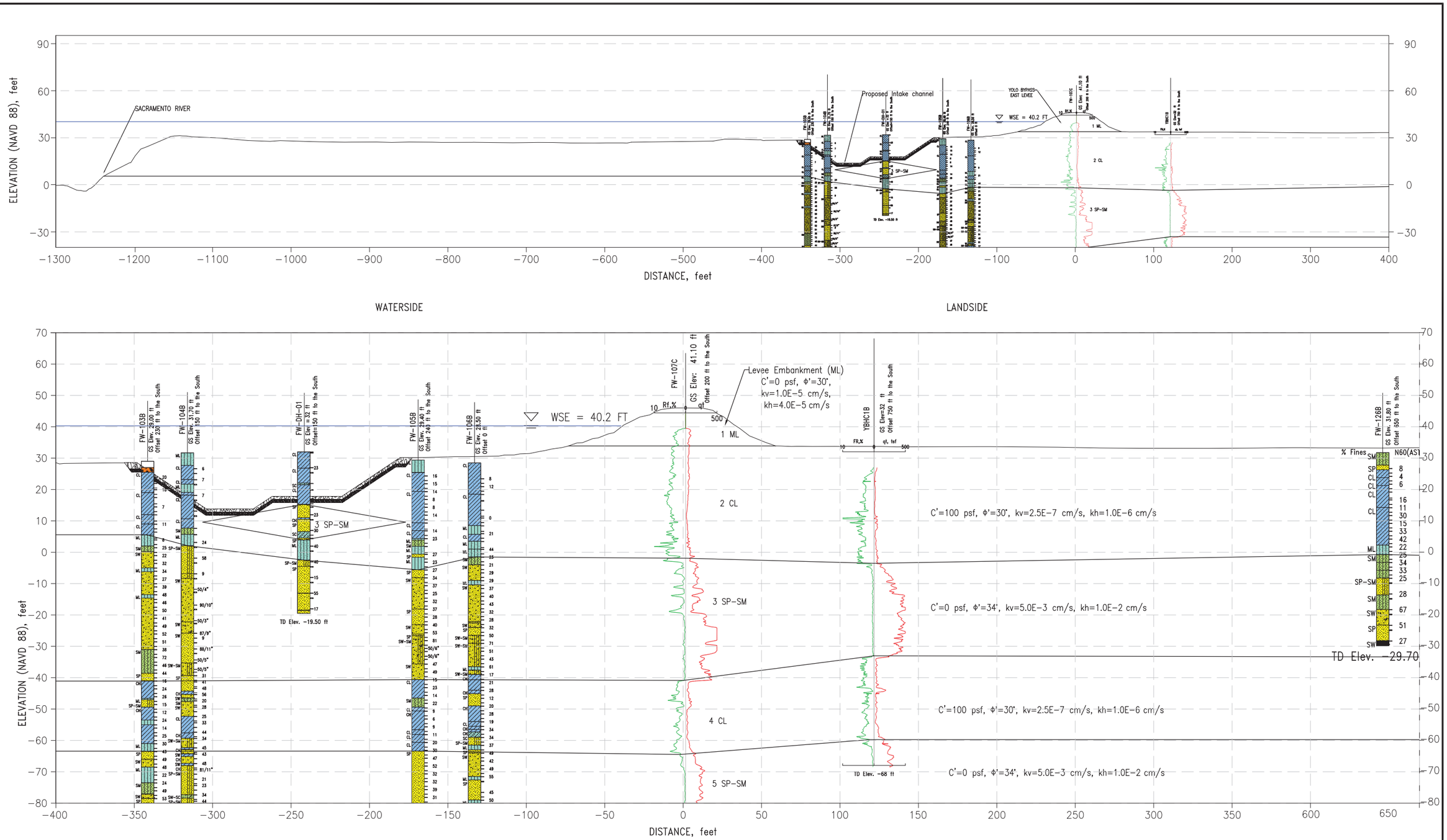
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Appendix A

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section A-A' Results

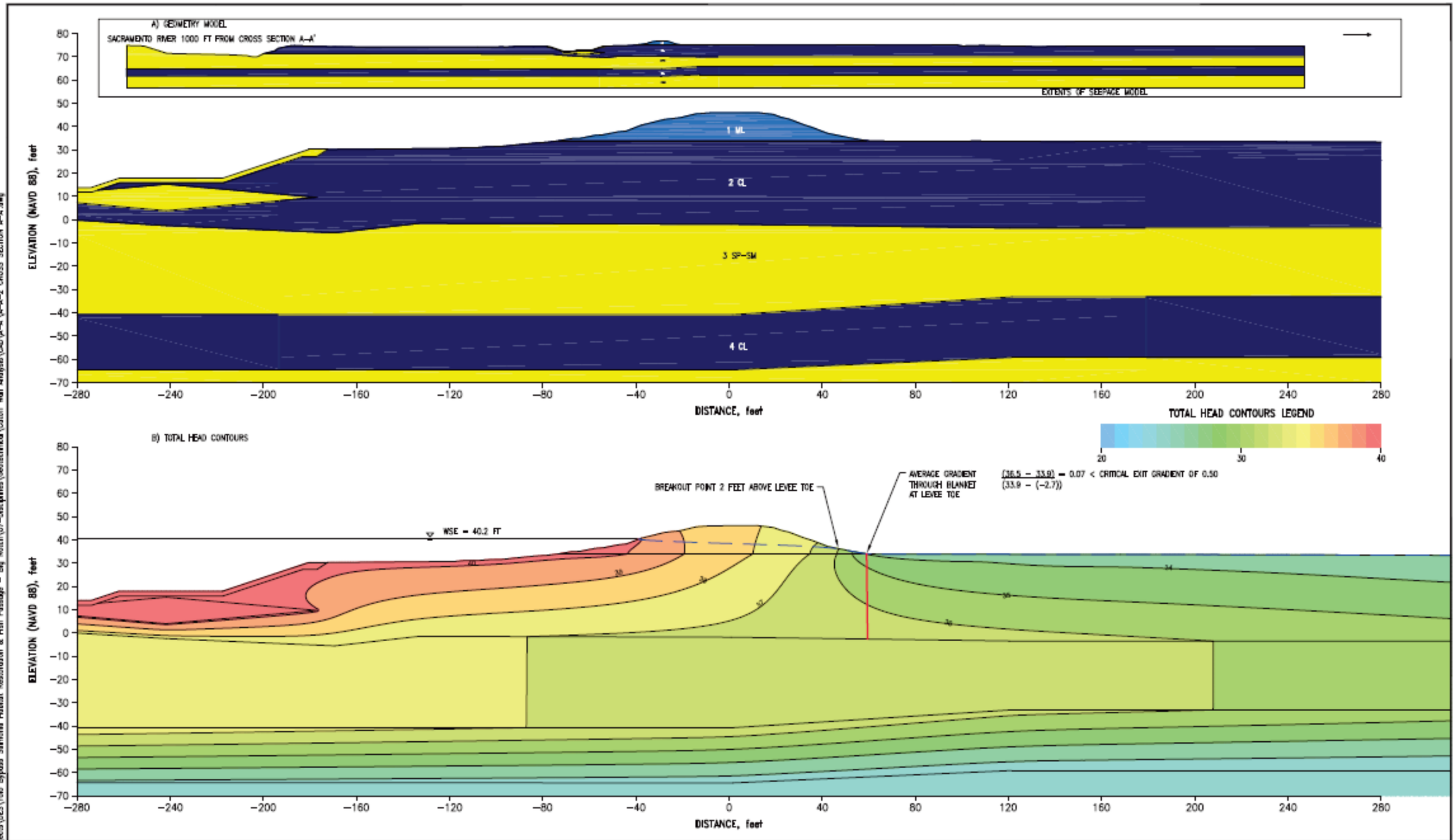
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	TRANSVERSE CROSS SECTION INTAKE CHANNEL CROSS SECTION A-A' STA 998+00	FIGURE A–A–1
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 22, 2021 – 3:08:39pm
DRAWING: \\Doe-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\01 – TRANSVERSE X-SEC\A-A-1 CROSS SECTION A-A'.dwg

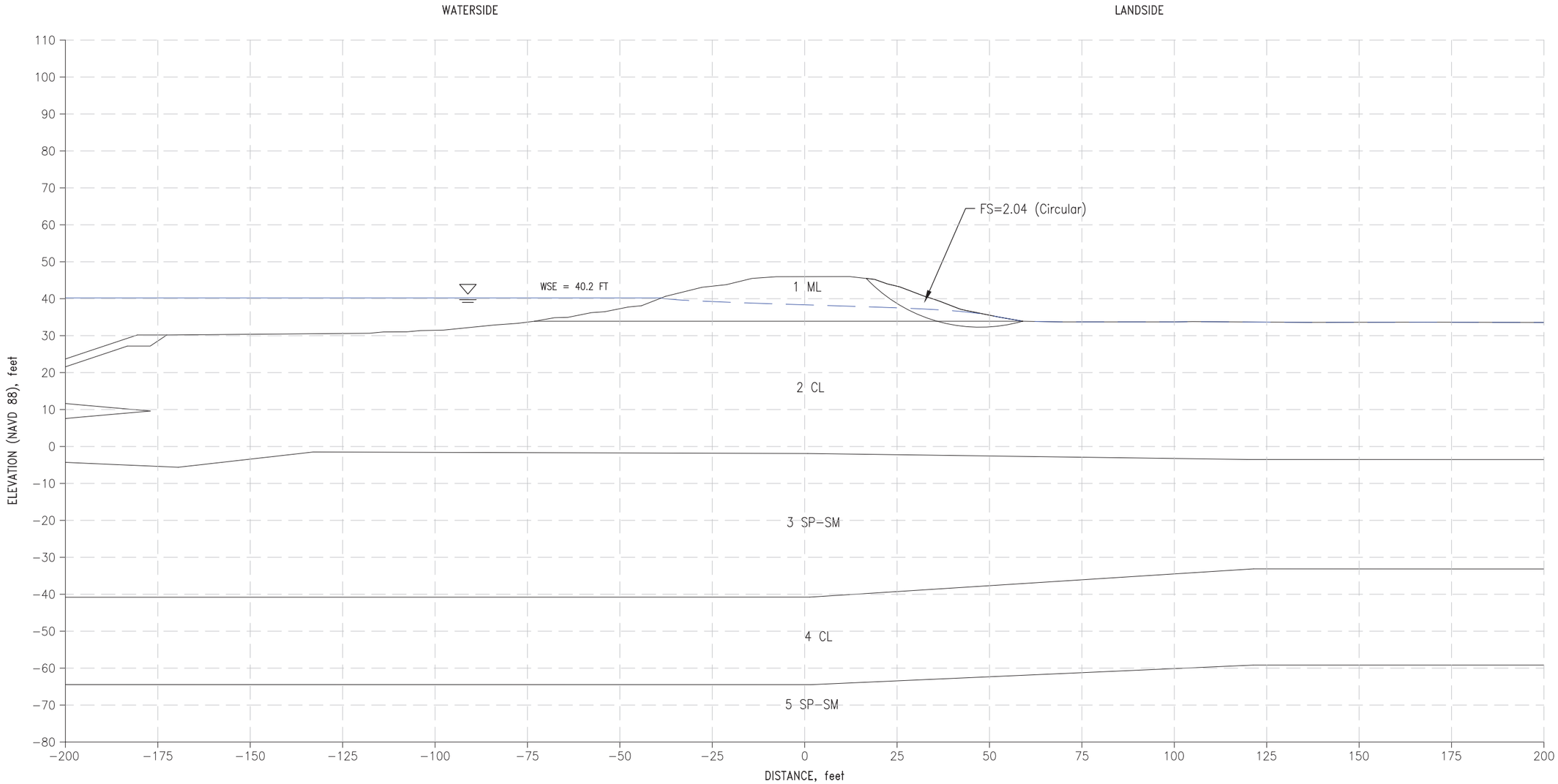
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE INTAKE CHANNEL CROSS SECTION A-A' STA 998+00	FIGURE A-A-2
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Jan 31, 2021 – 8:19:09pm
DRAWING: \\Dos-fla\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A'\A-A-2 CROSS SECTION A-A'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS INTAKE CHANNEL CROSS SECTION A-A' STA 998+00	FIGURE A-A-3
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

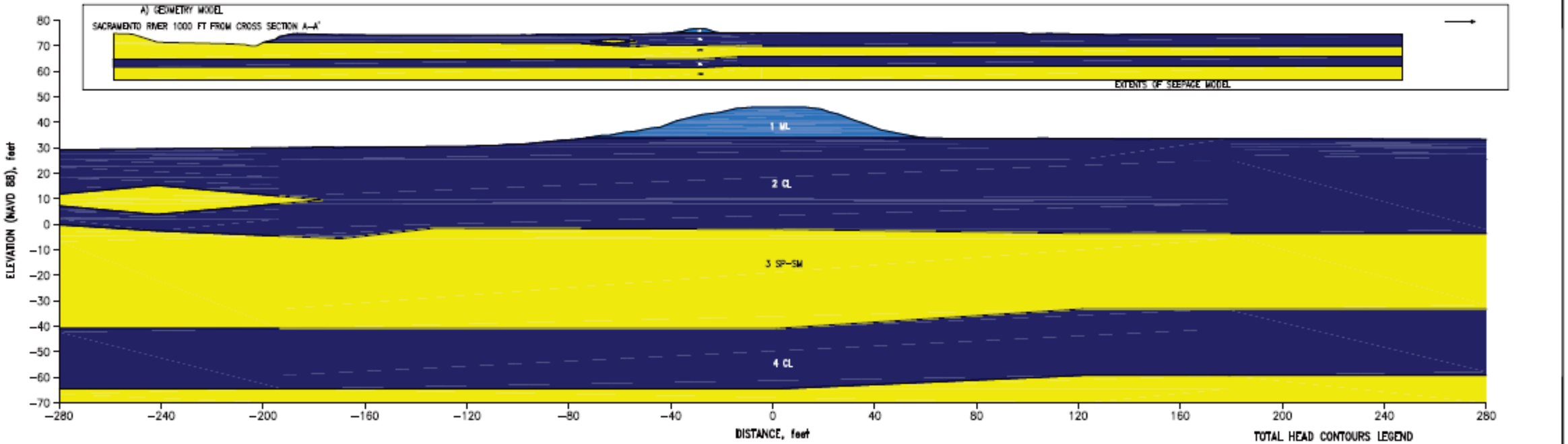
PLOT BY: MHAVEY - Jan 31, 2021 - 7:14:53pm
DRAWING: \\Doe-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A'\A-A-3 CROSS SECTION A-A'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

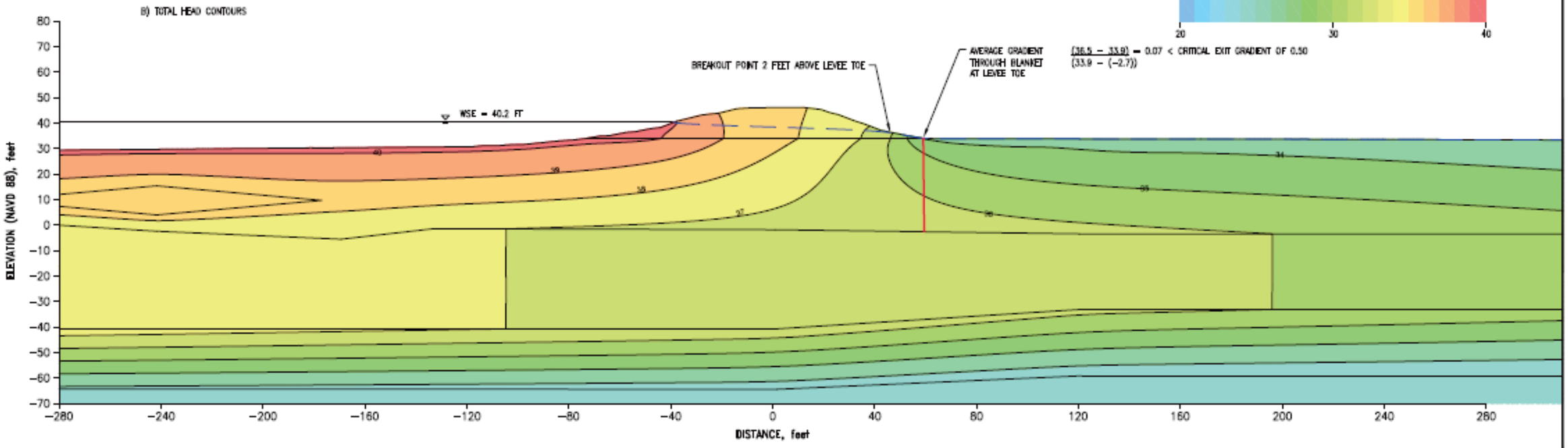
A) GEOMETRY MODEL

SACRAMENTO RIVER 1000 FT FROM CROSS SECTION A-A'

EXTENTS OF SEEPAGE MODEL



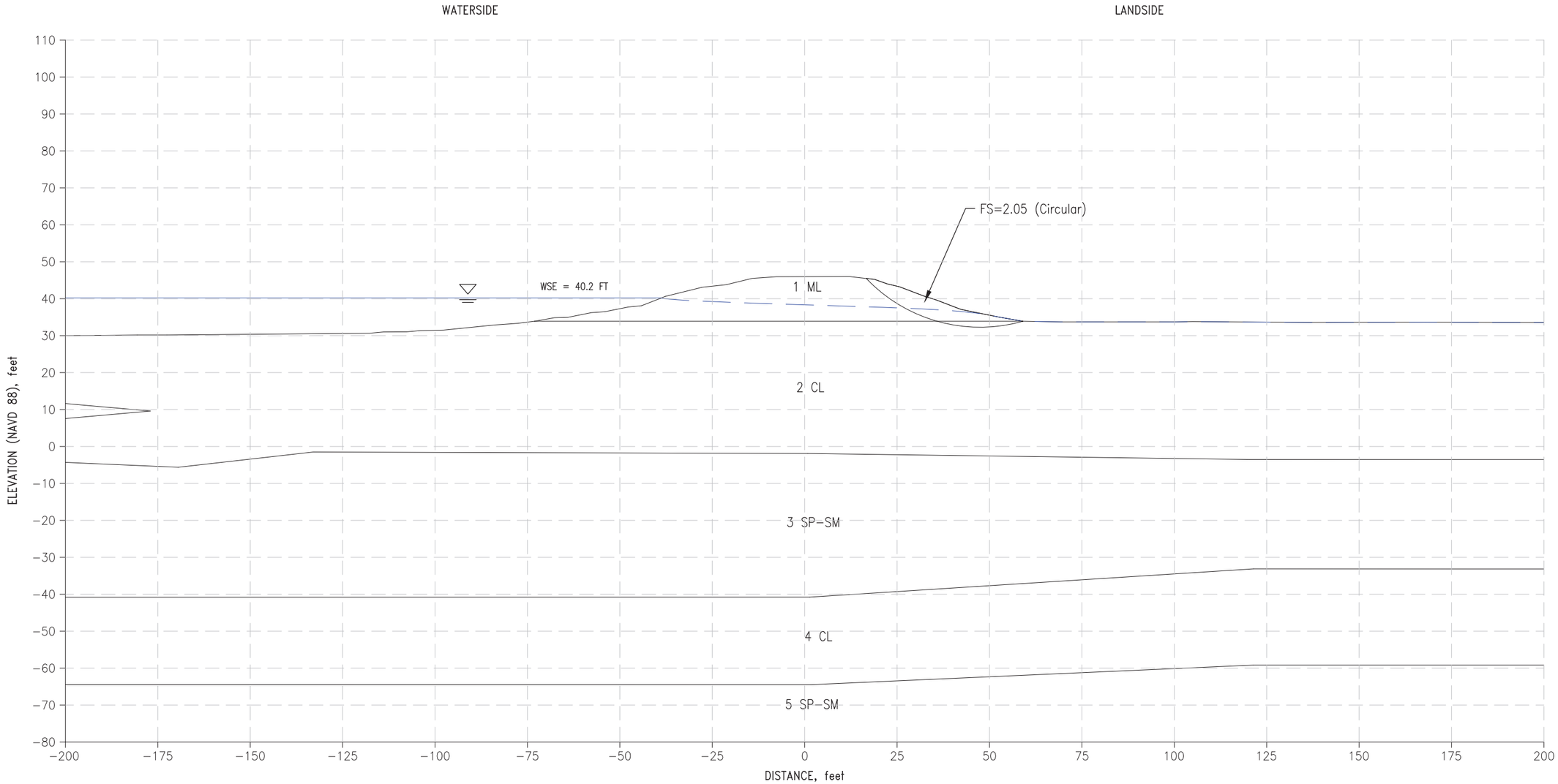
B) TOTAL HEAD CONTOURS



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE A–A–4
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	STEADY STATE SEEPAGE WITHOUT INTAKE CHANNEL CROSS SECTION A-A' STA 998+00	

PLOT BY: MHAVEY – Jan 31, 2021 – 8:32:32pm
DRAWING: \\dos-dlc\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07–Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A'\A-A-4 CROSS SECTION A-A'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



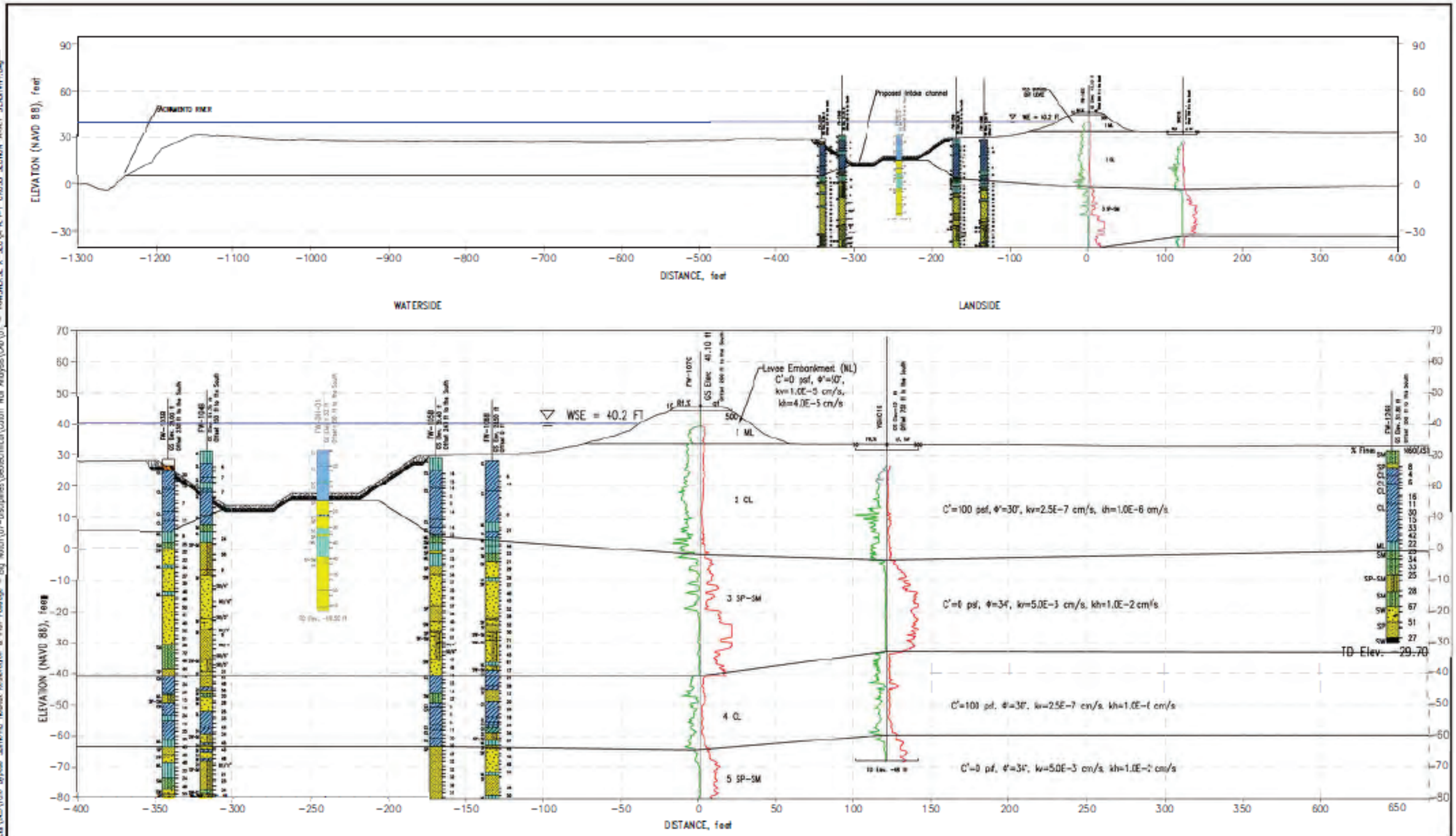
Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WITHOUT INTAKE CHANNEL CROSS SECTION A-A' STA 998+00	FIGURE A-A-5
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY - Jan 31, 2021 - 7:18:38pm
DRAWING: \\Doe-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A'\A-A-5 CROSS SECTION A-A'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section A-A Sensitivity Results

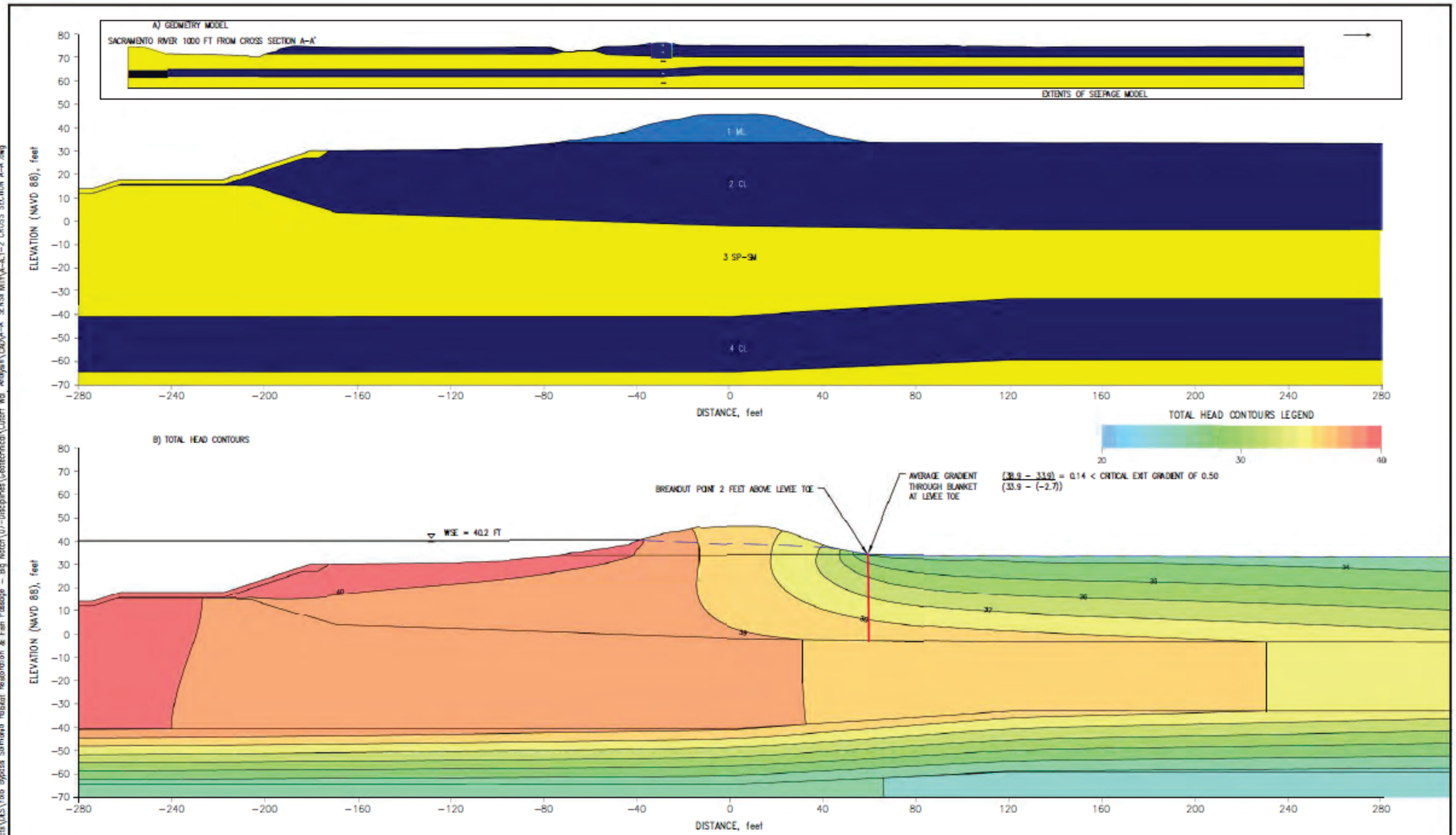
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE A–A–6
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	TRANSVERSE CROSS SECTION INTAKE CHANNEL CROSS SECTION A–A' SENSITIVITY STA 998+00	

PLOT BY: MHAVEY – Feb 22, 2021 – 3:12:24pm
DRAWING: \\Dwr-fs\Projects\CAD\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cad\Soil Analysis\CAD\01 – TRANSVERSE X-SEC\A-A-1-1 CROSS SECTION A-A-1' SENSITIVITY.dwg

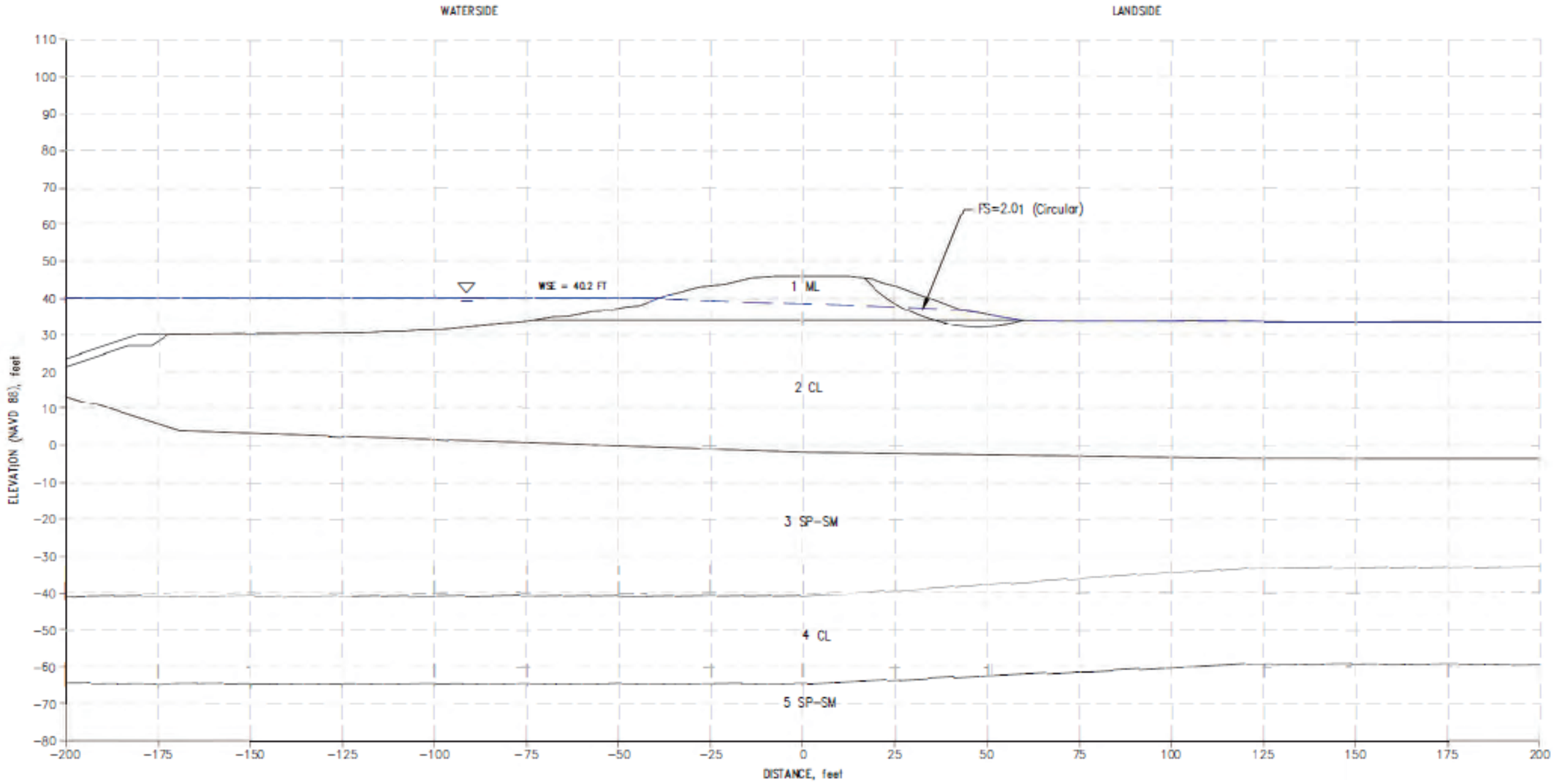
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE INTAKE CHANNEL CROSS SECTION A–A' SENSITIVITY STA 998+00	FIGURE A–A–7
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Jan 31, 2021 – 4:45:40pm
DRAWING: \\Doe-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A' SENSITIVITY\A-A_1-2 CROSS SECTION A-A'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



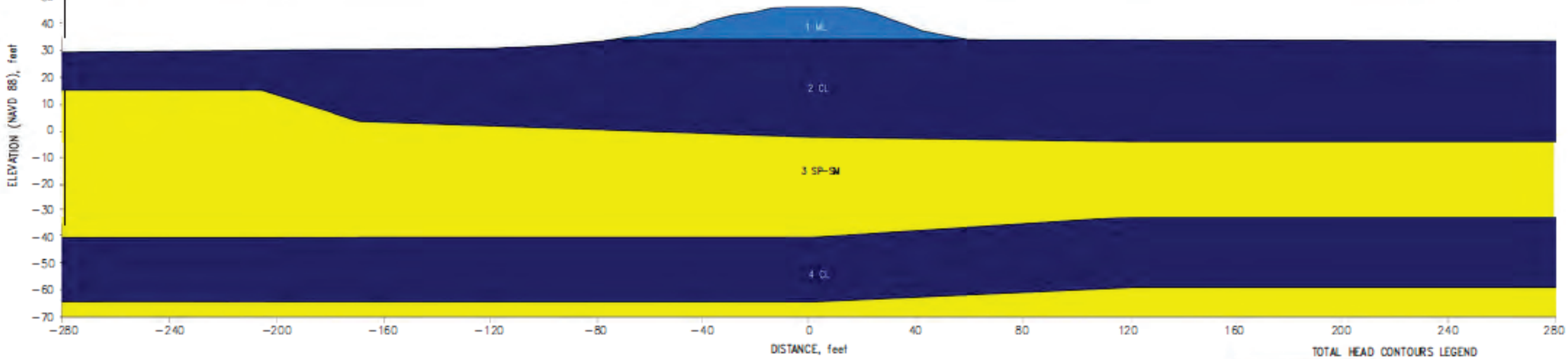
PLOT BY: MHAVEY - Jan 31, 2021 - 7:22:10pm
DRAWING: \\Dwr-fileVprojects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A' SENSITIVITY\A-A-1-3 CROSS SECTION A-A'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS INTAKE CHANNEL CROSS SECTION A-A' SENSITIVITY STA 998+00
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE		FIGURE A-A-8

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL
SACRAMENTO RIVER 1000 FT FROM CROSS SECTION A-A'



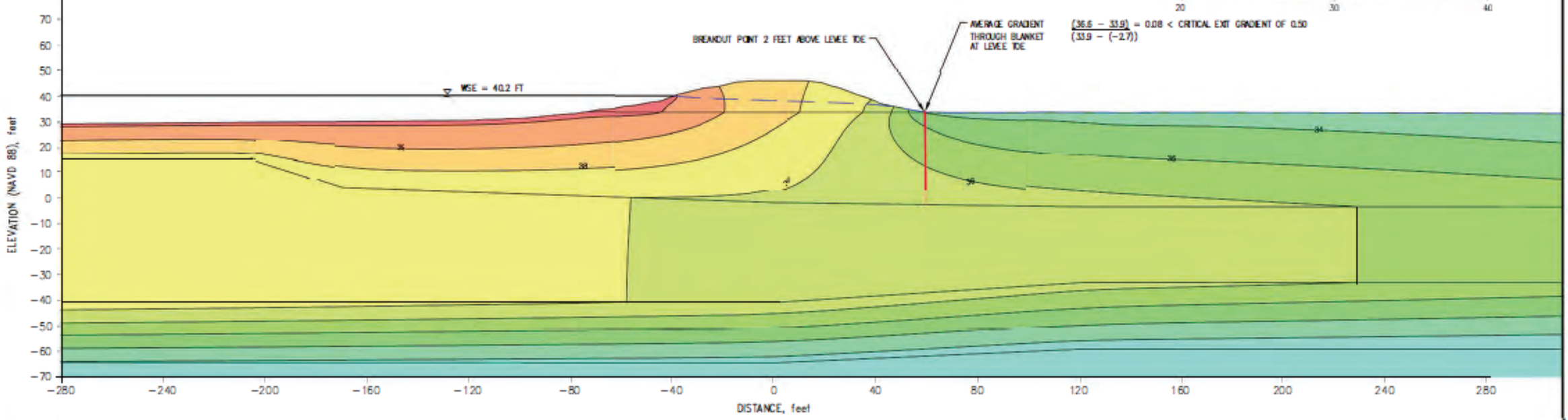


B) TOTAL HEAD CONTOURS

TOTAL HEAD CONTOURS LEGEND



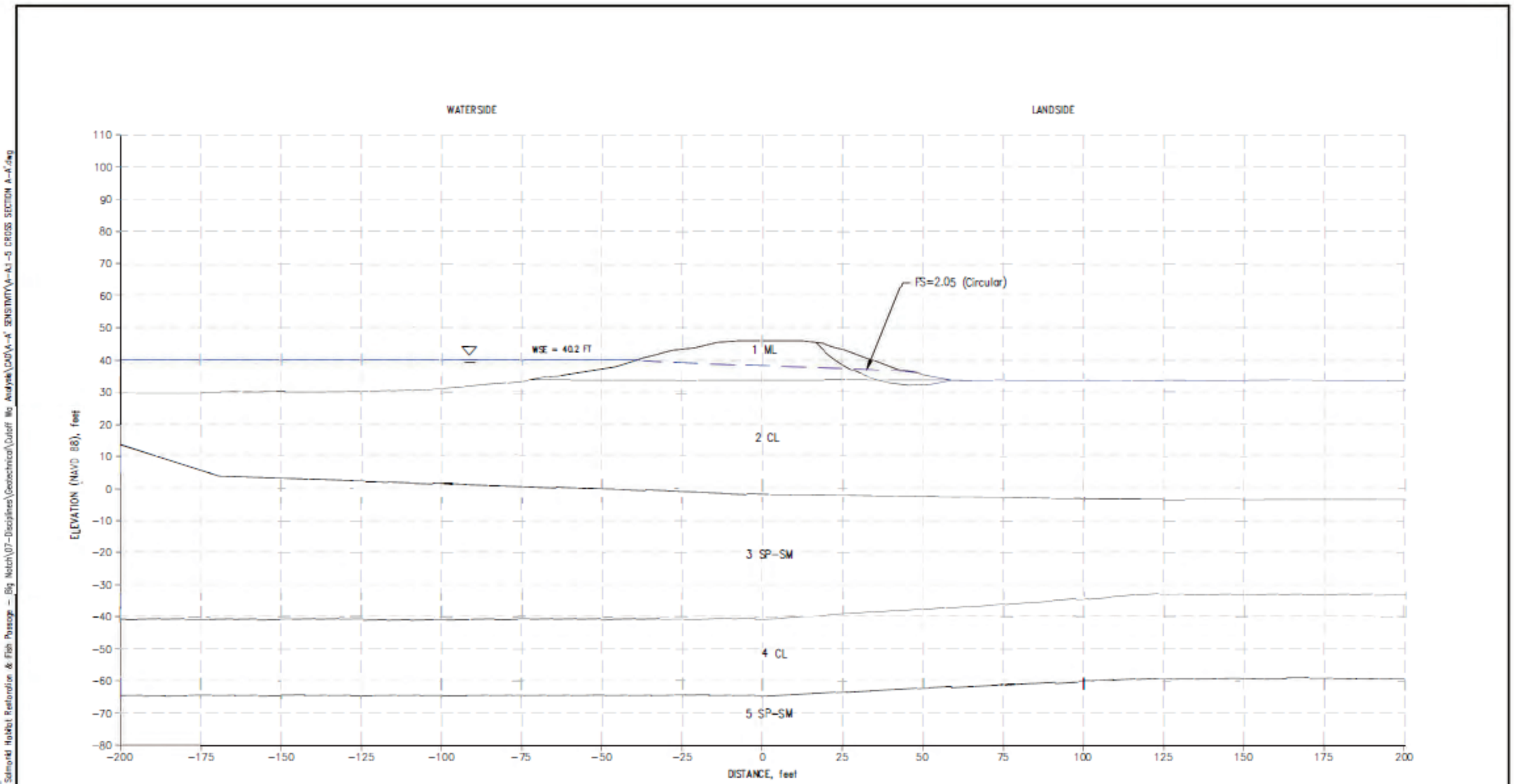
AVERAGE GRADIENT THROUGH BLANKET AT LEVEE TOE: (36.6 − 33.9) = 0.08 < CRITICAL EXIT GRADIENT OF 0.50 (33.9 − (−2.7))



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR DATE FEBRUARY 2021	PREPARED BY MATTHEW HAVEY CHECKED BY VISHNAN GOPALAN, PE, GE	BIG NOTCH PROJECT	STEADY STATE SEEPAGE WITHOUT INTAKE CHANNEL CROSS SECTION A-A' SENSITIVITY STA 998+00	FIGURE A-A-9

PLOT BY: MHAVEY - Jun 31, 2021 - 4:39:33pm
DRAWING: \\Dee-fs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A' SENSITIVITY\A-A.1-4 CROSS SECTION A-A'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



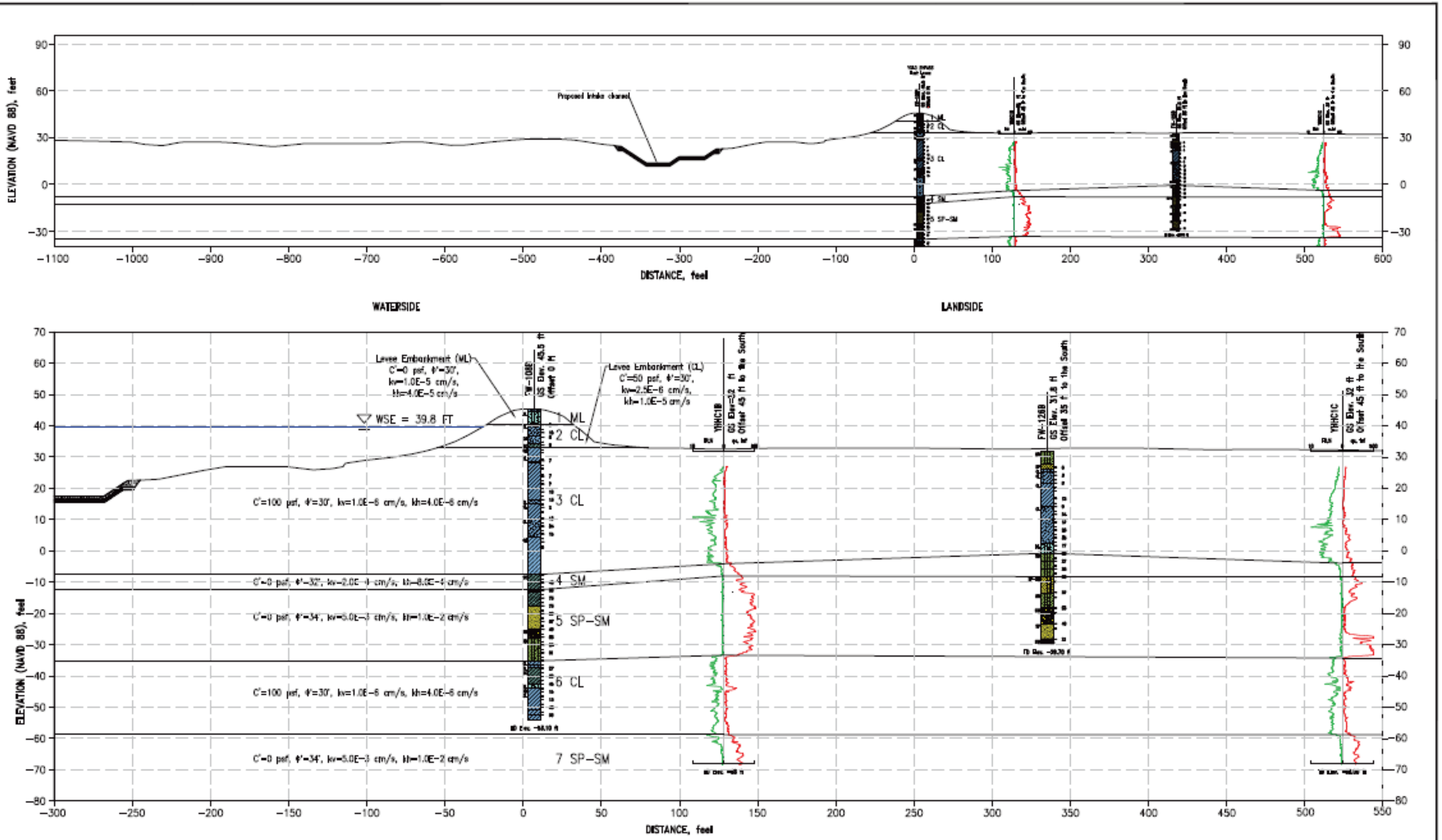
PLOT BY: MHAVEY - Jan 31, 2021 - 7:23:57pm
DRAWING: \\Dwr-fileV\Projects\DES\Yolo Bypass\Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\A-A' SENSITIVITY\A-A1-5 CROSS SECTION A-A'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WIHTOUT INTAKE CHANNEL CROSS SECTION A-A' SENSITIVITY STA 998+00	FIGURE A-A-10
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section B-B' Results

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE B–B–1
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	TRANSVERSE CROSS SECTION TRANSPORT CHANNEL CROSS SECTION B–B' STA 1005+70	

PLOT BY: MHAVEY – Feb 05, 2021 – 12:06:36pm
DRAWING: \\Dos-dfg\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07–Discipines\Geotechnical\Current Wall Analysis\CAD\01 – TRANSVERSE X-SECT\B–B–1 CROSS SECTION B–B'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL

EXTENTS OF SEEPAGE MODEL

1 ML
2 CL
3 CL
4 SM
5 SP-SM
6 CL
7 SP-SM

ELEVATION (NAVD 88), feet

DISTANCE, feet

TOTAL HEAD CONTOURS LEGEND

20 29.5 39

B) TOTAL HEAD CONTOURS

WSE = 39.8 FT

BREAKOUT POINT 2.0 FT ABOVE LEVEE TOE

AVERAGE GRADIENT THROUGH BLANKET AT LEVEE TOE

NO POSITIVE EXIT GRADIENT

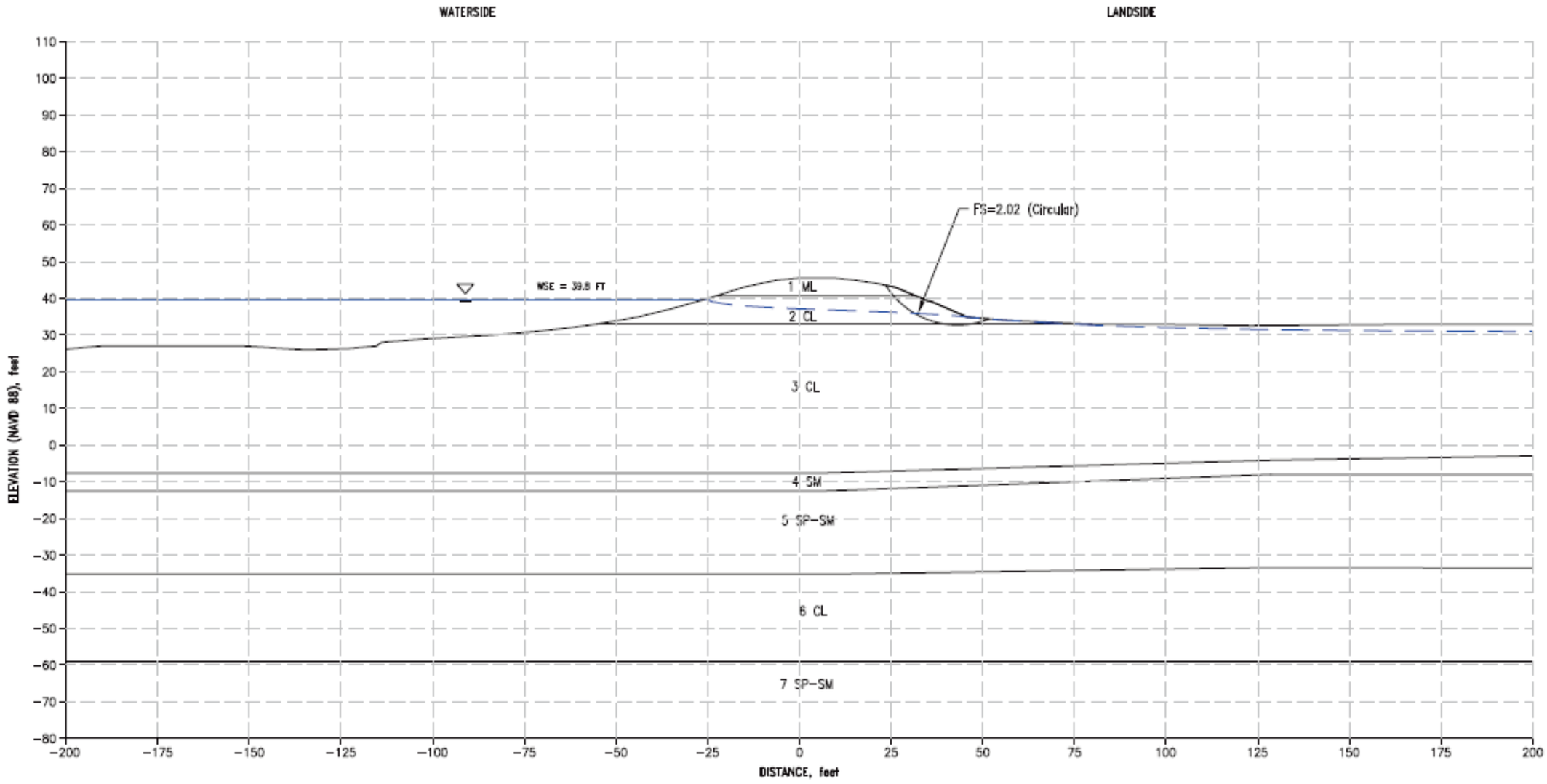
ELEVATION (NAVD 88), feet

DISTANCE, feet

PLOT BY: MHAVEY – Feb 17, 2021 – 11:09:00am
DRAWING: \\ad.water.ca.gov\dfs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07–Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\B–B–2 CROSS SECTION B–B'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE TRASNPORT CHANNEL CROSS SECTION B–B' STA 1005+70
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE		FIGURE B–B–2

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Feb 01, 2021 – 11:24:25am
DRAWING: \\Joe-fs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Current Wall Analysis\CAD\B-B-3 CROSS SECTION B-B'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR DATE FEBRUARY 2021	PREPARED BY MATTHEW HAVEY CHECKED BY VISHNAN GOPALAN, PE, GE	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS TRANSPORT CHANNEL CROSS SECTION B-B' STA 1005+70	FIGURE B-B-3

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL

EXTENTS OF SEEPAGE MODEL

1 ML
2 CL
3 CL
4 SM
5 SP-SM
6 CL
7 SP-SM

ELEVATION (NAVD 88), feet

DISTANCE, feet

TOTAL HEAD CONTOURS LEGEND

20 29.5 39

B) TOTAL HEAD CONTOURS

WSE = 39.8 FT

BREAKOUT POINT 2.0 FT ABOVE LEVEE TOE

AVERAGE GRADIENT THROUGH BLANKET AT LEVEE TOE

NO POSITIVE EXIT GRADIENT

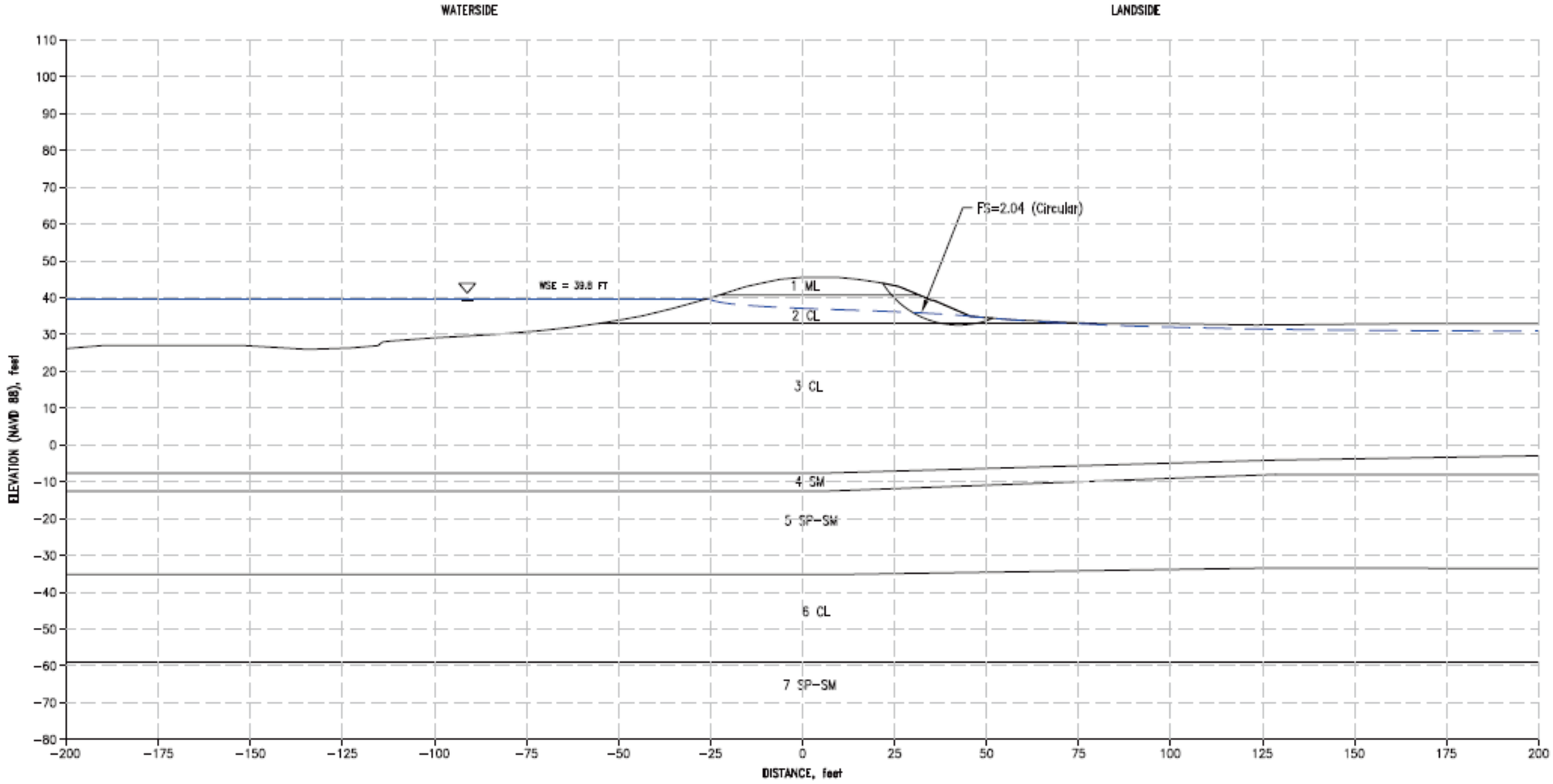
ELEVATION (NAVD 88), feet

DISTANCE, feet

PLOT BY: MHAVEY – Feb 17, 2021 – 11:14:18am
DRAWING: \\cws-ntw\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\B-B-4 CROSS SECTION B-B'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE WITHOUT TRANSPORT CHANNEL CROSS SECTION B-B' STA 1005+70	FIGURE B-B-4
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



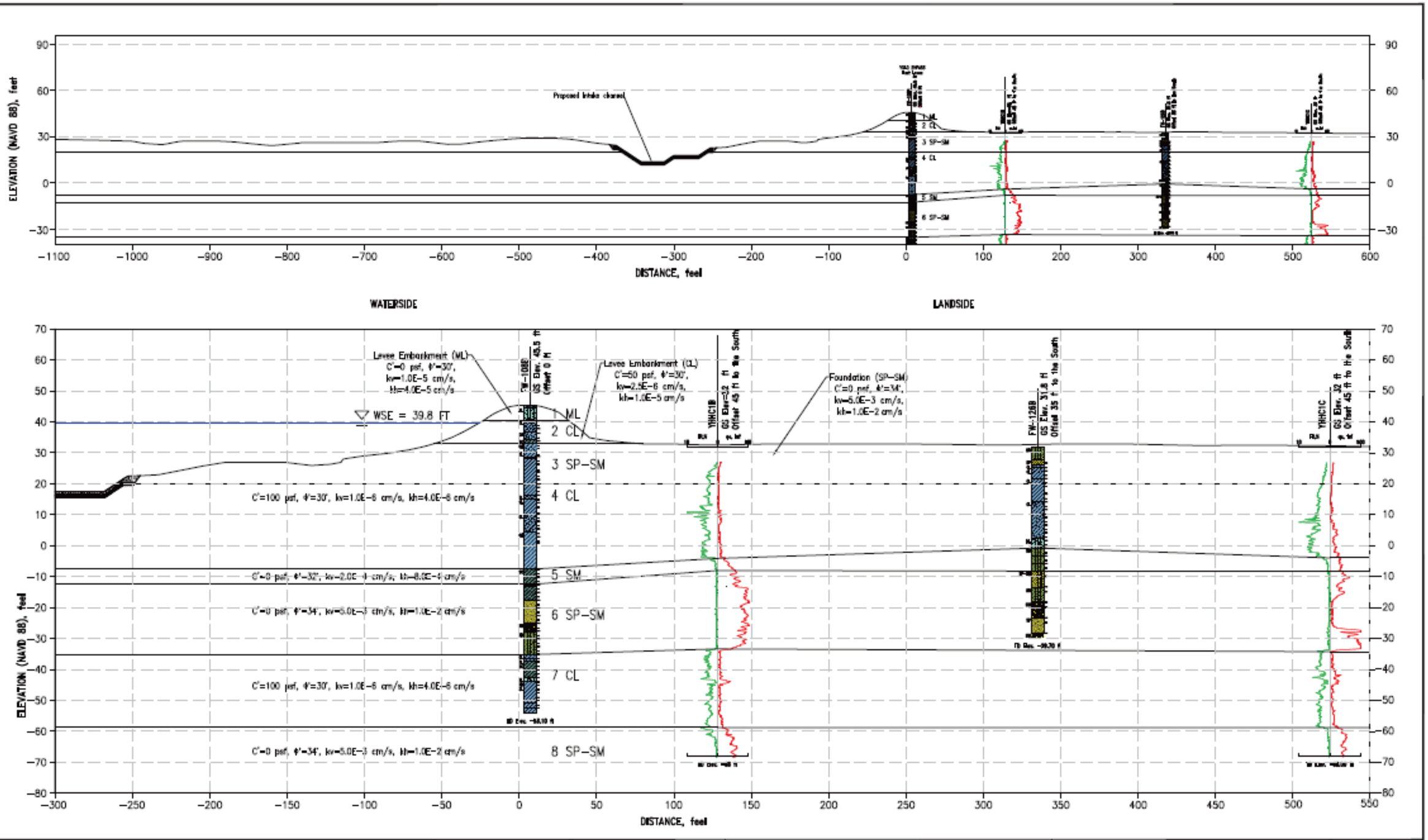
Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WITHOUT TRANSPORT CHANNEL CROSS SECTION B-B' STA 1005+70	FIGURE B-B-5
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY - Feb 01, 2021 - 11:35:50am
DRAWING: \\Joe-fs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Current Wall Analysis\C401\B-B-5 CROSS SECTION B-B' dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section C-C' Results

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

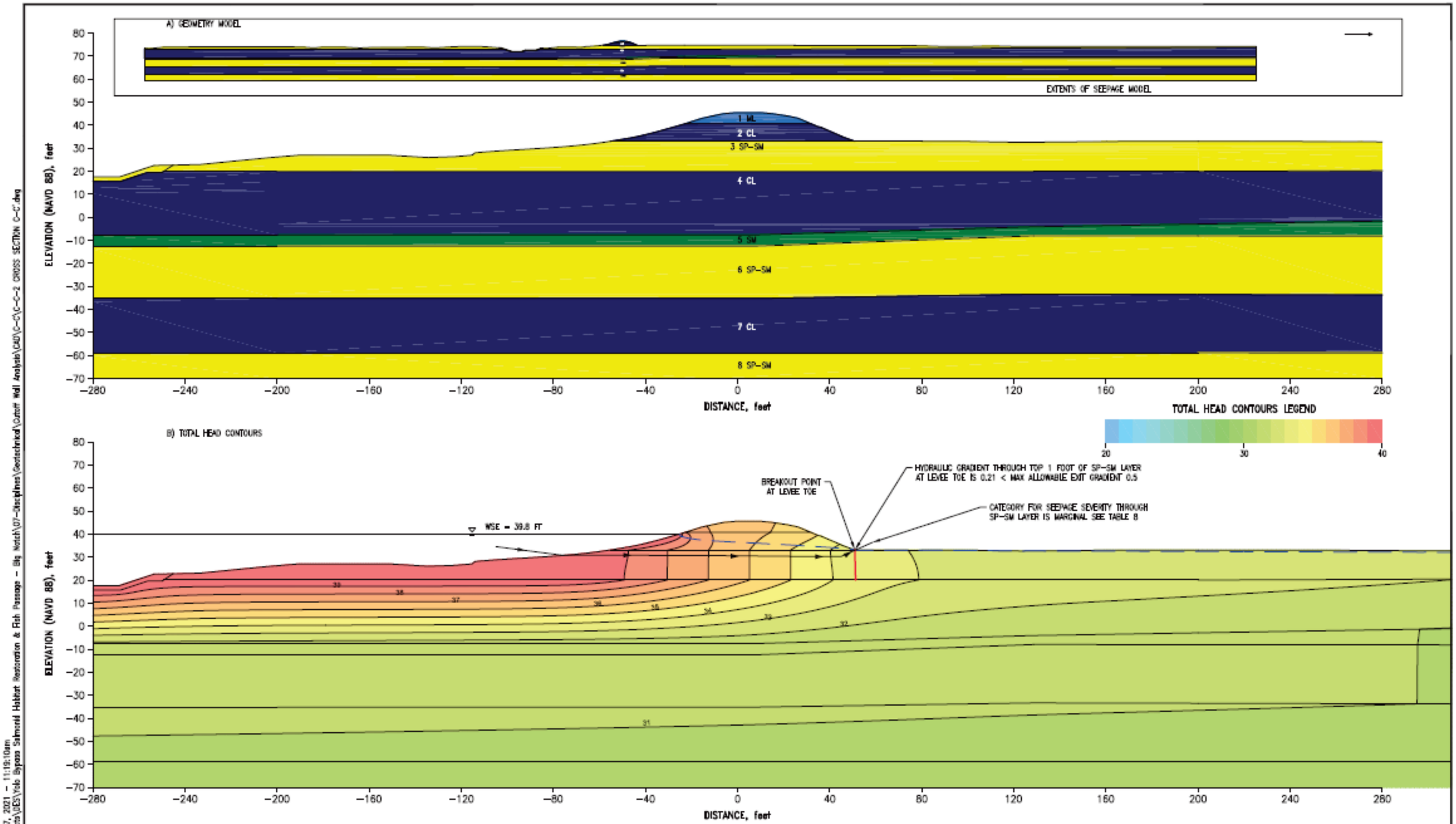


PLOT BY: MHAVEY – Feb 01, 2021 – 11:45:43am
DRAWING: \\dos-fs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\01 – TRANSVERSE X-SECTN\C-C-1 CROSS SECTION C-C' dwg

Department of Water Resources
Division of Engineering
Geotechnical Engineering

PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE C–C–1
DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	TRANSVERSE CROSS SECTION TRANSPORT CHANNEL CROSS SECTION C–C' STA 1009+00	

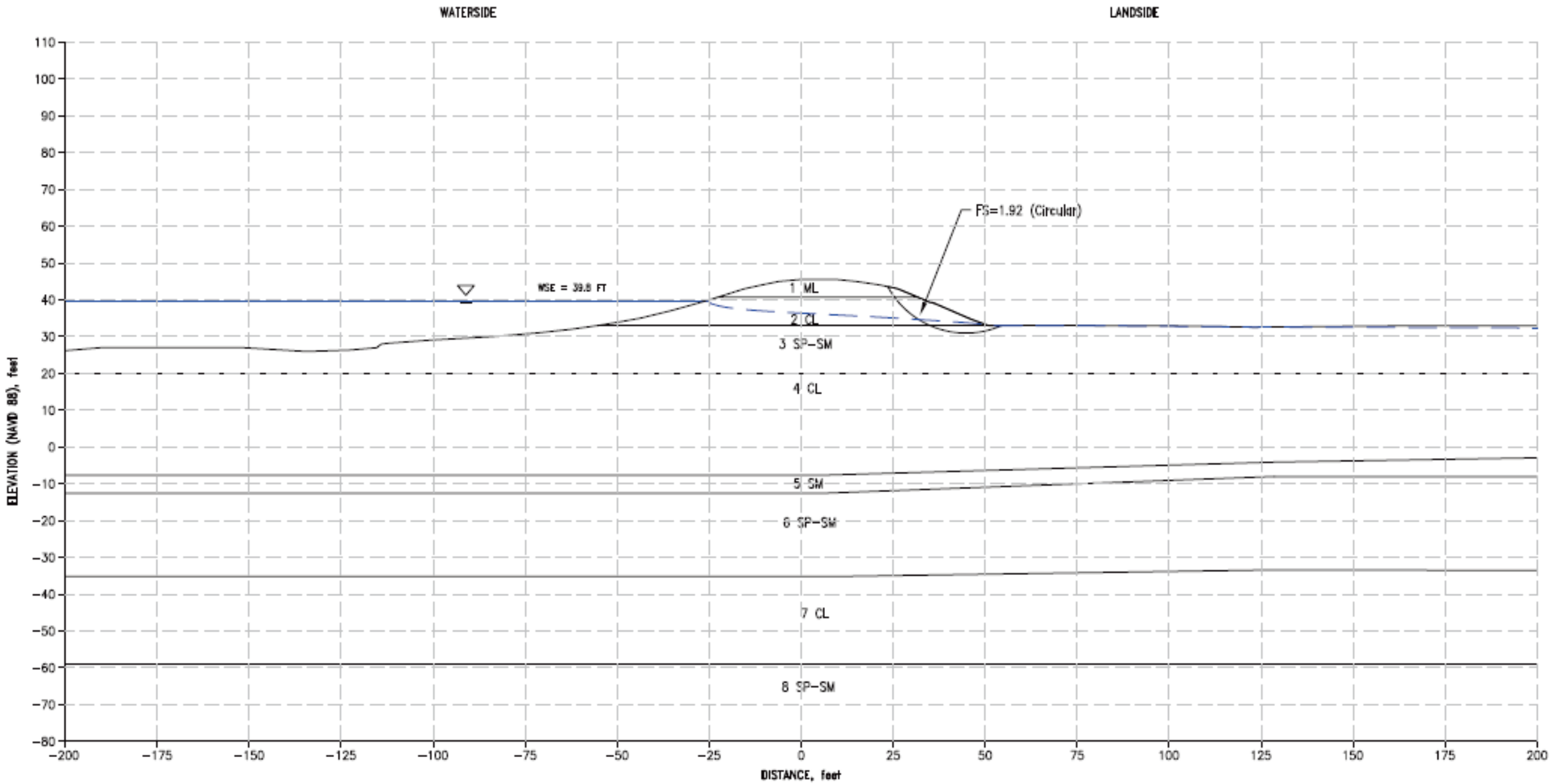
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Feb 17, 2021 – 11:19:10am
DRAWING: \\Dos-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\C-C\C-C-2 CROSS SECTION C-C' dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE TRANSPORT CHANNEL CROSS SECTION C-C' STA 1009+00	FIGURE C-C-2
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

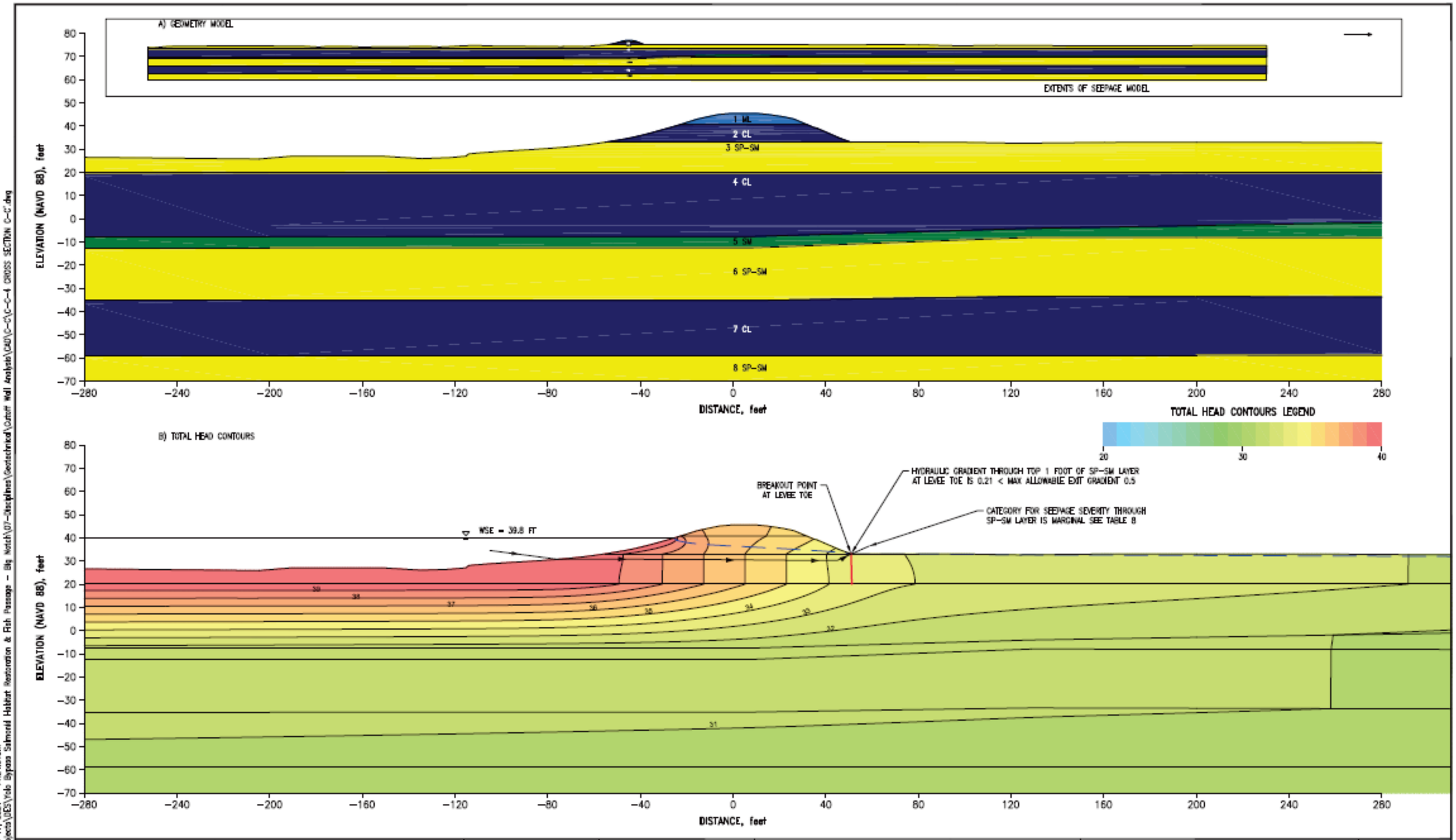
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Feb 01, 2021 – 11:42:03am
DRAWING: \\3ca-hlv\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\C-C'\C-C'-3 CROSS SECTION C-C' dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR DATE FEBRUARY 2021	PREPARED BY MATTHEW HAVEY CHECKED BY VISHNAN GOPALAN, PE, GE	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS TRANSPORT CHANNEL CROSS SECTION C-C' STA 1009+00	FIGURE C-C-3

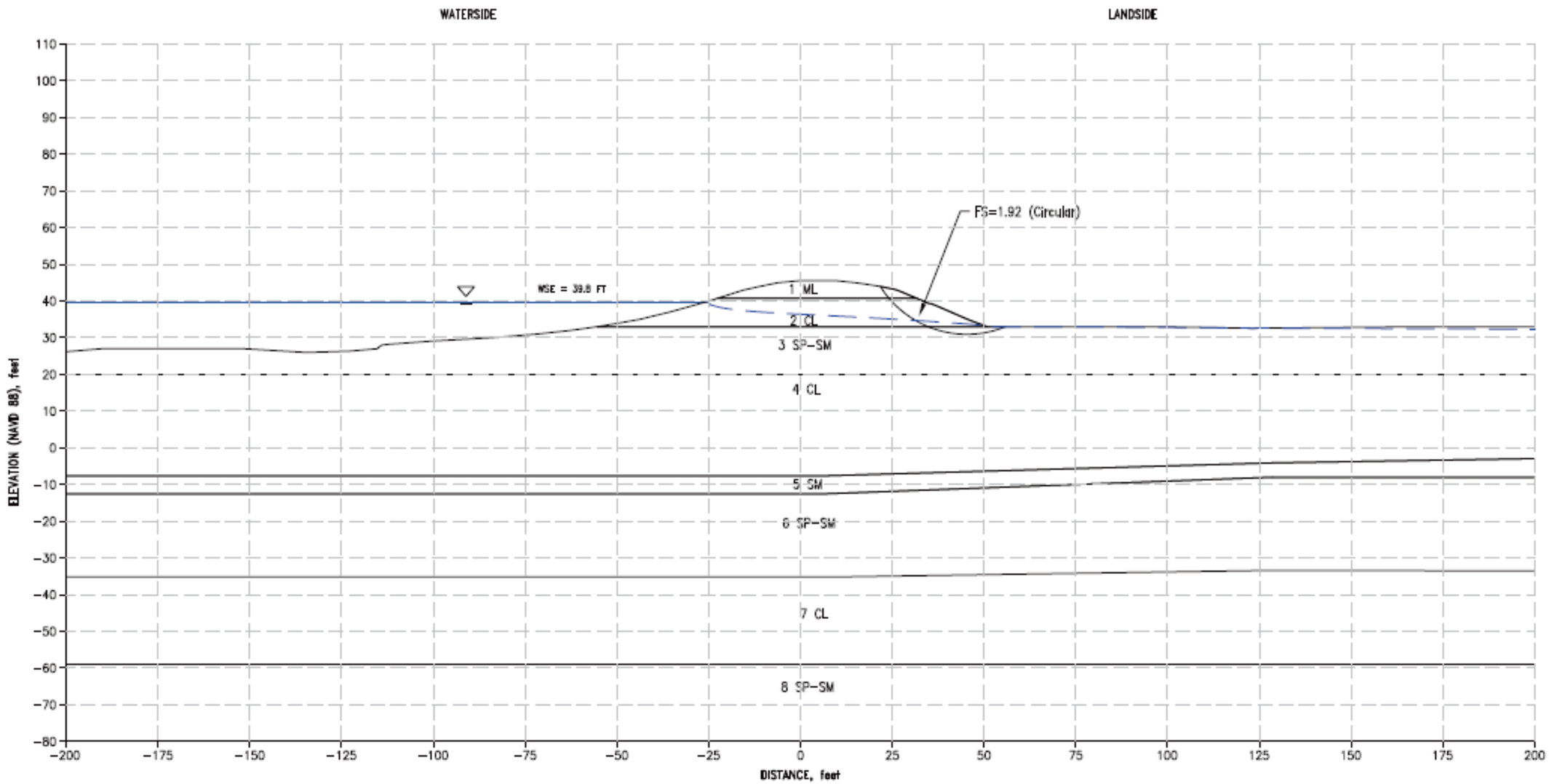
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Feb 17, 2021 – 11:24:01am
DRAWING: \\Dos-fs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\C-C\C-C-4 CROSS SECTION C-C'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE C–C–4
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	STEADY STATE SEEPAGE WITHOUT TRANSPORT CHANNEL CROSS SECTION C–C' STA 1009+00	

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



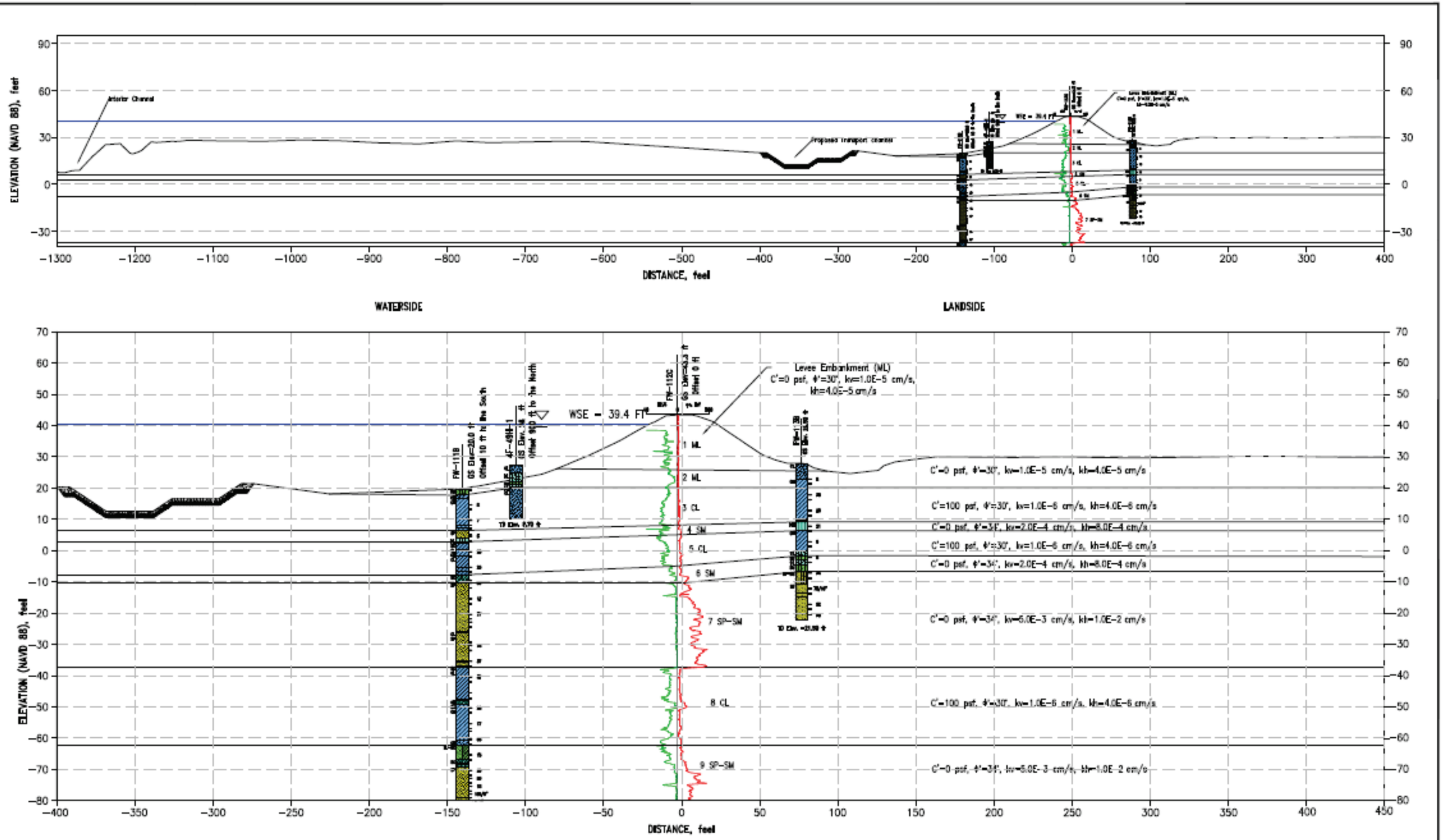
Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WITHOUT TRANSPORT CHANNEL CROSS SECTION C-C' STA 1009+00	FIGURE C-C-5
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 01, 2021 – 11:41:34am
DRAWING: \\Dwr-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Current Wall Analysis\CAD\C-C\C-C-5 CROSS SECTION C-C'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section D-D' Results

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE D–D–1
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	TRANSVERSE CROSS SECTION TRANSPORT CHANNEL CROSS SECTION D–D' STA 1019+50	

PLOT BY: MHAVEY – Feb 17, 2021 – 11:31:52am
DRAWING: \\Dos-dlw\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07–Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\01 – TRANSVERSE x-SEC\D–D–1 CROSS SECTION D–D'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL

EXTENTS OF SEEPAGE MODEL

ELEVATION (NAVD 88), feet

DISTANCE, feet

1 ML
2 ML
3 CL
4 SM
5 CL
6 SM
7 SP-SM
8 CL
9 SP-SM

B) TOTAL HEAD CONTOURS

TOTAL HEAD CONTOURS LEGEND

20 29.5 39

WSE = 39.4 FT

BREAKOUT POINT 4 FT ABOVE LEVEE TOE

AVERAGE GRADIENT THROUGH BLANKET AT LEVEE TOE $\frac{(30.9 - 25.8)}{(25.8 - (9.2))}$ = 0.31 < CRITICAL EXIT GRADIENT OF 0.50

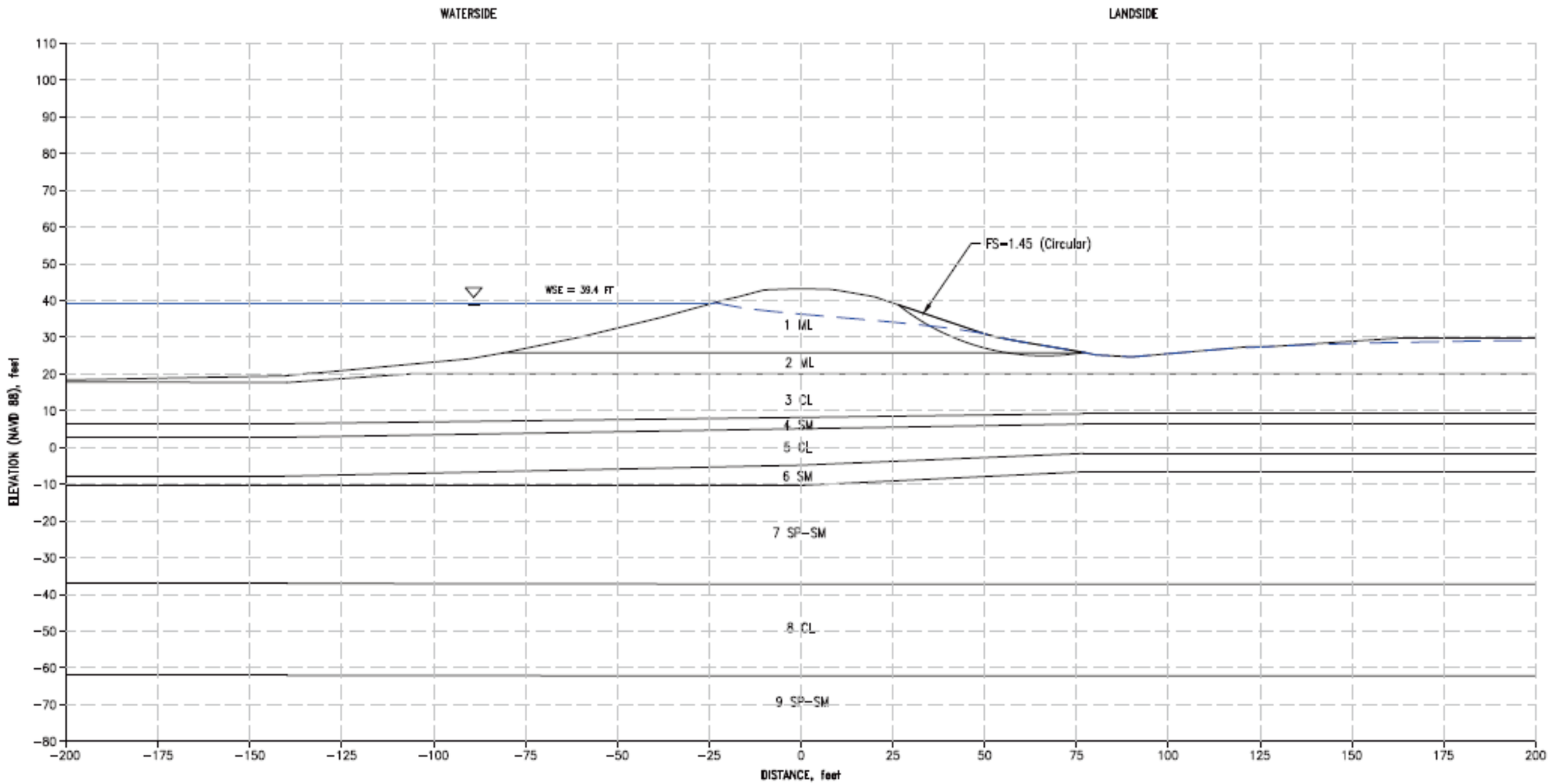
CATEGORY FOR SEVERITY OF SEEPAGE THROUGH ML LAYER IS NEGLIGIBLE SEE TABLE 8

AVERAGE GRADIENT THROUGH BLANKET AT DITCH BOTTOM APPROXIMATELY 15 FT FROM TOE $\frac{(30.8 - 24.6)}{(24.6 - (9.2))}$ = 0.39 < CRITICAL EXIT GRADIENT OF 0.53

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE ANALYSIS RESULTS TRANSPORT CHANNEL CROSS SECTION D-D' STA 1019+50	FIGURE D-D-2
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 05, 2021 – 2:07:34pm
DRAWING: \\Doe-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\D-D\D-D-2 CROSS SECTION D-D'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR ----	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS TRANSPORT CHANNEL CROSS SECTION D-D' STA 1019+50	FIGURE D-D-3
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY - Jan 26, 2021 - 12:48:17pm
DRAWING: \\Doe-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Current Wall Analysis\CAD\D-D\D-D-3 CROSS SECTION D-D'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL

EXTENTS OF SEEPAGE MODEL

ELEVATION (NAVD 88), feet

DISTANCE, feet

1 ML
2 ML
4 SM
6 SM
7 SP-SM
9 SP-SM

B) TOTAL HEAD CONTOURS

TOTAL HEAD CONTOURS LEGEND

20 23.5 39

WSE = 39.4 FT

BREAKOUT POINT 4 FT ABOVE LEVEE TOE

AVERAGE GRADIENT THROUGH BLANKET AT LEVEE TOE $\frac{(30.8 - 25.8)}{(25.8 - (9.2))}$ = 0.30 < CRITICAL EXIT GRADIENT OF 0.50

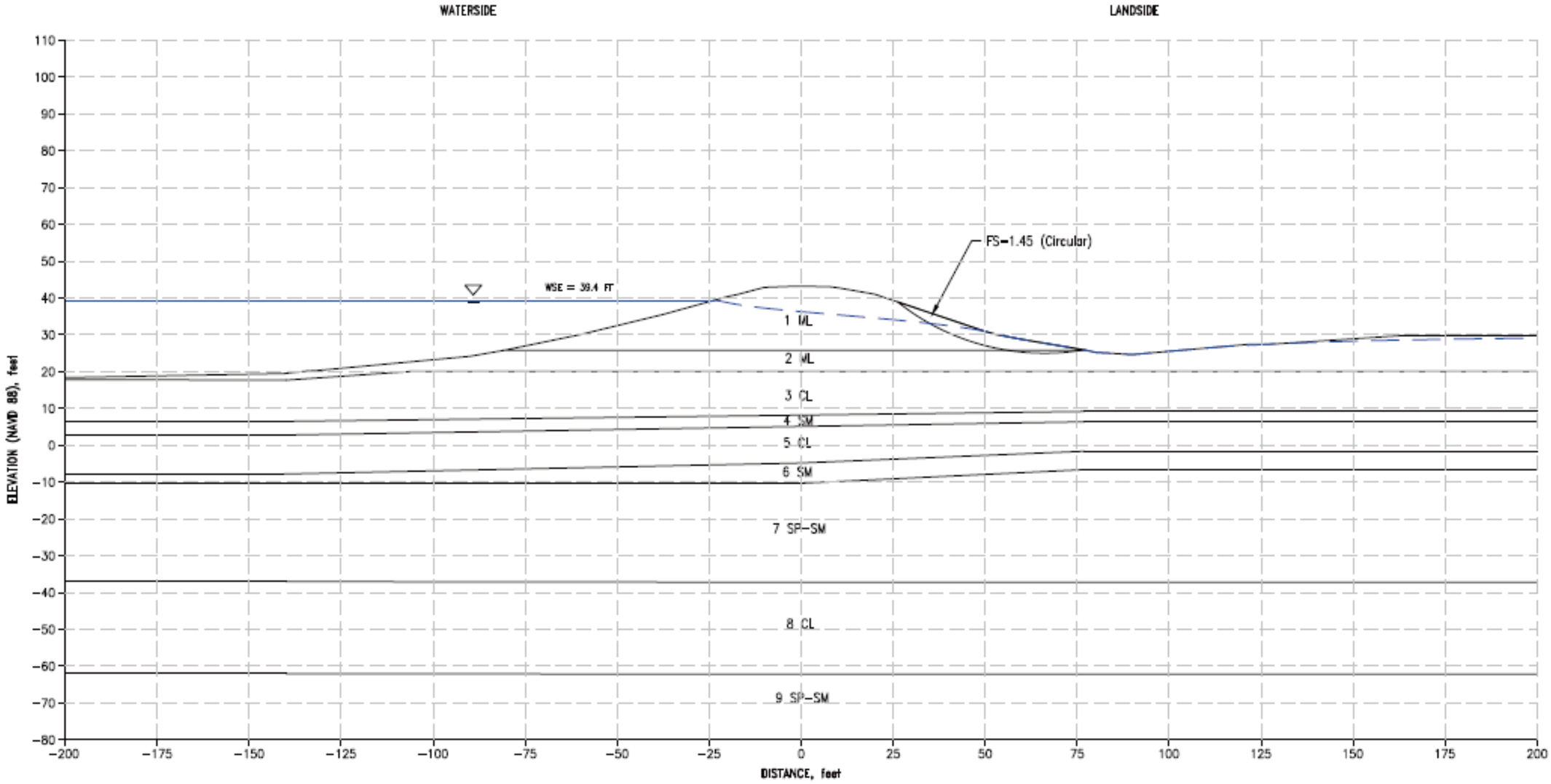
CATEGORY FOR SEVERITY OF SEEPAGE THROUGH ML LAYER IS NEGLIGIBLE SEE TABLE 8

AVERAGE GRADIENT THROUGH BLANKET AT DITCH BOTTOM APPROXIMATELY 15 FT FROM TOE $\frac{(30.7 - 24.6)}{(24.6 - (9.2))}$ = 0.39 < CRITICAL EXIT GRADIENT OF 0.53

PLOT BY: MHAVEY - Feb 05, 2021 - 2:23:12pm
DRAWING: \\Dwr-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\D-D\D-D-4 CROSS SECTION D-D'.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE ANALYSIS RESULTS WIHTOUT TRANSPORT CHANNEL CROSS SECTION D-D' STA 1019+50
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE		FIGURE D-D-4

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



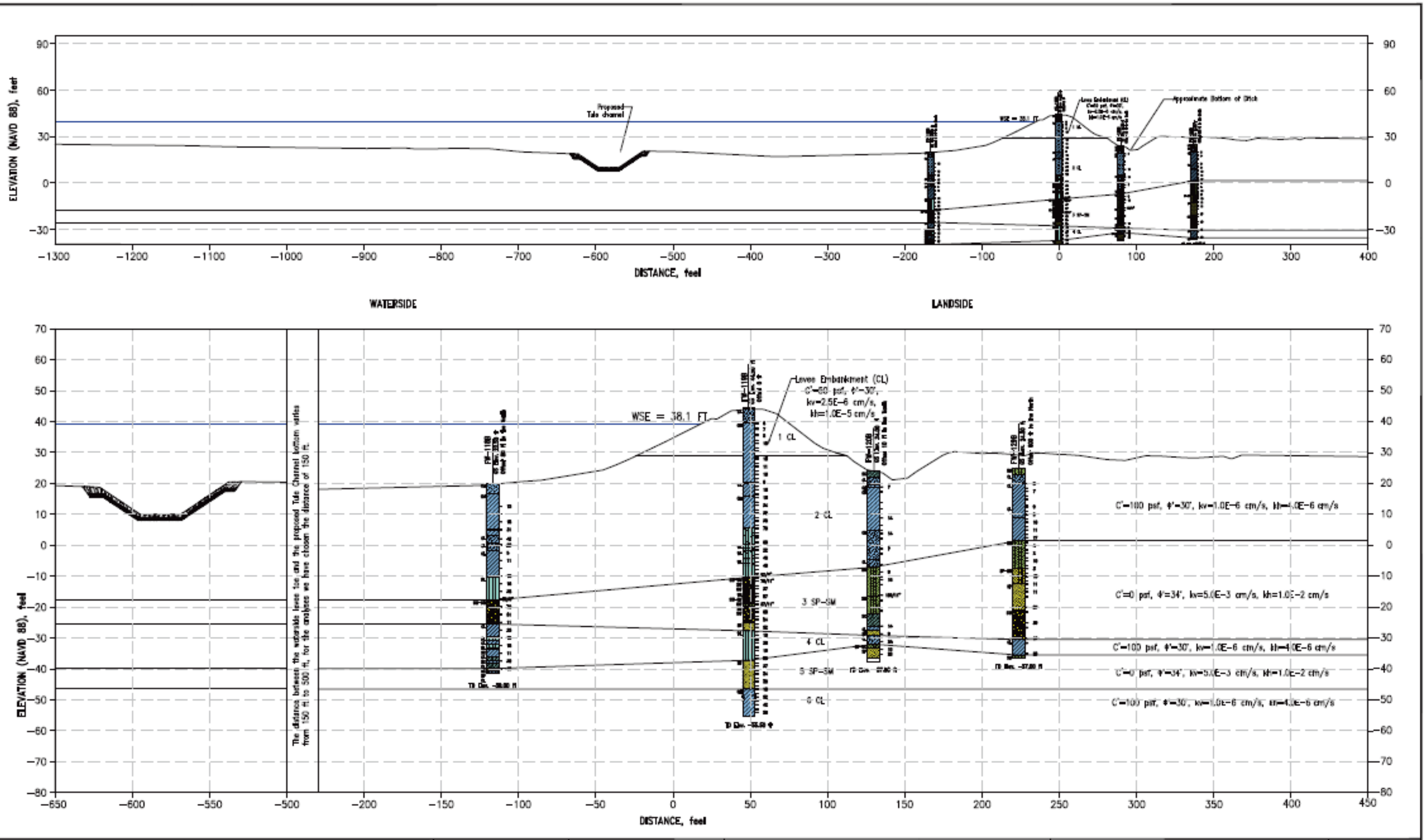
Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WITHOUT TRANSPORT CHANNEL CROSS SECTION D-D' STA 1019+50	FIGURE D-D-5
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY - Jan 26, 2021 - 12:49:48pm
DRAWING: \\Dot-nlk\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage - Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\D-D\D-D-5 CROSS SECTION D-D'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section E-E' Results

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Feb 05, 2021 – 1:45:08pm
DRAWING: \\Dos-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\01 – TRANSVERSE X-SECTION E-E-1 CROSS SECTION E-E.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE E-E-1
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	TRANSVERSE CROSS SECTION TULE CHANNEL CROSS SECTION E-E' STA 1064+00	

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL

EXTENTS OF SEEPAGE MODEL

ELEVATION (NAVD 88), feet

DISTANCE, feet

1 CL

2 CL

3 SP-SM

4 CL

5 SP-SM

6 CL

TOTAL HEAD CONTOURS LEGEND

B) TOTAL HEAD CONTOURS

WSE = 38.1 FT

BREAKOUT POINT 1 FT ABOVE LEVEE TOE

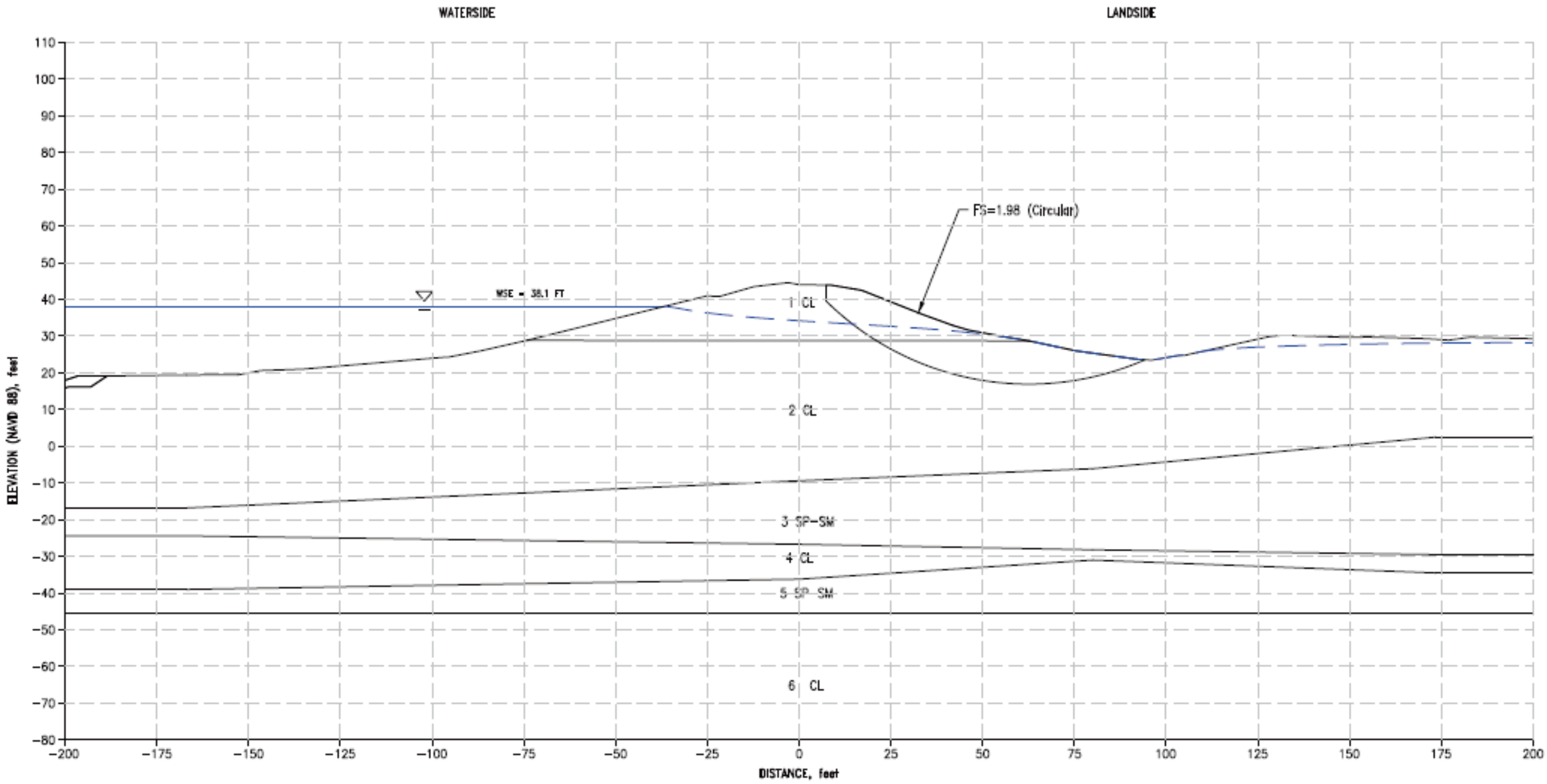
AVERAGE GRADIENT THROUGH BLANKET LEVEE TOE (28.8 − 28.7) / (28.7 − (−6.6)) = NO POSITIVE GRADIENT

AVERAGE GRADIENT THROUGH BLANKET AT DITCH BOTTOM, APPROXIMATELY 35 FT FROM TOE (28.8 − 23.4) / (23.4 − (−4.4)) = 0.19 < CRITICAL EXIT GRADIENT OF 0.57

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE ANALYSIS RESULTS TULE CHANNEL CROSS SECTION E-E' STA 1064+00	FIGURE E-E-2
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 05, 2021 – 3:22:38pm
DRAWING: \\Dos-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\E-E\E-E-2 CROSS-SECTION E-E'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Note: Tension Crack depth of 4 feet assumed for the circular.

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR DATE FEBRUARY 2021	PREPARED BY MATTHEW HAVEY CHECKED BY VISHNAN GOPALAN, PE, GE	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS TULE CHANNEL CROSS SECTION E-E' STA 1064+00	FIGURE E-E-3

PLOT BY: MHAVEY – Feb 01, 2021 – 11:50:26am
DRAWING: \\Dos-nfs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-disciplines\Geotechnical\Current Wall Analysis\CAD\E-E\E-E-3 CROSS SECTION E-E'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

A) GEOMETRY MODEL

EXTENTS OF SEEPAGE MODEL

1 CL

2 CL

3 SP-SM

4 CL

5 SP-SM

6 CL

ELEVATION (NAVD 88), feet

DISTANCE, feet

B) TOTAL HEAD CONTOURS

TOTAL HEAD CONTOURS LEGEND

BREAKOUT POINT 1 FT ABOVE LEVEE TOE

AVERAGE GRADIENT THROUGH BLANKET LEVEE TOE (28.8 − 28.7) / (28.7 − (−6.6)) = NO POSITIVE GRADIENT

AVERAGE GRADIENT THROUGH BLANKET AT DITCH BOTTOM, APPROXIMATELY 35 FT FROM TOE (28.7 − 23.4) / (23.4 − (−4.4)) = 0.19 < CRITICAL EXIT GRADIENT OF 0.57

WSE = 38.1 FT

ELEVATION (NAVD 88), feet

DISTANCE, feet

PLOT BY: MHAVEY – Feb 05, 2021 – 3:30:10pm
DRAWING: \\Dos-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\E-E\E-E-4 CROSS SECTION E-E'.dwg

Department of Water Resources
Division of Engineering
Geotechnical Engineering

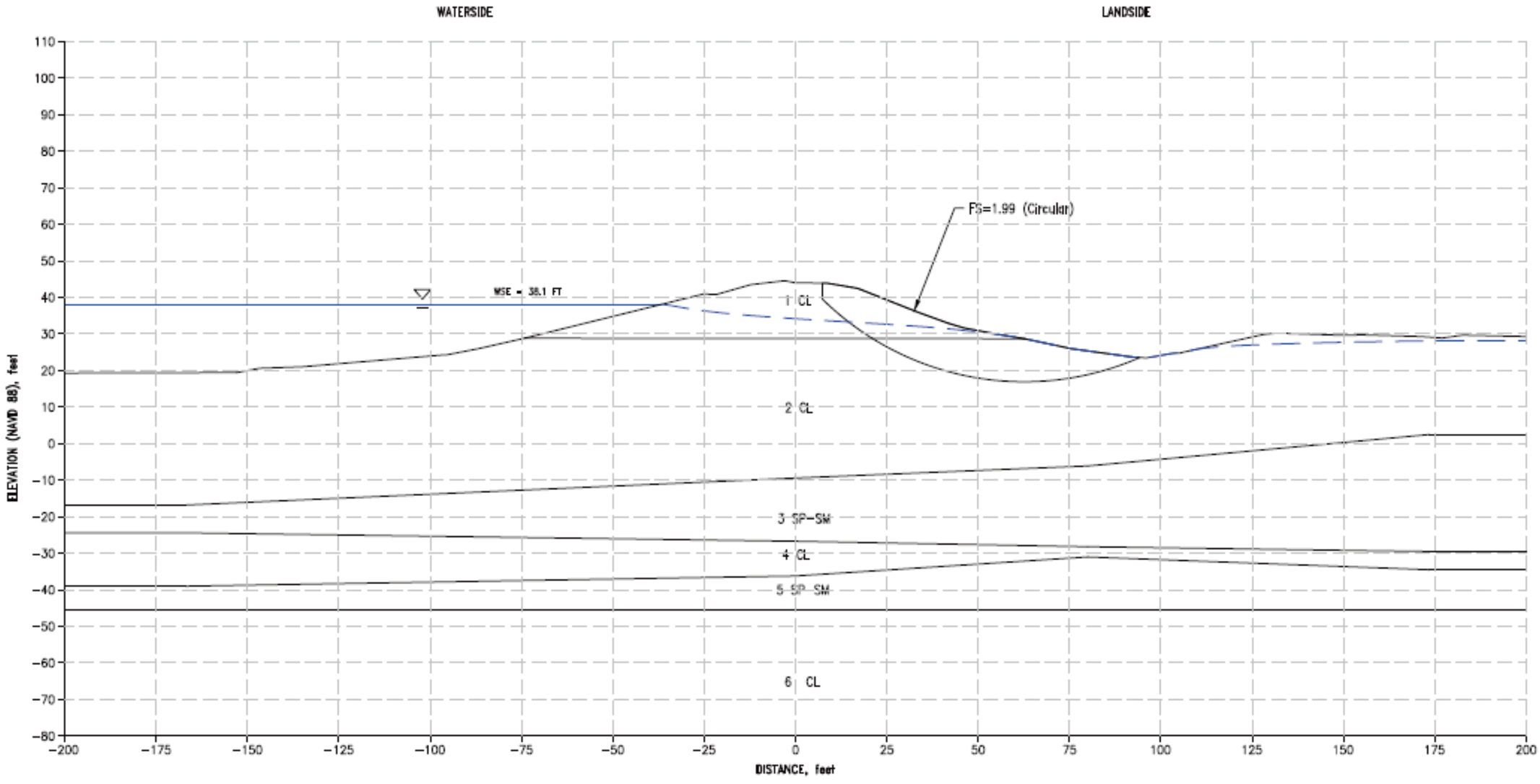
PREPARED FOR	PREPARED BY: MATTHEW HAVEY
DATE: FEBRUARY 2021	CHECKED BY: VISHNAN GOPALAN, PE, GE

BIG NOTCH PROJECT

STEADY STATE SEEPAGE ANALYSIS RESULTS
WITHOUT TULE CHANNEL
CROSS SECTION E-E'
STA 1064+00

FIGURE
E-E-4

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Note: Tension Crack depth of 4 feet assumed for the circular.

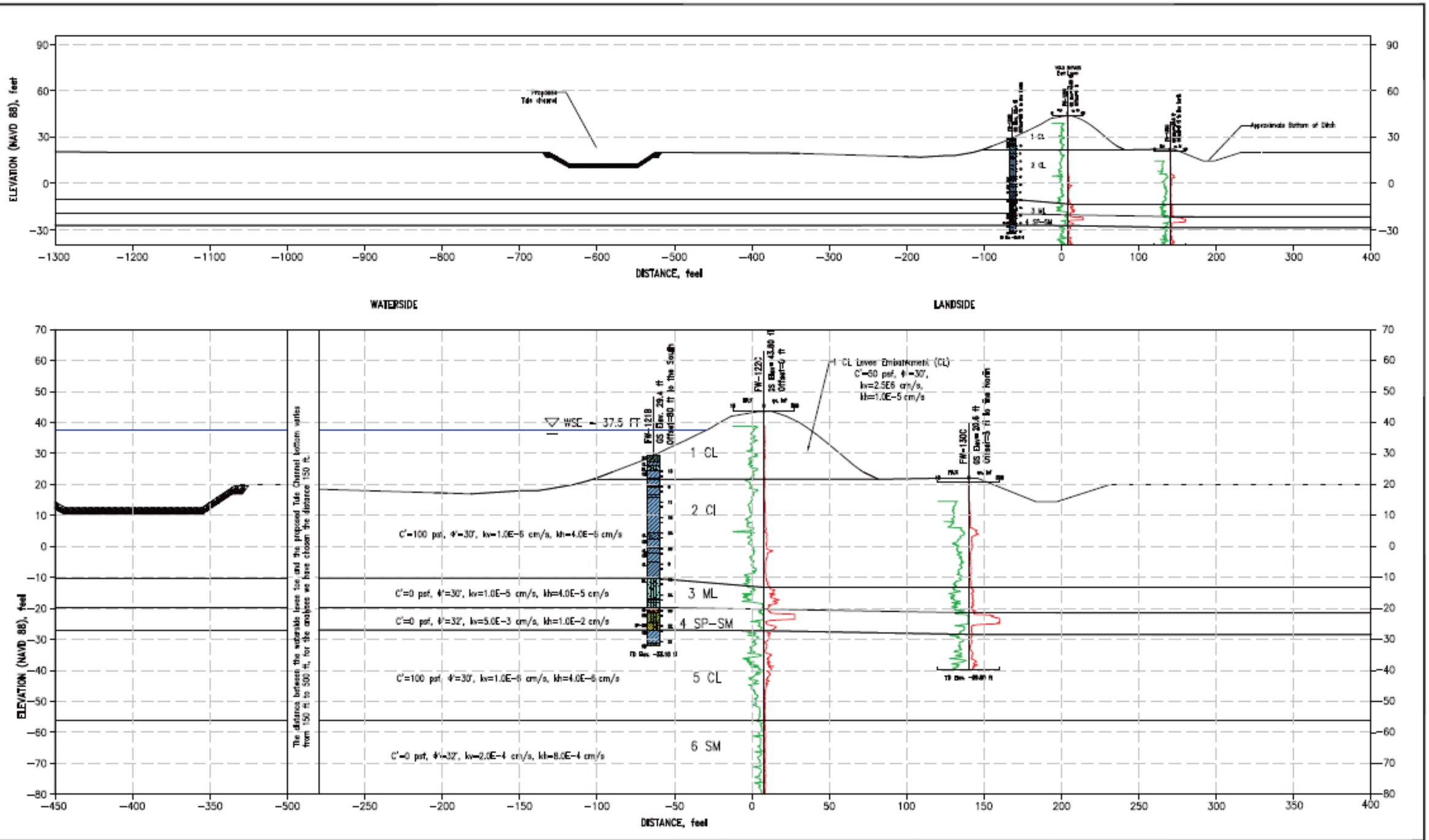
Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WITHOUT TULE CHANNEL CROSS SECTION E-E' STA 1064+00	FIGURE E-E-5
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 01, 2021 – 11:56:15am
DRAWING: \\Jos-fil\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Current Wall Analysis\CAD\E-E\E-E-5 CROSS SECTION E-E'.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Cross Section F-F' Results

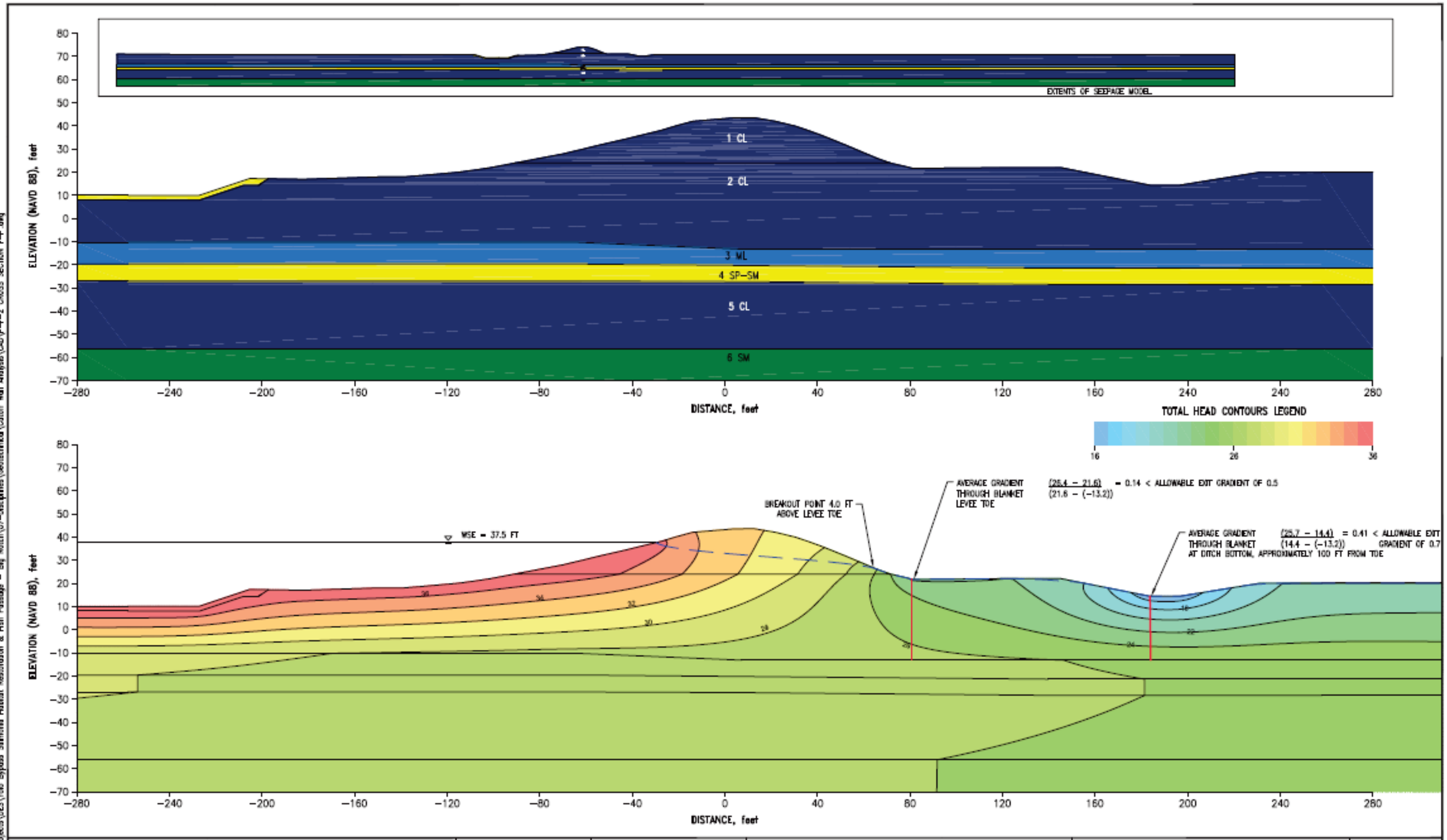
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Jan 29, 2021 – 10:30:48am
DRAWING: \\Dos-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\01 – TRANSVERSE X-SECTION F-F-1 CROSS SECTION F-F-2.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	FIGURE F-F-1
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE	TRANSVERSE CROSS SECTION TULE CHANNEL CROSS SECTION F-F' STA 1080+70	

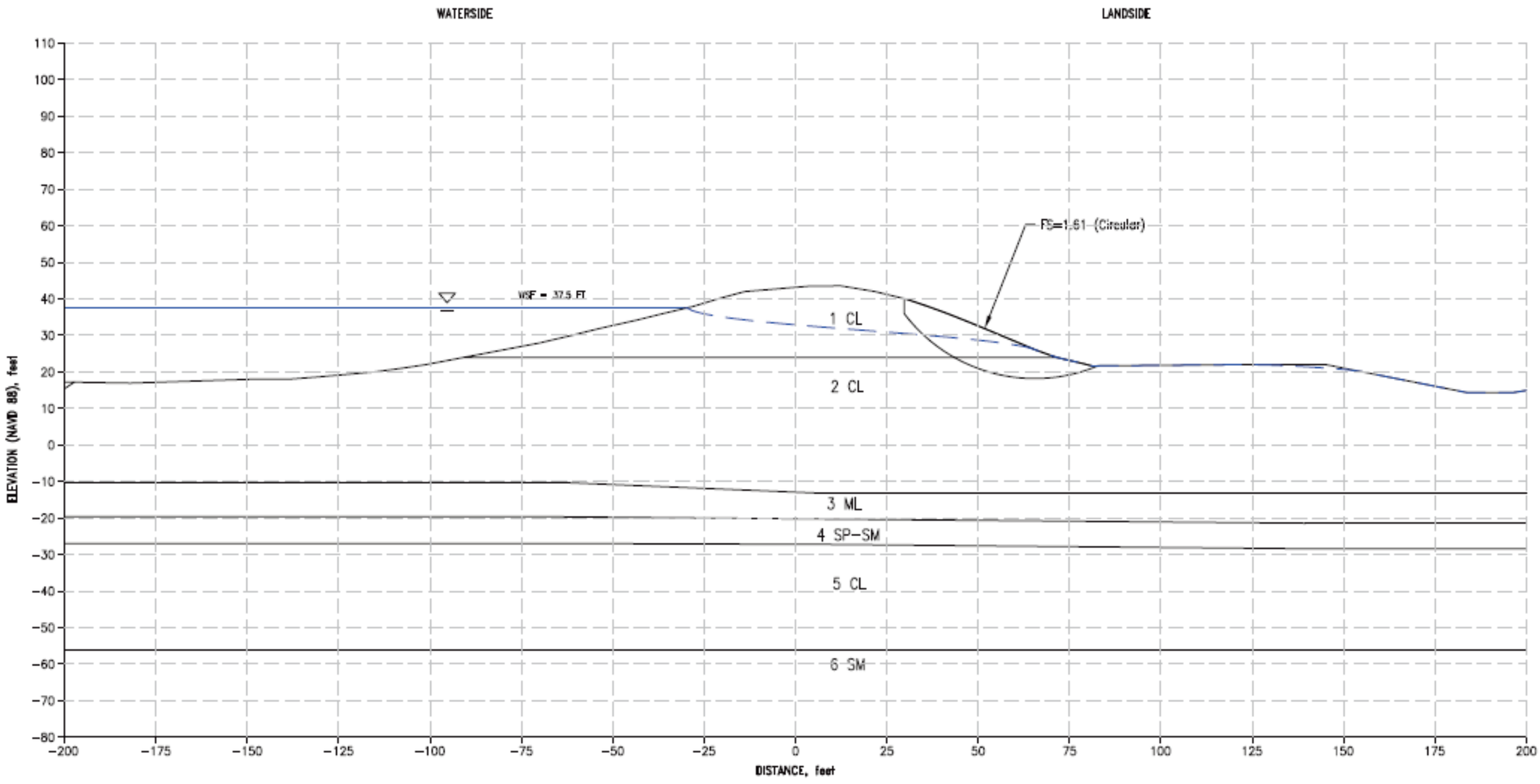
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE TULE CHANNEL CROSS SECTION F-F' STA 1080+70	FIGURE F-F-2
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 05, 2021 – 3:34:27pm
DRAWING: \\Dos-fs\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\F-F-2 CROSS SECTION F-F.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

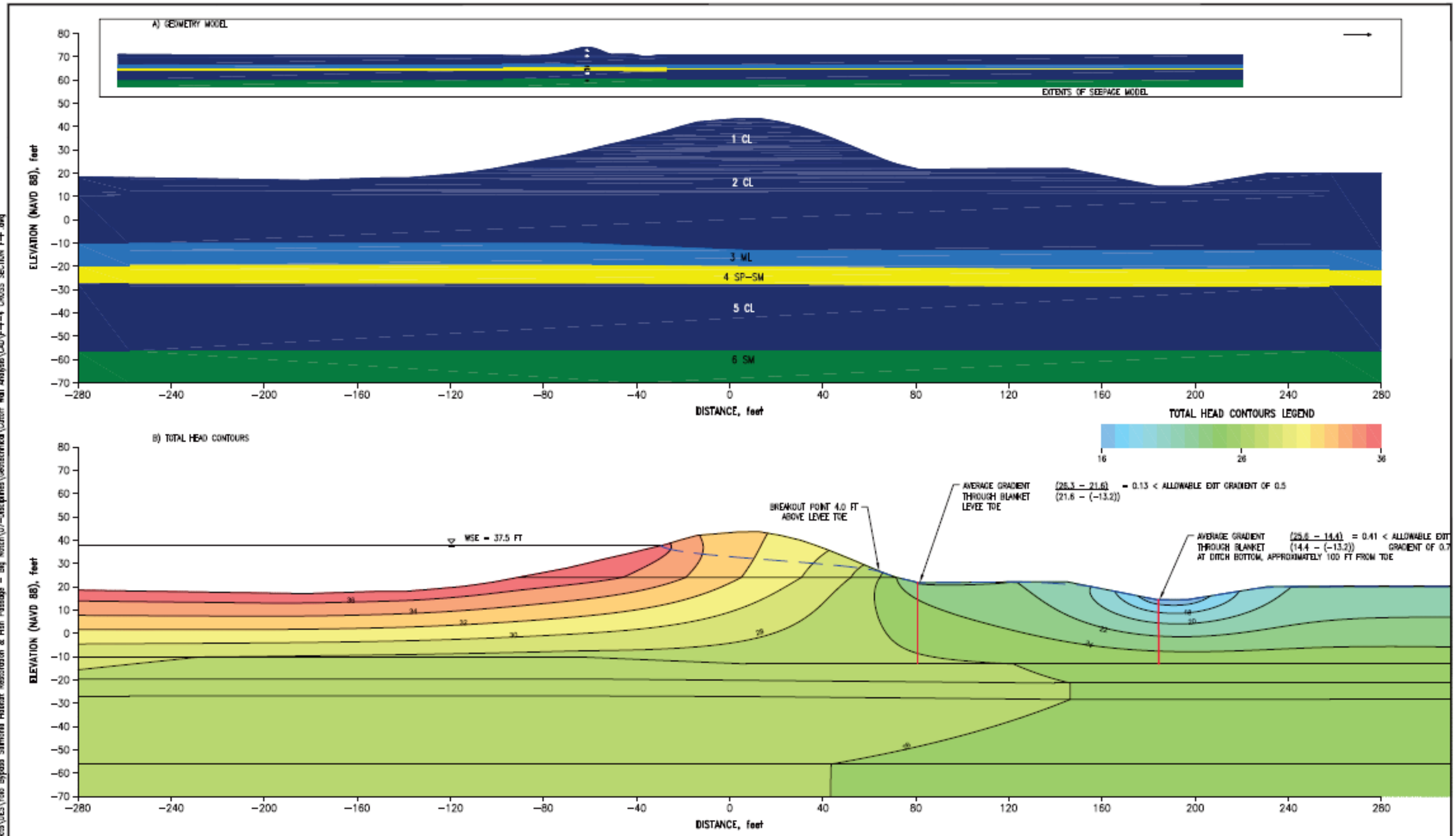


Note: Tension Crack depth of 4 feet assumed for the circular.

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS TULE CHANNEL CROSS SECTION F-F' STA 1080+70	FIGURE F-F-3
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

PLOT BY: MHAVEY – Feb 01, 2021 – 12:12:07pm
DRAWING: \\Dos-hlk\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\F-F-3 CROSS SECTION F-F.dwg

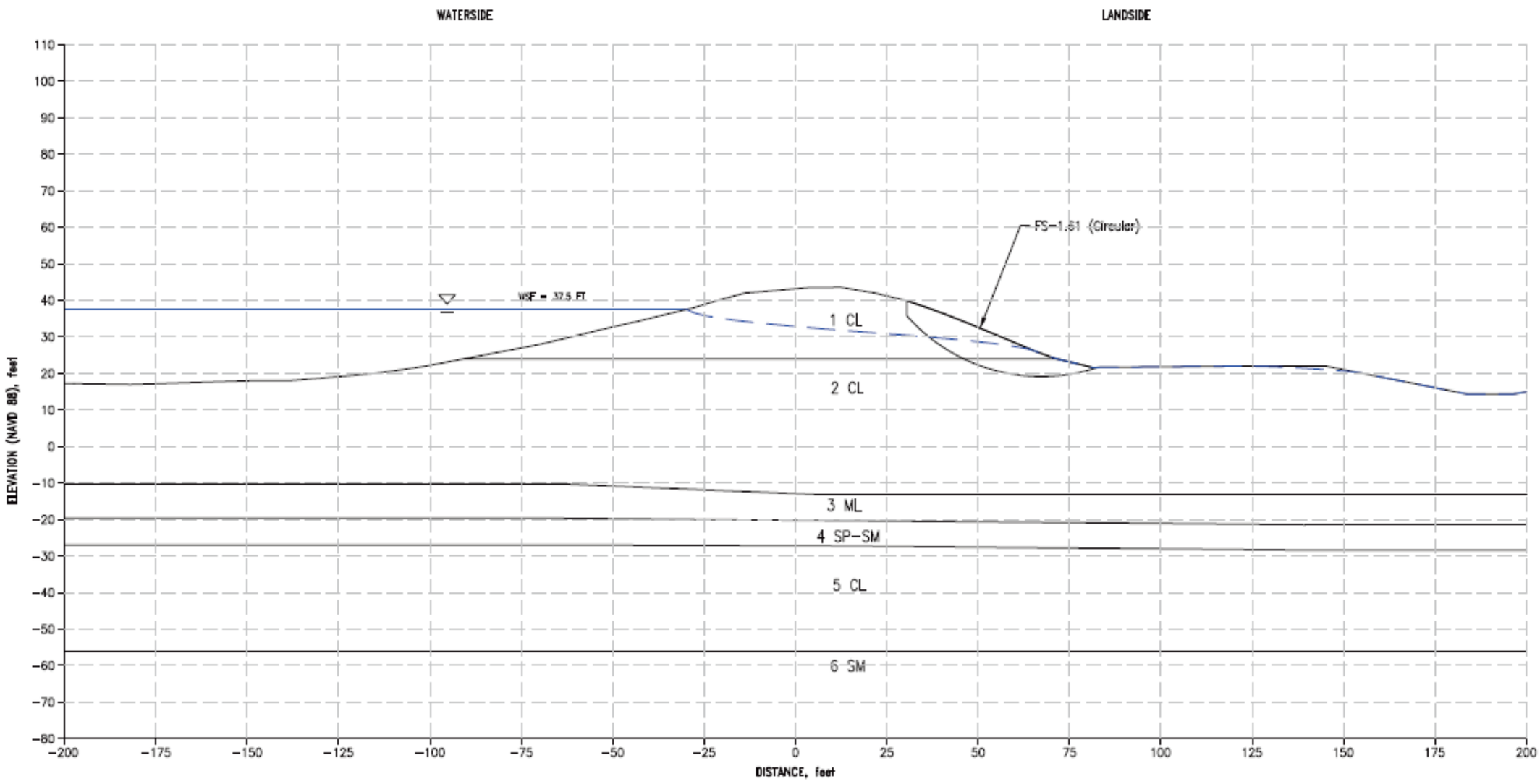
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



PLOT BY: MHAVEY – Feb 05, 2021 – 3:39:42pm
DRAWING: \\Dos-file\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\F-F-4 CROSS SECTION F-F.dwg

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR	PREPARED BY MATTHEW HAVEY	BIG NOTCH PROJECT	STEADY STATE SEEPAGE WITHOUT TULE CHANNEL CROSS SECTION F-F' STA 1080+70	FIGURE F-F-4
	DATE FEBRUARY 2021	CHECKED BY VISHNAN GOPALAN, PE, GE			

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Note: Tension Crack depth of 4 feet assumed for the circular.

Department of Water Resources Division of Engineering Geotechnical Engineering	PREPARED FOR DATE FEBRUARY 2021	PREPARED BY MATTHEW HAVEY CHECKED BY VISHNAN GOPALAN, PE, GE	BIG NOTCH PROJECT	SLOPE STABILITY ANALYSIS RESULTS WITHOUT TULE CHANNEL CROSS SECTION F-F' STA 1080+70	FIGURE F-F-5

PLOT BY: MHAVEY – Feb 01, 2021 – 12:16:40pm
DRAWING: \\Dos-hlk\Projects\DES\Yolo Bypass Salmonid Habitat Restoration & Fish Passage – Big Notch\07-Disciplines\Geotechnical\Cutoff Wall Analysis\CAD\F-F-5 CROSS SECTION F-F.dwg

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

APPENDIX B
Recent and Historical Geotechnical Explorations

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Recent Borings

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,550.00 East 6,665,224.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG

FW-103B

Sheet 1 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/26/20 — DATE COMPLETED 10/28/20	GROUND ELEVATION 29.10 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 126.0 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Tyler Rouse	TOTAL DEPTH OF FILL 3.5 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 10 ft: HSA, 10 - 126 ft: RD	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger / PQ Rotary Bit	DRILLING ROD TYPE AND DIAMETER PQ and NWJ	FIELD LOGGER Chris Silva
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH 8" PVC to 12'	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 14.5 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		ENGINEERED FILL, 0.0 to 3.5'														
	1		0.0 to 2.0' Granodiorite Boulder.														Hand auger 0.0 to 5.0' bgs
	2	(GP)s	2.0 to 3.5' Poorly Graded GRAVEL with Sand, (GP)s: About 60% coarse, subrounded to rounded gravel, maximum size 2.4 inches; about 35% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; brown (10YR 4/3), dry; no reaction with HCl.	Hand Auger													
25	3																
	4		RECENT ALLUVIUM, (Qal) 3.5 to 126.5'														
	5				SPT	53	3 10 10	20	24								S1-5.0-5.8 (5.0' to 5.8')
	6	(CL)s	3.5 to 10.0' LEAN CLAY with Sand, (CL)s: About 85% low to medium plasticity fines with very high dry strength, no dilatancy, low to medium toughness; about 15% fine sand; very soft, brown (10YR 4/3), dry; no reaction with HCl.														
	7		From 4.0', Moist.	Auger	SPT	100	5 10 12	22	26			14	38	20	79		S2-7.0-8.5 (7.0' to 8.5') At 7' [Lab] LEAN CLAY with SAND (CL)
	8		From 7.0', About 80% fines with high dry strength, slow dilatancy; about 20% fine sand.														
20	9																S3-9.0-9.9 (9.0' to 9.9')
	10		10.0 to 17.0' LEAN CLAY, (CL): About 95% low to medium plasticity fines with high dry strength, slow dilatancy, low to medium toughness; about 5% fine sand; very stiff, dark brown (10YR 3/3), moist; no reaction with HCl.		SPT	60	5 8 10	18	21								
	11																
	12		From 11.5', About 90% medium plasticity fines with no dilatancy, medium toughness; about 10% fine sand.		SHELBY	100				2.0P							T1-11.5-13.5 (11.5' to 13.5') 300 psi downpressure
	13	CL															
15	14																
	15		From 14.5', Soft, wet; gradational change.	Rotary	SPT	93	1 3 4	7	8	0.4T		25	36	16	90		S4-14.5-15.9 (14.5' to 15.9') At 14.5' [Lab] LEAN CLAY (CL)
	16																
	17																
	18	s(CL)	17.0 to 20.0' SANDY LEAN CLAY, s(CL): About 65% low plasticity fines with high dry strength, no dilatancy, low toughness; about 35% fine sand; very stiff, dark brown, moist.		SHELBY	100						23	27	11	64	UW CN UC	T2-17.0-19.0 (17.0' to 19.0') At 17' [Lab] SANDY LEAN CLAY (CL)
10	19									2.5P							
	20																350 downpressure

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,550.00 East 6,665,224.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-103B
Sheet 2 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20	(CL)s	20.0 to 23.5' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with medium dry strength, slow dilatancy, medium toughness; about 15% fine sand; medium stiff, dark brown (10YR 3/3), moist; no reaction with HCl.		SPT	100	2 4 7	11	13	2.0P 1.7P 2.4P							S5-20.0-21.5 (20.0' to 21.5')
	21																
	22																
	23				SHELBY	100											T3-22.5-24.5 (22.5' to 24.5')
5	24	s(ML)	23.5 to 27.0' SANDY SILT, s(ML): About 60% nonplastic fines with medium dry strength, slow dilatancy, low toughness; about 40% fine sand; hard, dark brown, wet; no reaction with HCl.							2.8P							
	25				SPT	53	4 4 4	8	9						61		400 psi downpressure S6-25.0-25.8 (25.0' to 25.8')
	26																
	27	SM	27.0 to 28.8' SILTY SAND, (SM): About 60% fine sand; about 40% low plasticity fines with low dry strength, rapid dilatancy, low toughness; hard, dark brown (10YR 3/3), wet; no reaction with HCl.														
	28				SPT	73	3 11 14	25	30								S7-27.5-28.6 (27.5' to 28.6')
0	29	SP	28.8 to 34.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; medium dense to dense, very dark gray (7.5YR 3/1), wet; variable sand-to-fines ratio.														
	30				SPT	60	7 10 12	22	26						5		S8-30.0-30.9 (30.0' to 30.9')
	31																
	32			Rotary													
	33				SPT	80	7 14 18	32	38								S9-32.5-33.7 (32.5' to 33.7')
-5	34	s(ML/SM)	34.0 to 35.2' SANDY SILT, s(ML/SM): About 55% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 45% fine sand; very dark gray, wet.														
	35				SPT	80	13 16 18	34	40						52		S10-35.0-36.2 (35.0' to 36.2')
	36	SW	35.2 to 38.1' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; medium dense to dense, very dark gray (7.5YR 3/1), wet; variable sand-to-fines ratio.														
	37																
	38		37.9 to 42.5' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; dense, very dark gray (7.5YR 3/1), wet; variable sand-fines ratio.		SPT	73	10 12 15	27	32								S11-37.5-38.6 (37.5' to 38.6')
-10	39																
	40	SP	From 38.1', About 95% fine to medium sand; about 5% nonplastic fines; gradational change.														
	41				SPT	60	11 19 20	39	46								S12-40.0-40.9 (40.0' to 40.9')
	42																
	43	s(ML/SM)	42.5 to 43.6' SANDY SILT, s(ML/SM): About 55% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 45% fine sand; very dark gray, wet.		SPT	73	16 20 28	48	57						54		S13-42.5-43.6 (42.5' to 43.6')
-15	44	SP	*Description on next page.*														
	45																

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,550.00 East 6,665,224.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-103B
Sheet 3 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45		43.6 to 60.0' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; dense, very dark gray (7.5YR 3/1), wet; variable sand-fines ratio. *(Continued)*		SPT	93	8 20 26	46	54								**S14-45.0-46.4 (45.0' to 46.4')**
	46																
	47																
	48				SPT	80	15 21 29	50	59								**S15-47.5-48.7 (47.5' to 48.7')**
-20	49																
	50				SPT	67	10 20 21	41	49						7		**S16-50.0-51.0 (50.0' to 51.0')**
	51																
	52																
	53	SP			SPT	53	18 26 23	49	58								**S17-52.5-53.3 (52.5' to 53.3')**
-25	54																Drilling ended 10/26/2020 Drilling began 10/27/2020
	55		From 55.0', Very dense, olive brown (2.5Y 4/3), gradational color change.														
	56		From 56.1', Trace fine subangular to subrounded gravel, maximum dimension 0.6 inches.		SPT	60	10 24 28	52	62								**S18-55.0-55.9 (55.0' to 55.9')**
	57			Rotary													
	58				SPT	53	18 27 24	51	60								**S19-57.5-58.3 (57.5' to 58.3')**
-30	59																
	60		60.0 to 67.6' SILTY SAND, (SM): About 85% fine to medium, angular to subrounded sand; about 15% nonplastic fines; dense to very dense, dark brown (7.5YR 3/2), wet; no reaction with HCl.		SPT	60	12 20 18	38	45								**S20-60.0-60.9 (60.0' to 60.9')**
	61																
	62																
	63				SPT	53	11 32 40	72	85								**S21-62.5-63.3 (62.5' to 63.3')**
-35	64	SM	From 63.6', About 85% fine to coarse sand; about 15% nonplastic fines; gradational change.														
	65																
	66				SPT	60	8 20 26	46	54								**S22-65.0-65.9 (65.0' to 65.9')**
	67																
	68		67.6 to 70.0' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, brown (10YR 4/3), wet; no reaction with HCl.		SPT	67	18 20 24	44	52								**S23-67.5-68.5 (67.5' to 68.5')**
-40	69	SP	From 68.5', Very dark greenish gray, gradational change.														
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,550.00 East 6,665,224.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-103B
Sheet 4 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70		70.0 to 75.6' FAT CLAY, (CH): About 95% high plasticity fines with high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, bluish gray, moist; no reaction with HCl.														
	71				SPT	100	4 6 10	16	19	4.1P >4.5P							S24-70.0-71.5 (70.0' to 71.5')
	72																
	73	CH			SPT	100	5 9 15	24	28	>4.5P >4.5P		32	53	26	92		S25-72.5-74.0 (72.5' to 74.0') At 72.5' [Lab] FAT CLAY (CH)
-45	74																
	75																
	76	s(ML)	75.6 to 76.0' SANDY SILT, s(ML): About 70% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 30% fine sand; bluish black, wet.		SPT	100	1 9 17	26	31	>4.5P 1.6P					68		S26-75.0-75.6 (75.0' to 75.6') S27-75.6-76.5 (75.6' to 76.5')
	77	SP-SM SW SW	76.0 to 78.4' Poorly Graded SAND with Silt, (SP-SM): About 90% fine sand; about 10% nonplastic fines; bluish black, wet; no reaction with HCl.														
	78				SPT	100	8 5 10	15	18								S28-77.5-78.4 (77.5' to 78.4')
	79		78.4 to 90.0' FAT CLAY, (CH): About 100% high plasticity fines with high dry strength, no dilatancy, high toughness; stiff, bluish gray, moist; no reaction with HCl.							1.2P							S29-78.4-79.0 (78.4' to 79.0')
-50	80		From 80.0', Very stiff, gradational change.														
	81				SPT	100	2 4 8	12	14	2.1P 2.6P 2.4P							S30-80.0-81.5 (80.0' to 81.5')
	82			Rotary													
	83		From 82.5 to 84.0', SILT About 100% nonplastic fines with medium dry strength, slow dilatancy, low toughness; stiff to very stiff, bluish gray, moist; gradational change.		SPT	100	4 11 13	24	28	1.5P >4.5P >4.5P		31	43	16	99		S31-82.5-84.0 (82.5' to 84.0') At 82.5' [Lab] SILT (ML)
-55	84	CH															
	85																
	86				SPT	100	3 4 10	14	17	4.1P 4.3P >4.5P							S32-85.0-86.5 (85.0' to 86.5')
	87																
	88				SPT	100	5 10 15	25	30	>4.5P >4.5P >4.5P							S33-87.5-89.0 (87.5' to 89.0')
-60	89																
	90																
	91	s(ML) SP	90.0 to 92.5' SANDY SILT, s(ML): About 70% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 30% fine sand; hard, bluish black, wet; no reaction with HCl.		SPT	100	4 10 20	30	36	>4.5P >4.5P							S34-90.0-91.5 (90.0' to 91.5')
	92																
	93	SP	92.5 to 97.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, bluish black, wet; no reaction with HCl.		SPT	100	9 14 29	43	51								S35-91.5-93.0 (92.5' to 94.0')
-65	94																
	95																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,550.00 East 6,665,224.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-103B
Sheet 5 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95		92.5 to 97.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, bluish black, wet; no reaction with HCl. *(Continued)*		SPT	80	5 22 27	49	58								**S36-95.0-96.2 (95.0' to 96.2')**
	96	SP															
	97																
	98		97.5 to 102.5' SILT with Sand, (ML)s: About 85% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 15% fine sand; hard, dark greenish gray, moist; no reaction with HCl.		SPT	100	6 15 33	48	57	>4.5P >4.5P 4.1P							**S37-97.5-99.0 (97.5' to 99.0')**
-70	99																
	100	(ML)s															
	101				SPT	93	1 8 14	22	26	>4.5P >4.5P >4.5P							**S38-100.0-101.4 (100.0' to 101.4')**
	102																
	103		102.5 to 106.1' SILTY SAND, (SM): About 70% fine sand; about 30% nonplastic fines; medium stiff, very dark greenish gray, wet; no reaction with HCl.		SPT	67	4 11 13	24	28								**S39-102.5-103.5 (102.5' to 103.5')**
-75	104	SM															
	105				SPT	100	8 15 34	49	58								**S40-105.0-106.5 (105.0' to 106.5')**
	106																
	107		106.1 to 110.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; very dark greenish gray, wet; no reaction with HCl.	Rotary													
	108	SP	From 107.5', About 95% fine sand; about 5% nonplastic fines; very dense.		SPT	67	6 23 30	53	63								**S41-107.5-108.5 (107.5' to 108.5')**
-80	109																
	110		110.0 to 112.5' SANDY SILT, s(ML): About 70% nonplastic fines with low dry strength, slow dilatancy, low toughness; about 30% fine to medium, subangular to subrounded sand; very dark greenish gray, wet; no reaction with HCl.		SPT	87	12 23 23	46	54						73		**S42-110.0-111.3 (110.0' to 111.3')**
	111	s(ML)															
	112																
	113		112.5 to 122.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; no reaction with HCl.		SPT	67	12 25 35	60	71								**S43-112.5-113.5 (112.5' to 113.5')** Drilling ended 10/27/2020 Drilling began 10/28/2020
-85	114																
	115																
	116				SPT	73	16 30 24	54	64								**S44-115.0-116.1 (115.0' to 116.1')**
	117	SP															
	118		At 117.8', 0.2' layer of fine subangular to subrounder gravel, 0.5" maximum dimension.		SPT	80	33 22 38	60	71								**S45-117.5-118.7 (117.5' to 118.7')**
-90	119																
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,550.00 East 6,665,224.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-103B
Sheet 6 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	120		112.5 to 122.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; no reaction with HCl. *(Continued)*		SPT	80	15 24 32	56	66								**S46-120.0-121.2 (120.0' to 121.2')**
	121	SP															
	122																
	123		122.5 to 126.0' Well-Graded SAND with Silt and Gravel, (SW-SM)g: About 65% fine to coarse, subangular to subrounded sand; about 25% fine to coarse, angular to subrounded gravel, maximum size 1.0 inches; about 10% nonplastic fines; very dense, dark greenish gray, wet; no reaction with HCl.	Rotary		56	37 50/5"									**S47-122.5-123.0 (122.5' to 123.0')**
-95	124	(SW-SM)g			NSD												**At 123.4' SPT Refusal**
	125																**S48-125.0-125.5 (125.0' to 125.5')**
	126					50	17 50/6"										**At 126' SPT Refusal** Total depth of 126.0' reached at 10:05 hours on 10/28/2020.
	127		126.0 to 60.0' Poorly Graded SAND, (SP): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; medium dense to dense, very dark gray (7.5YR 3/1), wet; variable sand-to-fines ratio.														
	128		127.0 to 38.1' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; medium dense to dense, very dark gray (7.5YR 3/1), wet; variable sand-to-fines ratio.														
-100	129																
	130		128.0 to 38.1' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; medium dense to dense, very dark gray (7.5YR 3/1), wet; variable sand-to-fines ratio.														
	131																
	132		Tremie-grouted with 95% cement, 5% bentonite by weight														
	133																
-105	134																
	135																
	136																
	137																
	138																
-110	139																
	140																
	141																
	142																
	143																
-115	144																
	145																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,620.00 East 6,665,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-104B
Sheet 1 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/19/20 — DATE COMPLETED 10/21/20	GROUND ELEVATION 32.10 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 124.9 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Tyler Rouse	TOTAL DEPTH OF FILL
DRILLING METHOD 0 - 5 ft: HA, 5 - 124.9 ft: HSA	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER NWJ	FIELD LOGGER Chris Silva
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Dry Core, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 23.5 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		RECENT ALLUVIUM, (Qal) 0.0 to 124.9'														
	1	(ML)s	0.0 to 4.0' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; very soft, dark brown, dry; no reaction with HCl.	Hand Auger													Hand auger 0.0 to 5.0' bgs
30	2																
	3																
	4	CL	4.0 to 8.5' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; very soft, dark brown, no reaction with HCl.														
	5				SPT	73	3 2 4	6	7			19	36	14	87		S1-5.0-6.1 (5.0' to 6.1') At 5' [Lab] LEAN CLAY (CL)
	6																
25	7				DCORE	100				2.3T							Box 1-6.5-8.5 (6.5' to 8.5')
	8																
	9	(CL)s	8.5 to 10.0' LEAN CLAY with Sand, (CL)s: About 75% low to medium plasticity fines with medium dry strength, no dilatancy, low to medium toughness; about 25% fine sand; soft, dark brown, moist; no reaction with HCl.		SPT	67	2 3 4	7	8			19	29	11	73		S2-8.5-9.5 (8.5' to 9.5') At 8.5' [Lab] LEAN CLAY with SAND (CL)
	10																
	11	ML	10.0 to 12.6' SILT, (ML): About 95% nonplastic fines with low dry strength, slow to rapid dilatancy, low toughness; about 5% sand; soft, dark brown, moist; no reaction with HCl.		DCORE	100				1.2T 2.2T 2.7T					93		Box 1-10.0-13.5 (10.0' to 13.5')
20	12			Auger													
	13	(CL)s	12.6 to 13.5' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 15% fine sand; very soft, dark brown, moist; no reaction with HCl.														
	14				SPT	100	1 3 4	7	8	2.5P							S3-13.5-15.0 (13.5' to 15.0')
	15		13.5 to 21.0' LEAN CLAY, (CL): About 95% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, brown, moist; no reaction with HCl.														
	16				DCORE	100				2.7P 2.5P 2.4P							Box 2-15.0-18.5 (15.0' to 18.5')
15	17	CL															
	18																
	19		From 18.8', About 90% fines with medium dry strength, slow dilatancy; about 10% fine sand; medium stiff, dark brown, moist; no reaction with HCl.		SPT	100	4 5 6	11	13	2.5P 2.4P		22	39	16	97		S4-18.5-20.0 (18.5' to 20.0') At 18.5' [Lab] LEAN CLAY (CL)
	20																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,620.00 East 6,665,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-104B
Sheet 2 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20	CL								2.1T							Box 2-20.0-21.9 (20.0' to 21.9')
	21		21.0 to 24.0' SANDY LEAN CLAY, s(CL): About 65% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 35% fine sand; very stiff, dark brown, moist.												72		
10	22	s(CL)			DCORE	48											
	23									2.2P 2.5P 3.5P							
	24		24.0 to 26.0' SILTY SAND, (SM): About 55% fine sand; about 45% nonplastic fines; dark brown, moist.														Wet at 23.5' bgs
	25	SM			SHELBY	100						27			45	UW CN SG	T1-24.0-26.0 (24.0' to 26.0') 500 psi downpressure
	26		26.0 to 29.6' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, slow to rapid dilatancy, low toughness; about 15% fine sand; soft, dark brown, moist; no reaction with HCl.														
5	27				DCORE	100				0.6T							Box 2-26.0-28.5 (26.0' to 28.5')
	28	(ML)s															
	29				SPT	100	6 11 13	24	28	1.7P 2.2P							S5-28.5-30.0 (28.5' to 30.0')
	30		29.6 to 40.0' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium, subangular sand; about 10% nonplastic fines; very dense, very dark gray, wet; no reaction with HCl.														Box 3-30.0-31.3 (30.0' to 31.3')
	31																
0	32			Auger	DCORE	37									13		
	33																
	34		From 34.1', About 95% fine to coarse sand; about 5% nonplastic fines; gradational change.		SPT	100	7 18 40	58	69						6		S6-33.5-35.0 (33.5' to 35.0')
	35	SP-SM															
	36																
-5	37				DCORE	0											
	38																
	39		From 38.5 to 40.0', Medium dense.		SPT	73	2 3 6	9	11			23			6		S7-38.5-39.6 (38.5' to 39.6')
	40		40.0 to 53.9' Poorly Graded SAND, (SP): About 95% fine to medium, subangular sand; about 5% nonplastic fines; very dense, very dark gray, wet; no reaction with HCl.														Box 2-40.0-40.6 (40.0' to 40.6')
	41																
-10	42	SP			DCORE	17											
	43																
	44					100	22 50/4"								4		S8-43.5-44.3 (43.5' to 44.3') At 43.5' [Lab] POORLY GRADED SAND (SP)
	45				DCORE	48											

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,620.00 East 6,665,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-104B
Sheet 3 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines % < #200	Other Lab Tests	REMARKS
	45		40.0 to 53.9' Poorly Graded SAND, (SP): About 95% fine to medium, subangular sand; about 5% nonplastic fines; very dense, very dark gray, wet; no reaction with HCl. *(Continued)*														At 44.3' SPT Refusal
	46																**Box 3-45.0-47.0 (45.0' to 47.0')**
-15	47				DCORE	48											
	48																
	49	SP			SPT	100	13 40 50/4"								5		**S9-48.5-49.8 (48.5' to 49.8')**
	50																
	51																Heaving sand
-20	52				DCORE	0											
	53																
	54		53.9 to 57.5' Poorly Graded SAND with Gravel, (SP)g: About 80% fine to medium, subangular to subrounded sand; about 15% fine, subangular to subrounded gravel, maximum size 0.6 inches; about 5% nonplastic fines; very dense, very dark gray, wet; no reaction with HCl.			100	30 50/3"										**At 54.3' SPT Refusal**
	55				NSD												**S10-55.0-55.8 (55.0' to 55.8')**
	56	(SP)g															Heaving sand
-25	57			Auger													
	58		57.5 to 67.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular sand; about 5% nonplastic fines; very dense, very dark gray, wet; no reaction with HCl.		SPT	100	17 37 50/3"					21			7		**S11-57.5-58.8 (57.5' to 58.8')**
	59		From 58.6', About 95% fine to coarse sand; about 5% nonplastic fines; loose, brown.		SPT	73	4 2 7	9	11								**S12-59.0-60.1 (59.0' to 60.1')**
	60		From 59.8', About 95% fine to medium sand; about 5% nonplastic fines; very dense, very dark gray.		NSD												
	61																Heaving sand
-30	62	SP															
	63		From 62.5', About 95% fine to coarse sand; about 5% nonplastic fines; gradational change, trace fine subrounded gravel, maximum dimension 0.5 inches.		SPT	93	23 38 50/5"										**S13-62.5-63.8 (62.5' to 63.8')**
	64																
	65				NSD												Heaving sand
	66																**S14-66.0-66.9 (66.0' to 66.9')**
-35	67				SPT	100	33 50/5"										**At 66.9' SPT Refusal**
	68	-SW-SM	67.0 to 71.0' Well-Graded SAND with Silt, (SW-SM): About 90% fine to coarse, subangular sand; about 10% nonplastic fines; very dense, very dark gray, wet; no reaction with HCl.		NSD												Heaving sand
	69		At 69.0', 0.4' layer of fine clean sand.														
	70				SPT	100	29 50/5"										**S15-69.0-69.9 (69.0' to 69.9')** **At 69.9' SPT Refusal**

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,620.00 East 6,665,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-104B
Sheet 4 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70	SW-SM	From 69.7', Trace fine to coarse subrounded to subangular gravel, maximum dimension 0.8 inches.		NSD												
	71	SP	71.0 to 76.0' Poorly Graded SAND, (SP): About 100% fine sand; dense, bluish black, wet; no reaction with HCl.		SPT	100	7 15 16	31	37								S16-71.0-72.5 (71.0' to 72.5')
-40	72		At 71.8', 0.2' layer of well-graded fine to coarse sand.														
	73		At 72.3', 0.3' layer of fat clay.		SPT	100	6 18 23	41	49								S17-73.0-74.5 (73.0' to 74.5')
	74		At 74.0', Trace fine subangular gravel.														
	75				SPT	100	5 20 28	48	57	>4.0P							S18-75.0-76.5 (75.0' to 76.5')
	76	CH	76.0 to 77.0' FAT CLAY, (CH): About 95% high plasticity fines with high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, bluish gray, moist; no reaction with HCl.														
-45	77	SP			SPT	100	15 30 26	56	66								S19-77.0-78.5 (77.0' to 78.5')
	78	SM	77.0 to 78.2' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; very dense, bluish black, wet; no reaction with HCl.														
	79		78.2 to 79.3' SILTY SAND, (SM): About 85% fine sand; about 15% low plasticity fines with low dry strength, rapid dilatancy, low toughness; bluish black, wet; no reaction with HCl.		SPT	100	2 7 13	20	24								S20-79.0-80.5 (79.0' to 80.5')
	80	SP															
	81		79.3 to 84.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; medium dense, bluish black, wet; no reaction with HCl.		SPT	100	5 6 22	28	33								S21-81.0-82.5 (81.0' to 82.5')
-50	82			Auger													Drilling ended 10/19/2020
	83				NSD												Drilling began 10/20/2020
	84		84.0 to 89.3' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, bluish gray, moist; no reaction with HCl.		SPT	100	8 10 15	25	30	3.4P		31	46	25	93		S22-84.0-85.5 (84.0' to 85.5') At 84' [Lab] LEAN CLAY (CL)
	85																
	86	CL															
-55	87				SPT	100	7 13 20	33	39	1.6P							S23-86.0-87.5 (86.0' to 87.5')
	88																
	89				NSD												
	90	s(CH)	89.3 to 91.0' SANDY FAT CLAY, s(CH): About 65% high plasticity fines with high dry strength, no dilatancy, high toughness; about 35% fine sand; very stiff, bluish gray, moist; no reaction with HCl.		SPT	100	11 20 24	44	52	>4.0P							S24-89.0-90.5 (89.0' to 90.5')
	91	SP-SM	91.0 to 94.0' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium, subangular sand; about 10% nonplastic fines; dense, bluish black, wet; no reaction with HCl.														
-60	92		From 91.6', About 90% fine to coarse sand; about 10% nonplastic fines; gradational change.		SPT	100	5 16 18	34	40								S25-91.0-92.5 (91.0' to 92.5')
	93				NSD												
	94	s(CH)	*Description on next page.*		SPT	100	6 18	45	53								S26A-94.0-94.6 (94.0' to 94.6')
	95	SP															S26B-94.6-95.5 (94.6' to 95.5')

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,620.00 East 6,665,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-104B
Sheet 5 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95	SP	94.0 to 94.6' SANDY FAT CLAY, s(CH): About 65% high plasticity fines with high dry strength, no dilatancy, high toughness; about 35% fine sand; very stiff, bluish gray, moist; no reaction with HCl.	Auger	SPT	100	27	45	53								
	96	s(CH)			NSD												S27A-96.0-96.8 (96.0' to 96.8')
-65	97	SP	94.6 to 96.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; very dense, bluish black, wet; no reaction with HCl. *(Continued)*		SPT	100	7 18 25	43	51								S27B-96.8-97.5 (96.8' to 97.5')
	98				NSD												
	99	s(CH)	96.0 to 96.8' SANDY FAT CLAY, s(CH): About 65% high plasticity fines with high dry strength, no dilatancy, high toughness; about 35% fine sand; very stiff, bluish gray, moist; no reaction with HCl.		SPT	100	16 20 28	48	57								S28A-99.0-99.7 (99.0' to 99.7')
-70	100																S28B-99.7-100.5 (99.7' to 100.5')
	101		96.8 to 99.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; very dense, bluish black, wet; no reaction with HCl.		SPT	100	15 31 50/5"										S29-101.0-102.4 (101.0' to 102.4')
	102		99.0 to 99.7' SANDY FAT CLAY, s(CH): About 65% high plasticity fines with high dry strength, no dilatancy, high toughness; about 35% fine sand; very stiff, bluish gray, moist; no reaction with HCl.														
	103				NSD												
	104	SP-SM	99.7 to 109.0' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium, subangular to subrounded sand; about 10% nonplastic fines; very dense, bluish black, wet; no reaction with HCl.		SPT	87	4 10 11	21	25			27			9		S30-104.0-105.3 (104.0' to 105.3')
-75	105																
	106																S31-106.0-106.5 (106.0' to 106.5')
	107				SPT	33	0 7 16	23	27								Sample partially washed out.
	108				NSD												
	109	SP-SC	109.0 to 110.1' Poorly Graded SAND with Clay, (SP-SC): About 90% fine to medium, subangular to subrounded sand; about 10% medium plasticity fines; bluish black, wet; no reaction with HCl.		SPT	100	7 14 20	34	40								S32-109.0-110.5 (109.0' to 110.5')
	110																
	111		110.1 to 122.1' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium, subangular to subrounded sand; about 10% nonplastic fines; very loose, bluish black, wet; no reaction with HCl.		SPT	100	4 18 26	44	52								S33-111.0-112.5 (111.0' to 112.5')
-80	112																
	113				NSD												
	114				SPT	100	8 20 35	55	65			20			15		S34-114.0-115.5 (114.0' to 115.5')
	115	SP-SM															
	116																
	117				SPT	100	9 15 24	39	46								S35-116.0-117.5 (116.0' to 117.5')
-85	118				NSD												
	119				SPT	100	8 18	42	50								S36-119.0-120.5 (119.0' to 120.5')
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,620.00 East 6,665,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-104B
Sheet 6 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
120	120	SP-SM	110.1 to 122.1' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium, subangular to subrounded sand; about 10% nonplastic fines; very loose, bluish black, wet; no reaction with HCl. *(Continued)*	Auger	SPT	100	24	42	50								
-90	121																S37-121.0-122.5 (121.0' to 122.5')
	122	SW	122.1 to 124.9' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; very dense, bluish black, wet; no reaction with HCl.		SPT	100	8 23 25	48	57								
	123				NSD												
	124																S38-124.0-124.9 (124.0' to 124.9')
	125		At 124.8', Andesite fragments in shoe of SPT.			100	11 50/5"										At 124.9' SPT Refusal Total depth of 124.9' reached at 15:05 hours 10/20/2020
	126		Tremie-grouted with 95% cement, 5% bentonite by weight														
-95	127																
	128																
	129																
	130																
	131																
-100	132																
	133																
	134																
	135																
	136																
-105	137																
	138																
	139																
	140																
	141																
-110	142																
	143																
	144																
	145																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,481.00 East 6,665,463.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-105B
Sheet 1 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/28/20 — DATE COMPLETED 10/30/20	GROUND ELEVATION 29.90 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 125.4 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Tyler Rouse	TOTAL DEPTH OF FILL 4 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 19 ft: HSA, 19 - 125.4 ft: RD	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger / PQ Rotary Bit	DRILLING ROD TYPE AND DIAMETER PQ and NWJ	FIELD LOGGER Chris Silva
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH PVC, 8-in., 19 ft	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING N/A due to rotary wash drilling method — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0	(ML)s	ENGINEERED FILL, 0.0 to 4.0'	Hand Auger													
	1		0.0 to 2.2' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; brown, dry; no reaction with HCl.														Hand-augered to 2.2' bgs, removed boulders, hand-augered to 5.0' bgs.
	2																
	3		2.2 to 4.0' Granodiorite Boulders - Engineered Fill.														
	4		RECENT ALLUVIUM, (Qal) 4.0 to 125.4'														
25	5				SPT	33	2 7 9	16	19						85		S1-5.0-5.5 (5.0' to 5.5')
	6		4.0 to 10.0' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 15% fine sand; brown, dry; no reaction with HCl.														
	7	(CL)s															
	8				SPT	67	5 7 8	15	18				37	17	91		S2-7.5-8.5 (7.5' to 8.5') At 7.5' [Lab] LEAN CLAY (CL)
	9																
20	10		10.0 to 20.0' LEAN CLAY, (CL): About 95% low to medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 5% fine sand; stiff, dark brown, moist; no reaction with HCl.	Auger	SPT	100	5 7 7	14	17				38	19	100		S3-10.0-11.5 (10.0' to 11.5') At 10' [Lab] LEAN CLAY (CL)
	11																
	12																
	13				SPT	100	3 3 5	8	9	2.5T							S4-12.5-14.0 (12.5' to 14.0')
	14																
15	15	CL															
	16		At 15.6', 0.2' layers of poorly graded fine sand.		SPT	100	1 3 5	8	9	2.8T							S5-15.0-16.5 (15.0' to 16.5')
	17																
	18		From 17.5', Brown, gradational change.		SPT	100	3 6 8	14	17	3.0T							S6-17.5-19.0 (17.5' to 19.0')
	19																Drilling ended 10/28/2020
10	20			Rotary													Drilling began 10/29/2020

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,481.00 East 6,665,463.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-105B
Sheet 2 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20	s(CL)	20.0 to 22.5' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 30% fine sand; very stiff, brown, moist; no reaction with HCl.		SHELBY	100				3.5P			28	12	68	CN DS UC	T1-20.0-22.0 (20.0' to 22.0') At 20' [Lab] SANDY LEAN CLAY (CL) 500 psi downpressure
	21																
	22																
	23	(CL)s	22.5 to 25.0' LEAN CLAY with Sand, (CL)s: About 75% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 25% fine sand; very stiff, brown, moist; no reaction with HCl.		SPT	100	3 5 9	14	17	2.5P >4.5P 2.7P		24	31	14	71		S7-22.5-24.0 (22.5' to 24.0') At 22.5' [Lab] LEAN CLAY with SAND (CL)
	24																
5	25	(ML)s	25.0 to 25.5' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; very stiff, brown, moist; no reaction with HCl.		SPT	100	5 12 11	23	27	>4.5P 3.5P 3.2P		27			44		S8A-25.0-25.5 (25.0' to 25.5') S8B-25.5-26.5 (25.5' to 26.5')
	26	SM															
	27		25.5 to 27.5' SILTY SAND, (SM): About 55% fine sand; about 45% nonplastic fines with low dry strength, low toughness; very stiff, brown, moist; no reaction with HCl.														
	28				SHELBY	100								NP	77		T2-27.5-29.5 (27.5' to 29.5') 500 psi downpressure
	29	(ML)s	27.5 to 30.0' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; very stiff, brown, moist; no reaction with HCl.							>4.5P							
0	30	SP	30.0 to 31.1' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; very dark gray, wet; no reaction with HCl.		SPT	100	8 15 12	27	32								S9-30.0-31.1 (30.0' to 31.1')
	31														5		S10-31.1-31.5 (31.1' to 31.5')
	32	ML	31.1 to 32.5' SILT, (ML): About 95% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 5% fine sand; stiff, dark grayish brown, moist; no reaction with HCl.	Rotary													
	33	s(ML)	32.5 to 33.7' SANDY SILT, s(ML): About 60% nonplastic fines; about 40% fine sand.		SPT	80	7 11 12	23	27					NP	58		S11-32.5-33.7 (32.5' to 33.7')
	34	ML															
-5	35		33.7 to 35.0' SILT, (ML): About 95% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 5% fine sand; stiff, dark grayish brown, moist; no reaction with HCl.														
	36	SP	35.0 to 37.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; very dark gray, wet; no reaction with HCl.		SPT	73	10 11 16	27	32						8		S12-35.0-36.1 (35.0' to 36.1')
	37																
	38		37.5 to 56.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% fines; medium dense to dense, very dark gray, wet; no reaction with HCl.		SPT	53	6 15 19	34	40								S13-37.5-38.3 (37.5' to 38.3')
	39																
-10	40				SPT	67	15 19 18	37	44						8		S14-40.0-41.0 (40.0' to 41.0')
	41	SP															
	42																
	43				SPT	73	10 12 13	25	30								S15-42.5-43.6 (42.5' to 43.6')
	44																
-15	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,481.00 East 6,665,463.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-105B
Sheet 3 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45		37.5 to 56.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% fines; medium dense to dense, very dark gray, wet; no reaction with HCl. *(Continued)*														
	46				SPT	67	13 15 17	32	38						8		S16-45.0-46.0 (45.0' to 46.0')
	47																
	48		From 47.5', About 95% fine sand; about 5% nonplastic fines; medium dense to dense, very dark gray, wet; no reaction with HCl.		SPT	67	11 18 19	37	44								S17-47.5-48.5 (47.5' to 48.5')
	49																
-20	50	SP			SPT	80	10 14 14	28	33						7		S18-50.0-51.2 (50.0' to 51.2')
	51																
	52																
	53		From 52.5', About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; medium dense to dense, very dark gray, wet; no reaction with HCl.		SPT	67	5 16 24	40	47								S19-52.5-53.5 (52.5' to 53.5')
	54																
-25	55																
	56		From 55.5', About 90% coarse, subangular to subrounded sand; about 10% fine, subangular to subrounded gravel; dark gray, wet; no reaction with HCl.		SPT	67	9 20 33	53	63								S20-55.5-56.0 (55.5' to 56.0')
	57																S21-56.0-56.5 (56.0' to 56.5')
	58		56.0 to 65.0' Well-Graded SAND with Silt and Gravel, (SW-SM)g: About 75% fine to coarse, subangular to subrounded sand; about 15% fine, subangular gravel; about 10% nonplastic fines; very dense, brown, wet; no reaction with HCl.	Rotary	SPT	73	25 42 39	81	96						7		S22-57.5-58.6 (57.5' to 58.6')
	59																
-30	60	(SW-SM)g															S23-60.0-60.5 (60.0' to 60.5')
	61				NSD	50	24 50/6"										At 61' SPT Refusal
	62																
	63					70	24 50/6"										S24-62.5-63.2 (62.5' to 63.2')
	64				NSD												At 63.5' SPT Refusal
-35	65		65.0 to 70.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; dense, very dark gray, wet; no reaction with HCl.		SPT	53	12 24 23	47	56						7		S25-65.0-65.8 (65.0' to 65.8')
	66																
	67																
	68	SP	From 67.5', About 95% fine to coarse sand; about 5% nonplastic fines; gradational change.		SPT	67	23 25 24	49	58								S26-67.5-68.5 (67.5' to 68.5')
	69																
-40	70																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,481.00 East 6,665,463.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-105B
Sheet 4 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70																
	71	CL	70.0 to 75.9' LEAN CLAY, (CL): About 95% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, bluish gray, moist; no reaction with HCl.		SPT	100	3 5 10	15	18	3.9P 3.5P 3.7P							
	72																
	73				SPT	100	4 9 14	23	27	2.1P 3.2P >4.5P			44	17	93		S28-72.5-74.0 (72.5' to 74.0') At 72.5' [Lab] SILT (ML)
	74																
-45	75				SPT	100	0 2 12	14	17								S29-75.0-75.9 (75.0' to 75.9')
	76	SM	75.9 to 78.8' SILTY SAND, (SM): About 85% fine sand; about 15% low plasticity fines; medium dense, bluish black, wet; no reaction with HCl.							1.5P							S30-75.9-76.5 (75.9' to 76.5')
	77																
	78				SPT	100	6 11 11	22	26								S31-77.5-79.0 (77.5' to 79.0')
	79	CL	78.8 to 80.0' LEAN CLAY, (CL): About 95% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, bluish gray, moist; no reaction with HCl.														
-50	80	ML	80.0 to 81.5' SILT, (ML): About 100% low plasticity fines with low dry strength, rapid dilatancy, low toughness; hard, bluish gray, wet; no reaction with HCl.		SPT	100	2 3 6	9	11	4.1P 4.3P >4.5P			46	17	98		S32-80.0-81.5 (80.0' to 81.5') At 80' [Lab] SILT (ML)
	81																
	82	CH	81.5 to 86.0' FAT CLAY, (CH): About 100% high plasticity fines with high dry strength, no dilatancy, high toughness; hard, bluish gray, moist; no reaction with HCl.	Rotary													
	83				SPT	0	3 2 4	6	7								
	84																
-55	85				SPT	100	3 4 5	9	11	2.3P >4.5P							S34-85.0-86.0 (85.0' to 86.0')
	86	(CL)s	86.0 to 87.5' LEAN CLAY with Sand, (CL)s: About 80% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 20% fine sand; stiff, bluish gray, moist; no reaction with HCl.							1.2P							S35-86.0-86.5 (86.0' to 86.5')
	87																
	88	s(CL)	87.5 to 90.0' SANDY LEAN CLAY, s(CL): About 60% medium plasticity fines with medium dry strength, slow dilatancy, low toughness; about 40% fine sand; medium stiff, bluish gray, moist; no reaction with HCl.		SPT	100	4 4 7	11	13	0.9P 1.1P 1.3P							S36-87.5-89.0 (87.5' to 89.0')
	89																
-60	90	(CL)s	90.0 to 92.8' LEAN CLAY with Sand, (CL)s: About 80% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 20% fine sand; stiff, bluish gray, moist; no reaction with HCl.		SPT	100	7 9 11	20	24	1.1P 1.4P 1.9P							S37-90.0-91.5 (90.0' to 91.5')
	91																
	92																
	93	SP	92.8 to 110.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; dense to very dense, bluish black, wet; no reaction with HCl.		SPT	80	5 9 21	30	36	1.8P							S38-92.5-93.7 (92.5' to 93.7')
-65	94																
	95																

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,481.00 East 6,665,463.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-105B
Sheet 5 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95		92.8 to 110.0' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; dense to very dense, bluish black, wet; no reaction with HCl. *(Continued)*														
	96			Rotary	SPT	73	10 24 23	47	56						12		**S39-95.0-96.1 (95.0' to 96.1')**
	97		From 95.6', Trace fine subrounded gravel, maximum dimension 0.6 inches.														
	98				SPT	33	10 23 29	52	62								**S40-97.5-98.0 (97.5' to 98.0')**
	99																Drilling ended 10/29/2020 Drilling began 10/30/2020
-70	100		From 100.0', About 95% fine sand; about 5% nonplastic fines; dense, no gravel.														
	101				SPT	93	9 18 14	32	38								**S41-100.0-101.4 (100.0' to 101.4')**
	102																
	103	SP			SPT	87	7 15 17	32	38								**S42-102.5-103.8 (102.5' to 103.8')**
	104																
-75	105				SPT	67	12 16 23	39	46								**S43-105.0-106.0 (105.0' to 106.0')**
	106																
	107																
	108				SPT	87	8 16 15	31	37								**S44-107.5-108.8 (107.5' to 108.8')**
	109																
-80	110		110.0 to 115.8' SILTY SAND, (SM): About 70% fine to coarse, subangular to subrounded sand; about 30% nonplastic fines with low dry strength, rapid dilatancy, low toughness; very dense, very dark greenish gray, moist; no reaction with HCl.		SPT	100	17 35 50/3"								43		**S45-110.0-111.3 (110.0' to 111.3')**
	111																
	112				NSD												
	113	SM	At 113.4', 0.2' layer of fine subrounded gravel.			80	15 50/6"										**S46-112.5-113.3 (112.5' to 113.3')** **At 113.5' SPT Refusal**
	114				NSD												
-85	115																
	116		At 115.6', 0.2' layer of well-graded sand with gravel, maximum dimension 0.8".		SPT	60	36 42 23	65	77								**S47-115.0-115.9 (115.0' to 115.9')**
	117	SP	115.8 to 117.5' Poorly Graded SAND, (SP): About 95% fine, subangular to subrounded sand; about 5% nonplastic fines; dense, bluish black, wet; no reaction with HCl.														
	118				SPT	67	34 30 27	57	67								**S48-117.5-118.5 (117.5' to 118.5')**
	119	SW	117.5 to 125.0' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; no reaction with HCl.														
-90	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,481.00 East 6,665,463.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-105B
Sheet 6 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	120																
	121	SW	117.5 to 125.0' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; no reaction with HCl. *(Continued)*		SPT	67	17 23 32	55	65								**S49-120.0-121.0 (120.0' to 121.0')**
	122																
	123		From 122.5', Dense.	Rotary	SPT	73	17 22 25	47	56						10		**S50-122.5-123.6 (122.5' to 123.6')**
-95	125	GP	125.0 to 125.4' Poorly Graded GRAVEL, (GP): About 100% fine, subrounded gravel; very dense, bluish black, wet; no reaction with HCl.			50	50/5"										**S51-125.0-125.2 (125.0' to 125.2')**
	126																Total depth of 125.4' reached at 11:45 hours on 10/30/2020
	127		Tremie-grouted with 95% cement, 5% bentonite by weight														
	128																
	129																
-100	130																
	131																
	132																
	133																
	134																
-105	135																
	136																
	137																
	138																
	139																
-110	140																
	141																
	142																
	143																
	144																
-115	145																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,694.00 East 6,665,554.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-106B
Sheet 1 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/22/20 — DATE COMPLETED 10/24/20	GROUND ELEVATION 29.10 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 125.9 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Tyler Rouse	TOTAL DEPTH OF FILL
DRILLING METHOD 0 - 5 ft: HA, 5 - 10 ft: HSA, 10 - 125.9 ft: RD	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger / PQ Rotary Bit	DRILLING ROD TYPE AND DIAMETER PQ and NWJ	FIELD LOGGER Chris Silva
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH PVC, 8"-in., 10 ft	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING N/A due to rotary wash drilling method — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		RECENT ALLUVIUM, (Qal) 0.0 to 125.9'														
	1		0.0 to 10.0' LEAN CLAY with Sand, (CL)s: About 85% low to medium plasticity fines with medium dry strength, slow dilatancy, medium toughness; about 15% fine sand; very soft, dark brown, dry; no reaction with HCl.	Hand Auger													Hand auger 0.0-5.0' bgs
	2																
	3																
25	4		From 2.0', Moist.														
	5	(CL)s			SPT	87	2 2 6	8	9	3.0T							S1-5.0-6.3 (5.0' to 6.3')
	6		From 5.7', Very stiff, very dark brown.	Auger													
	7																
	8				SPT	100	7 4 8	12	14	2.7T		20	40	21	85		S2-7.5-9 (7.5' to 9.0') At 7.5' [Lab] LEAN CLAY with SAND (CL)
20	9																
	10		10.0 to 21.0' LEAN CLAY, (CL): About 95% medium plasticity fines with medium dry strength, no to slow dilatancy, medium toughness; about 5% fine sand; very stiff, brown, moist; no reaction with HCl.		SHELBY	100										UW CN UC	T1-10.0-12.0 (10.0' to 12.0') At 10' [Lab] LEAN CLAY (CL) 350 psi downpressure
	11											25	39	16	95		
	12									4.3P							
	13																
15	14			Rotary	NSD												
	15	CL															T2-15.0-17.0 (15.0' to 17.0')
	16				SHELBY	100						29					250 psi downpressure
	17									1.9P							
	18				SPT	100	0 0 0	0	0	2.0P 2.0P		28	40	16	95		S3-17.5-19.0 (17.5' to 19.0') At 17.5' [Lab] LEAN CLAY (CL)
10	19																
	20																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,694.00 East 6,665,554.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-106B
Sheet 2 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20	CL															**T3-20.0-21.8 (20.0' to 21.8')** **At 20' [Lab] LEAN CLAY (CL)** 500 psi downpressure
	21	(ML)s	21.0 to 22.8' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; hard, brown, moist; no reaction with HCl.		SHELBY	100				>4.5P		22	35	15	98	UW CN DS UC	
	22	(ML)s															
	23	CL	22.8 to 25.0' LEAN CLAY, (CL): About 95% medium plasticity fines with medium dry strength, no to slow dilatancy, medium toughness; about 5% fine sand; very stiff, brown, moist; no reaction with HCl.		SPT	100	2 10 11	21	25	1.7P >4.5P >4.5P							**S4-22.5-24.0 (22.5' to 24.0')**
5	24	CL															
	25	(ML)s	25.0 to 27.5' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; hard, brown, moist; no reaction with HCl.		SHELBY	65				>4.5P							**T4-25.0-26.3 (25.0' to 26.3')** 350 psi downpressure
	26	(ML)s															
	27																
	28	s(ML)	27.5 to 30.0' SANDY SILT, s(ML): About 65% nonplastic fines with no dry strength, rapid dilatancy, low toughness; about 35% fine sand; soft, dark bluish gray, moist.		SPT	100	14 21 23	44	52	0.2T		21	23	2	67		**S5-27.5-29.0 (27.5' to 29.0')** **At 27.5' [Lab] SANDY SILT (ML)**
0	29	s(ML)															
	30	SM	30.0 to 32.5' SILTY SAND, (SM): About 70% fine sand; about 30% nonplastic fines with no dry strength, rapid dilatancy, low toughness; soft, dark brown, moist; no reaction with HCl.		SPT	80	5 13 10	23	27								**S6-30.0-31.2 (30.0' to 31.2')**
	31	SM															
	32																
	33	SP	32.5 to 37.5' Poorly Graded SAND, (SP): About 95% fine to medium, subangular sand; about 5% nonplastic fines; medium dense, very dark brown, wet; no reaction with HCl.	Rotary	SPT	33	7 10 11	21	25						7		**S7-32.5-33.0 (32.5' to 33.0')**
-5	34	SP															
	35	SP			SPT	53	7 15 14	29	34								**S8-35.0-35.8 (35.0' to 35.8')**
	36	SP															
	37																
	38	s(ML)	37.5 to 38.9' SANDY SILT, s(ML): About 60% nonplastic fines; about 40% fine sand; very dark brown, wet; no reaction with HCl.		SPT	93	17 14 15	29	34						57		**S9-37.5-38.9 (37.5' to 38.9')**
-10	39	SP	38.9 to 50.6' Poorly Graded SAND, (SP): About 95% fine to medium, subangular sand; about 5% nonplastic fines; medium dense, very dark brown, wet; no reaction with HCl.														Drilling ended 10/22/2020
	40	SP	From 40.0', Dense.		SPT	60	11 18 19	37	44								Drilling began 10/23/2020 **S10-40.0-40.9 (40.0' to 40.9')**
	41	SP	From 41.1', About 95% fine to coarse sand; about 5% nonplastic fines.														
	42	SP															
	43	SP	At 42.8', 0.2' layer of poorly graded sand, coarse, subangular to subrounded.		SPT	67	13 19 21	40	47						7		**S11-42.5-43.5 (42.5' to 43.5')**
-15	44																
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,694.00 East 6,665,554.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-106B
Sheet 3 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45	SP	38.9 to 50.6' Poorly Graded SAND, (SP): About 95% fine to medium, subangular sand; about 5% nonplastic fines; medium dense, very dark brown, wet; no reaction with HCl. *(Continued)*	SPT		80	5 18 25	43	51								S12-45.3-45.6 (45.3' to 45.6')
	46																
	47		At 45.3', 0.3' layer of poorly graded sand, coarse, subangular to subrounded.														S13-46.3-47.2 (46.3' to 47.2')
	48		At 47.8', 0.2' layer of poorly graded sand, coarse, subangular to subrounded.	SPT		80	4 13 19	32	38						7		S14-47.8-49.0 (47.8' to 49.0')
-20	49																
	50			SPT		60	2 10 18	28	33								S15-50.6-51.0 (50.6' to 51.0')
	51	SW	50.6 to 51.0' Poorly Graded SAND About 100% coarse, subangular to subrounded sand; very dark brown, wet.														S16-51.0-51.5 (51.0' to 51.5')
	52		51.0 to 52.5' Well-Graded SAND, (SW): About 95% fine to medium, subangular sand; about 5% nonplastic fines; medium dense, very dark brown, wet; no reaction with HCl.														
	53	SP		SPT		73	10 13 19	32	38						7		S17-52.5-53.6 (52.5' to 53.6')
-25	54		52.5 to 55.0' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, black, wet; no reaction with HCl.														
	55	(SW-SM)g	55.0 to 57.5' Well-Graded SAND with Silt and Gravel, (SW-SM)g: About 60% fine to coarse, angular to subrounded sand; about 30% fine, angular to subrounded gravel, maximum size 0.7 inches; about 10% nonplastic fines; very dense, dark greenish gray, wet; no reaction with HCl.	SPT		67	16 26 24	50	59								S18-55.0-56.0 (55.0' to 56.0')
	56																
	57			Rotary													
	58	SP-SM	57.5 to 65.0' Poorly Graded SAND with Silt, (SP-SM): About 85% fine to medium, angular to subrounded sand; about 10% nonplastic fines; about 5% fine to coarse, angular to subangular gravel, maximum size 1 inches; very dense, very dark greenish gray, wet; no reaction with HCl.	SPT		67	20 38 33	71	84						7		S19-57.5-58.5 (57.5' to 58.5')
-30	59																
	60		From 60.0', About 80% fine to medium sand; about 10% nonplastic fines; about 10% fine to coarse gravel, maximum size 1.5 inches; dense.	SPT		60	15 25 26	51	60								S20-60.0-60.9 (60.0' to 60.9')
	61																
	62																
	63			SPT		53	16 22 21	43	51								S21-62.5-63.3 (62.5' to 63.3')
-35	64																
	65	s(ML)g	65.0 to 66.1' SANDY SILT with Gravel, s(ML)g: About 55% nonplastic fines with low toughness; about 30% sand; about 15% fine to coarse, angular to subangular gravel; dense, very dark greenish gray, wet; no reaction with HCl.	SPT		73	16 28 33	61	72						53		S22-65.0-66.1 (65.0' to 66.1')
	66																
	67	SP-SM															
	68	CH	66.1 to 67.5' Poorly Graded SAND with Silt, (SP-SM): About 85% fine to medium, angular to subrounded sand; about 10% nonplastic fines; about 5% fine to coarse, angular to subangular gravel, maximum size 1 inches; very dense, very dark greenish gray, wet; no reaction with HCl.	SPT		100	10 7 10	17	20	>4.5P		38	57	28	96		S23-67.5-69.0 (67.5' to 69.0') At 67.5' [Lab] FAT CLAY (CH)
-40	69									>4.5P							
	70		*Description on next page.*														

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,694.00 East 6,665,554.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-106B
Sheet 4 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70	CH	67.5 to 72.5' FAT CLAY, (CH): About 95% high plasticity fines with high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, bluish gray, moist; no reaction with HCl. *(Continued)*		SPT	100	7 10 11	21	25	>4.5P 2.4P 2.2P							S24-70.0-71.5 (70.0' to 71.5')
	71																
	72		70.6' Very stiff.														
	73	(CH)s	72.5 to 73.6' FAT CLAY with Sand, (CH)s: About 85% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 15% fine sand; hard, bluish gray, moist; no reaction with HCl.		SPT	100	9 14 14	28	33						84		S25-72.5-73.6 (72.5' to 73.6')
-45	74																S26-73.6-74.0 (73.6' to 74.0')
	75	SP	73.6 to 77.5' Poorly Graded SAND, (SP): About 90% fine sand; about 10% nonplastic fines; medium dense, bluish black, wet; no reaction with HCl.		SPT	40	0 1 11	12	14								S27-75.0-75.6 (75.0' to 75.6')
	76		At 75.0', 0.3' layer of fat clay.														
	77																
	78	CH	77.5 to 82.5' FAT CLAY, (CH): About 95% high plasticity fines with high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, bluish gray, moist; no reaction with HCl.		SPT	100	4 10 10	20	24	2.0P 2.7P 2.5P							S28-77.5-79.0 (77.5' to 79.0')
-50	79																
	80																S29-80.0-81.5 (80.0' to 81.5')
	81				SPT	100	5 12 16	28	33	2.4P 2.4P 2.6P							
	82			Rotary													
	83	CL	82.5 to 84.0' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, bluish gray, moist; no reaction with HCl.		SPT	100	6 9 10	19	22	2.3P 3.0P 3.1P		33	42	19	93		S30-82.5-84.0 (82.5' to 84.0') At 82.5' [Lab] LEAN CLAY (CL)
-55	84	CH	84.0 to 85.0' FAT CLAY, (CH): About 95% high plasticity fines with high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, bluish gray, moist; no reaction with HCl.														
	85	s(CH)			SPT	100	4 15 19	34	40	2.5T 3.2T							S31-85.0-85.8 (85.0' to 85.8')
	86	SC	85.0 to 85.8' SANDY FAT CLAY, s(CH): About 60% high plasticity fines with high dry strength, no dilatancy, high toughness; about 40% fine sand; hard, bluish gray, moist; no reaction with HCl.														S32-85.8-86.5 (85.8' to 86.5')
	87																
	88	SP-SM	85.8 to 87.5' CLAYEY SAND, (SC): About 80% fine sand; about 20% low plasticity fines; bluish gray, moist; no reaction with HCl.		SPT	100	11 17 17	34	40								S33-87.5-89.0 (87.5' to 89.0')
-60	89		87.5 to 90.0' Poorly Graded SAND with Silt, (SP-SM): About 90% fine sand; about 10% nonplastic fines; dense, bluish black, moist; no reaction with HCl.														
	90	s(ML)	90.0 to 91.5' SANDY SILT, s(ML): About 60% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 40% fine sand; bluish black, wet; no reaction with HCl.		SPT	100	11 15 22	37	44						60		S34-90.0-91.5 (90.0' to 91.5')
	91																
	92	SP	91.5 to 92.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, bluish black, wet; no reaction with HCl.														
	93	SW			SPT	80	18 23 26	49	58								S35-92.5-93.7 (92.5' to 93.7')
-65	94		*Description on next page.*														
	95																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,694.00 East 6,665,554.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-106B
Sheet 5 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95	SW	92.5 to 100.0' Well-Graded SAND, (SW): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; dense to very dense, bluish black, wet; no reaction with HCl. *(Continued)*		SPT	67	14 20 22	42	50								**S36-95.0-96.0 (95.0' to 96.0')**
	96																
	97																
	98				SPT	73	14 26 23	49	58								**S37-97.5-98.6 (97.5' to 98.6')**
-70	99																
	100	s(ML)	100.0 to 101.1' SANDY SILT, s(ML): About 55% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 45% fine sand; bluish black, wet; no reaction with HCl.		SPT	73	13 27 28	55	65						53		**S38-100.0-101.1 (100.0' to 101.1')**
	101																
	102	SP	101.1 to 107.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; bluish black, wet; no reaction with HCl.														
	103				NSD												Driller missed sample interval.
-75	104																
	105				SPT	100	13 20 25	45	53								**S39-105.0-106.5 (105.0' to 106.5')**
	106																
	107			Rotary													
	108	s(ML)	107.5 to 108.6' SANDY SILT, s(ML): About 55% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 45% fine sand; bluish black, wet; no reaction with HCl.		SPT	100	15 25 25	50	59						56		**S40A-107.5-108.6 (107.5' to 108.6')**
-80	109	(ML)s	108.6 to 110.0' SILT with Sand, (ML)s: About 75% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 25% fine sand; very dark greenish gray, wet; no reaction with HCl.														**S40B-108.6-109.0 (108.6' to 109.0')**
	110				SPT	100	14 22 41	63	75								**S41-110.0-111.5 (110.0' to 111.5')**
	111	SM	110.0 to 112.0' SILTY SAND, (SM): About 75% fine sand; about 25% nonplastic fines; very dense, very dark greenish gray, wet; no reaction with HCl.														
	112																Drilling ended 10/23/2020 Drilling began 10/24/2020
	113	GC	112.0 to 120.0' CLAYEY GRAVEL, (GC): About 50% fine to coarse gravel; about 40% medium plasticity fines; about 10% fine to coarse sand; very dense, dark greenish gray, wet; no reaction with HCl.		SPT	100	37 50/5"								43		**S42-112.5-113.4 (112.5' to 113.4')** **At 113.4' SPT Refusal**
-85	114				NSD												
	115				SPT	80	16 27 32	59	70								**S43-115.0-116.2 (115.0' to 116.2')**
	116																
	117																
	118				SPT	67	22 31 28	59	70								**S44-117.5-118.5 (117.5' to 118.5')**
-90	119																
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Gated Headworks
Coordinates: North 2,040,694.00 East 6,665,554.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-106B
Sheet 6 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	120		120.0 to 124.0' Poorly Graded SAND with Clay, (SP-SC): About 85% fine to coarse sand; about 10% medium plasticity fines; about 5% fine gravel; very dense, dark greenish gray, wet; no reaction with HCl.														
	121				SPT	67	10 23 27	50	59								S45-120.0-121.0 (120.0' to 121.0')
	122	SP-SC															
	123			Rotary	SPT	62	20 28 50/4"										S46-122.5-123.3 (122.5' to 123.3')
-95	124																
	125	(SP-SC)g	124.0 to 125.9' Poorly Graded SAND with Clay and Gravel, (SP-SC)g: About 70% fine to coarse sand; about 20% fine to coarse gravel; about 10% medium plasticity fines; very dense, dark greenish gray, wet; no reaction with HCl.		NSD	44	12 50/5"										S47-125.0-125.4 (125.0' to 125.4')
	126																At 125.9' SPT Refusal Total depth of 125.9' bgs reached at 10:30 hours on 10/24/2020.
	127		Tremie-grouted with 95% cement, 5% bentonite by weight														
	128																
-100	129																
	130																
	131																
	132																
	133																
-105	134																
	135																
	136																
	137																
	138																
-110	139																
	140																
	141																
	142																
	143																
-115	144																
	145																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,039,907.00 East 6,665,617.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-108B
Sheet 1 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 11/2/20 — DATE COMPLETED 11/5/20	GROUND ELEVATION 45.90 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 99.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Tyler Rouse	TOTAL DEPTH OF FILL 33 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 50 ft: HSA, 50 - 99.5 ft: RD	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER PQ and NWJ	FIELD LOGGER S. Sochar, T. Butler
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH steel, 6"-in., 53 ft	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING N/A due to rotary wash drilling method — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
45	0		LEVEE FILL, 0.0 to 35.3'	Hand Auger													
	1	s(ML)	0.0 to 0.7' CLAYEY GRAVEL with Sand Gravel road base.														Hand auger 0.0-5.0' bgs
	2																
	3		0.7 to 4.8' SANDY SILT, s(ML): About 70% nonplastic fines; about 30% fine sand; brown, dry.														
	4																
40	5	s(CL)	4.8 to 8.7' SANDY LEAN CLAY, s(CL): About 65% low plasticity fines with medium dry strength, slow dilatancy, low toughness; about 35% fine sand; very stiff, yellowish brown, dry; no reaction with HCl; trace fine gravel.		SPT	67	2 3 3	6	7								S1-5.0-6.0 (5.0' to 6.0')
	6																
	7																
	8				SPT	67	5 7 8	15	18	3.7P							S2-7.5-8.5 (7.5' to 8.5')
	9	CL	8.7 to 11.0' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; very stiff to hard, yellowish brown, moist; no reaction with HCl.		SPT	100	2 3 5	8	9	4.0P		19	36	15	89		S3-9.0-10.5 (9.0' to 10.5') At 9' [Lab] LEAN CLAY (CL)
35	10																
	11	SC	11.0 to 12.2' CLAYEY SAND, (SC): About 60% fine sand; about 40% medium plasticity fines; yellowish brown, dry.														
	12			Auger	SPT	100	7 5 4	9	11	2.2P 1.7P							S4A-11.5-12.2 (11.5' to 12.2') S4B-12.2-13.0 (12.2' to 13.0')
	13	CH	12.2 to 15.0' FAT CLAY, (CH): About 90% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 10% fine sand; stiff to very stiff, yellowish brown, moist; no reaction with HCl; occasional white inclusions, 1/8-inch maximum dimension, with strong HCl reaction.														
	14																
	15				SHELBY	65				1.7P							T1-14.0-15.3 (14.0' to 15.3') 300 psi downpressure Felt like fat clay at top, lean clay at bottom.
30	16	CL	15.0 to 29.0' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; stiff, dark brown, moist; no reaction with HCl. From 17.0 to 17.2', Sandy zone.														
	17				SPT	100	2 3 4	7	8	1.3P		24	38	19	91		S5-16.5-18.0 (16.5' to 18.0') At 16.5' [Lab] LEAN CLAY (CL)
	18																
	19				SHELBY	70							45	23	97	UC	T2-19.0-20.4 (19.0' to 20.4') At 19' [Lab] LEAN CLAY (CL) 350 psi downpressure
	20																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,039,907.00 East 6,665,617.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-108B
Sheet 2 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		15.0 to 29.0' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; stiff, dark brown, moist; no reaction with HCl. *(Continued)*		SHELBY	70				3.4P			45	23	97	UC	
25	21																
	22				SPT	100	1 3 4	7	8			25	43	19			**S6-21.5-23.0 (21.5' to 23.0')**
	23																
	24	CL															
	25		From 24.5', About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff.		SPT	100	1 2 5	7	8	3.5P							**S7-24.0-25.5 (24.0' to 25.5')**
20	26																
	27		From 26.5', Reddish brown.		SPT	87	3 4 6	10	12	2.6P							**S8-26.5-27.8 (26.5' to 27.8')**
	28																
	29																
	30	(CL)s	29.0 to 30.5' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines; about 15% fine sand; very stiff, reddish brown, dry; no reaction with HCl.		SPT	100	3 5 8	13	15	3.4P							**S9-29.0-30.5 (29.0' to 30.5')**
15	31		30.5 to 35.3' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines with high dry strength, slow dilatancy, low toughness; about 30% fine sand; soft, reddish black, moist; no reaction with HCl.														
	32			Auger	SPT	100	1 1 1	2	2	0.4P			25	8	61		**S10-31.5-33.0 (31.5' to 33.0')** **At 31.5' [Lab] SANDY LEAN CLAY (CL)**
	33	s(CL)															
	34				NSD												Began initial switch to mud rotary. No groundwater yet. Tagged to 31.5' bgs because slough fell in.
	35																
	36		RECENT ALLUVIUM, (Qal) 35.3 to 99.5'		SPT	100	2 4 9	13	15	1.2P							**S11-35.0-36.5 (35.0' to 36.5')**
10	37		35.3 to 41.2' LEAN to FAT CLAY with Sand, (CL/CH)s: About 80% low plasticity fines with medium dry strength, slow dilatancy, low toughness; about 20% fine sand; stiff, moist.														
	38	(CL/CH)s			SPT	100	8 16 18	34	40	1.7P							Used more mud because circulation declined but was not lost, indication by returns. Driller thickened mud.
	39		From 38.0', Cylindrical weathering pattern.														**S12-37.5-39.0 (37.5' to 39.0')**
	40		From 40.0', Yellowish brown, decreasing sand content.														**S13A-40.0-41.2 (40.0' to 41.4')**
5	41				SPT	93	6 7 8	15	18	3.0P 2.6P			33	8			
	42		41.2 to 53.1' FAT CLAY, (CH): About 90% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 10% fine sand; yellowish brown, moist; no reaction with HCl.														Circulation improved, driller reported. **S13B-41.2-41.4 (41.2' to 41.4')** Using a lot of mud, driller reported. Stopped drilling. Tried one more SPT but same problem. Stopped drilling, decided to let mud settle overnight. Ended drilling 11/2/2020
	43	CH			SPT	0	0										
	44				NSD												Began drilling 11/3/2020
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,039,907.00 East 6,665,617.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-108B
Sheet 3 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45		41.2 to 53.1' FAT CLAY, (CH): About 90% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 10% fine sand; yellowish brown, moist; no reaction with HCl. *(Continued)*	Auger	NSD												Project Geology directed Cascade to replace PVC conductor casing with metal casing. Cascade pulled out PQ pipe first, then PVC conductor casing. Installed 6" steel conductor casing to 50' bgs and resumed mud rotary. Later pushed conductor casing to 53' bgs. Resulted in longer-than-expected interval of No Sample Drilling.
0	46																
	47																
	48		From 48.0', Increased sand content.														
	49	CH															
	50																
-5	51																
	52																
	53		53.1 to 63.0' CLAYEY SAND, (SC): About 85% fine sand; about 15% low plasticity fines; dense, dark olive gray, wet; no reaction with HCl; trace medium to coarse sand; some nodules cemented by clay, no HCl reaction.		SPT	53	11 13 20	33	39								**S14-53.0-53.8 (53.0' to 53.8')**
	54																
	55		From 55.5', About 75% fine to medium sand; about 15% low plasticity fines; about 10% fine gravel; trace coarse sand; occasional 2" thick layers with 10% fine gravel.		SPT	80	18 22 26	48	57								**S15-55.5-56.7 (55.5' to 56.7')**
-10	56																
	57																
	58	SC	From 58.0 to 58.4', About 55% fine to coarse sand; about 30% fine, subangular to angular gravel; about 15% low plasticity fines.		SPT	67	20 31 29	60	71								**S16-58.0-59.0 (58.0' to 59.0')**
	59		From 58.4 to 58.6', About 85% fine to medium sand; about 15% low plasticity fines; some rust staining.	Rotary													
	60		From 58.6', About 75% fine to medium sand; about 15% low plasticity fines; about 10% fine, subangular to subrounded gravel.		SPT	67	24 32 41	73	86								**S17-60.5-61.5 (60.5' to 61.5')**
-15	61																
	62																Ended drilling 11/3/2020 Began drilling 11/4/2020
	63		63.0 to 70.5' Poorly Graded SAND About 90% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; about 5% fine, subangular to subrounded gravel; very dense, no reaction with HCl; gap-graded sand.		SPT	87	26 32 41	73	86								**S18-63.0-64.3 (63.0' to 64.3')**
	64																
	65																
-20	66				SPT	33	17 24 26	50	59								**S19-65.6-66.0 (65.5' to 66.0')**
	67																
	68																Sand catcher added to S20
	69		From 68.5', About 95% fine to medium sand; about 5% nonplastic fines.		SPT	87	18 30 27	57	67								**S20-68.0-69.3 (68.0' to 69.3')**
	70																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,039,907.00 East 6,665,617.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-108B
Sheet 4 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70																
-25	71	SW	70.5 to 73.5' Well-Graded SAND, (SW): About 90% fine to coarse, subangular sand; about 5% nonplastic fines; about 5% fine, subangular gravel; dense, no reaction with HCl; metamorphic clasts.		SPT	33	21 23 26	49	58								S21-70.5-71.0 (70.5' to 71.0')
	72																
	73																Driller thickened mud, added 1 bag bentonite gel.
	74	(SM)g	73.5 to 79.0' SILTY SAND with Gravel, (SM)g: About 70% fine to coarse sand; about 15% low plasticity fines; about 15% fine, subangular gravel; very dense, no reaction with HCl.		SPT	53	20 26 27	53	63								S22-73.0-73.8 (73.0' to 73.8')
	75																
-30	76		From 75.5', About 50% fine to coarse, subangular sand; about 35% fine to coarse, subangular gravel; about 15% low plasticity fines; very dense.		SPT	33	16 29 33	62	73								S23-75.5-76.0 (75.5' to 76.0')
	77																
	78																S24-78.0-78.5 (78.0' to 78.5')
	79	(SC)g	79.0 to 80.7' CLAYEY SAND with Gravel, (SC)g: About 50% fine to coarse sand; about 35% fine to coarse, subangular gravel; about 15% medium plasticity fines; dark yellowish brown (10YR 4/6).		SPT	33	14 29 32	61	72								
-35	80																
	81	CL	80.7 to 81.8' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; hard, brown (10YR 4/3) and dark yellowish brown (10YR 3/4), no reaction with HCl; laminated, oxidized leaf impressions.		SHELBY	53				4.0P							M1A-80.5-81.0 (80.5' to 81.0')
	82			Rotary													M1B-81.0-81.3 (81.5' to 81.8')
	83		81.8 to 83.0' LEAN CLAY, (CL): About 100% medium plasticity fines with high dry strength, no dilatancy, medium toughness; hard, very dark greenish gray (5GY 3/1), moist; no reaction with HCl.		MCAL	60	9 13 14					36	9			M2-83.0-83.9 (83.0' to 83.9')
	84																
	85	SC	83.0 to 88.0' CLAYEY SAND, (SC): About 60% fine sand; about 40% low plasticity fines; medium dense, very dark greenish gray (5GY 3/1), no reaction with HCl; micaceous, bedded with lean clay.		MCAL	67	9 13 17										M3-85.5-86.5 (85.5' to 86.5')
-40	86																
	87																
	88	(ML)s	88.0 to 89.3' SILT with Sand, (ML)s: About 80% low plasticity fines with medium dry strength, slow dilatancy, low toughness; about 20% fine sand.		MCAL	67	10 18 27										M4-88.0-89.0 (88.0' to 89.0')
	89	SM	89.3 to 89.5' SILTY SAND, (SM): About 85% fine to medium sand; about 15% nonplastic fines; micaceous.														
	90																
-45	91	CL	89.5 to 99.5' LEAN CLAY, (CL): About 95% low to medium plasticity fines with medium to high dry strength, slow dilatancy, low toughness; about 5% fine sand; very dark greenish gray (5GY 3/1), moist; no reaction with HCl; micaceous.		MCAL	80	3 4 11										M5-90.5-91.7 (90.5' to 91.7')
	92																
	93																M6-93.0-94.5 (93.0' to 94.5')
	94				MCAL	100	2 6 7										
	95																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,039,907.00 East 6,665,617.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-108B
Sheet 5 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95		89.5 to 99.5' LEAN CLAY, (CL): About 95% low to medium plasticity fines with medium to high dry strength, slow dilatancy, low toughness; about 5% fine sand; very dark greenish gray (5GY 3/1), moist; no reaction with HCl; micaceous. *(Continued)*														
-50	96	CL		MCAL	100		6 21 25										M7A-95.5-96.0 (95.5' to 96.0') M7B-96.0-96.5 (96.0' to 96.5') M7C-96.5-97.0 (96.5' to 97.0')
	97		From 96.5 to 98.0', About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff.	Rotary													
	98																M8-98.0-99.5 (98.0' to 99.5')
	99			MCAL	100		11 8 12			3.5P							
	100		Tremie-grouted with 95% cement, 5% bentonite by weight														
-55	101																
	102																
	103																
	104																
	105																
-60	106																
	107																
	108																
	109																
	110																
-65	111																
	112																
	113																
	114																
	115																
-70	116																
	117																
	118																
	119																
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

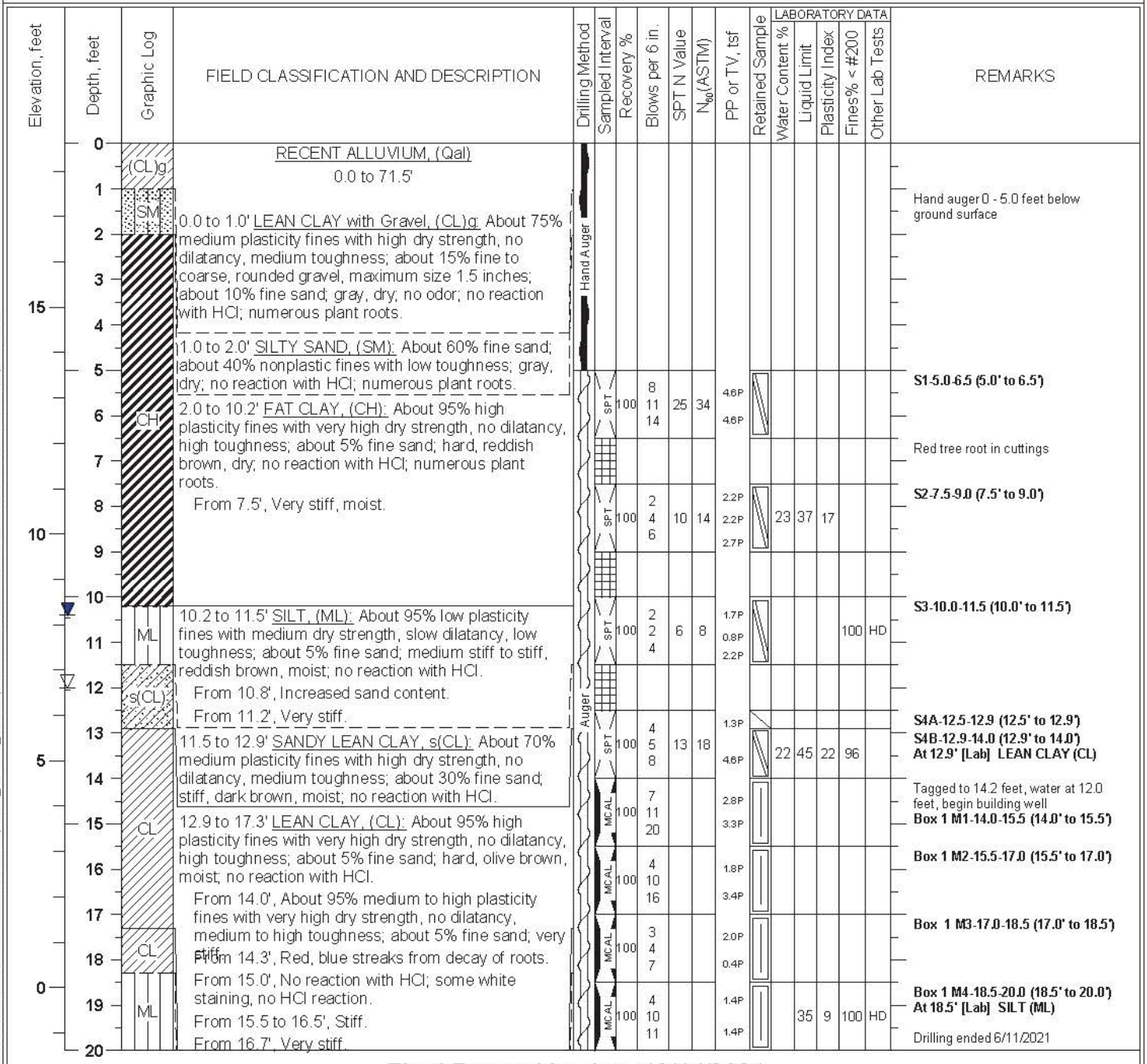
Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Transport Channel
Coordinates: North 2,039,204.18 East 6,665,350.39
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-109B
Sheet 1 of 4

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 6/11/21 — DATE COMPLETED 6/16/21	GROUND ELEVATION 18.61 ft — ELEVATION BASIS Ground Survey	TOTAL DEPTH OF BORING 71.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Javier Ruiz Rea — HELPER'S NAME Zachary LeBlan	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 60 ft: HSA, 60 - 71.5 ft: RD	DRILL RIG MAKE AND MODEL Diedrich D-50	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger / PQ Rotary Bit	DRILLING ROD TYPE AND DIAMETER NWJ	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Mod-Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 82%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 12.0 ft — AFTER DRILLING (DATE-TIME) 10.4 ft on	



1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Transport Channel
Coordinates: North 2,039,204.18 East 6,665,350.39
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-109B
Sheet 2 of 4

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		17.3 to 18.3' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, slow dilatancy, medium toughness; about 10% fine sand; stiff, olive brown, wet; no reaction with HCl.		MCAL	73	11 11 12			1.7P							Drilling began 6/14/2021 **Box 1 M5-20.0-21.1 (20.0' to 21.1')**
	21																
	22	ML	From 18.0', Soft.		MCAL	87	8 6 8			1.4P			34	9	93		**Box 2 M6-21.5-22.8 (21.5' to 22.8')** **At 21.5' [Lab] SILT (ML)**
	23		18.3 to 23.9' SILT, (ML): About 95% low plasticity fines with low dry strength, slow to rapid dilatancy, low toughness; about 5% fine sand; stiff, olive brown, wet; no reaction with HCl; borderline lean clay. *(Continued)*														
-5	24	(ML)s	At 22.2', 1.5-inch-by-0.5-inch gray streaks, no HCl reaction.		MCAL	100	4 5 10			1.1P							**Box 2 M7-23.0-24.5 (23.0' to 24.5')**
	25	ML	23.9 to 24.5' SILT with Sand, (ML)s: About 85% no to low plasticity fines with low dry strength, slow dilatancy, low toughness; about 15% fine sand; stiff, olive brown, wet; no reaction with HCl.		MCAL	100	8 11 21						30	6	100	HD	**Box 2 M8-24.5-26.0 (24.5' to 26.0')** **At 24.5' [Lab] SILT (ML)**
	26	SP															
		(ML)s															
	27		24.5 to 25.7' SILT, (ML): About 95% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 5% fine sand; olive brown, wet; no reaction with HCl.		MCAL	87	7 11 23										**Box 2 M9-26.0-27.3 (26.0' to 27.3')**
	28	SM															Water at 11.0 feet
-10	29		25.7 to 26.2' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dark gray, wet; no reaction with HCl.		MCAL	100	8 9 31								13		**Box 2 M10-27.5-29.0 (27.5' to 29.0')**
	30		26.2 to 27.0' SILT with Sand, (ML)s: About 85% no to low plasticity fines with low dry strength, slow dilatancy, low toughness; about 15% fine sand; stiff, olive brown, wet; no reaction with HCl.		SPT	100	6 15 21	36	49								**S5-30.0-31.5 (30.0' to 31.5')**
	31																Build well screen, 27 - 32 feet
	32		27.0 to 29.0' SILTY SAND, (SM): About 85% sand; about 15% nonplastic fines with no dry strength, rapid dilatancy, low toughness.	Auger	NSD												
	33		From 28.0', Occasional 0.5-inch-by-0.5-inch lenses of lean clay.														Driller reamed out drill bit with 35-foot NWJ rod and poured water down hole.
-15	34	SP	From 28.3', About 90% fine to coarse sand; about 5% nonplastic fines; about 5% fine, subrounded to subangular gravel; dense.														
	35		29.0 to 40.0' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense to very dense, dark gray, wet; no reaction with HCl.		SPT	73	3 6 7	13	18								**S6-35.0-36.1 (35.0' to 36.1')**
	36																Tagged to 35.0 feet
	37		From 35.0', About 95% fine sand; about 5% nonplastic fines; medium dense, lenses of lean clay absent; trace medium to coarse sand.		NSD												
	38																
-20	39																
	40	SC	40.0 to 40.3' CLAYEY SAND, (SC): About 80% fine sand; about 20% medium plasticity fines; medium dense, olive gray (5Y 4/2), wet; no reaction with HCl.		SPT	93	7 10 19	29	40								**S7-40.0-41.4 (40.0' to 41.4')**
	41		40.3 to 59.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; medium dense, olive gray (5Y 4/2), wet; no reaction with HCl.														
	42		40.7 to 41.0' Trace medium and coarse sand.		NSD												
	43	SP															
-25	44																
	45																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Transport Channel
Coordinates: North 2,039,204.18 East 6,665,350.39
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-109B
Sheet 3 of 4

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45		40.3 to 59.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; medium dense, olive gray (5Y 4/2), wet; no reaction with HCl. *(Continued)*		SPT	100	18 45 50/2.5"										
	46																**S8-45.0-46.2 (45.0' to 46.2')** Driller poured water down hole.
	47		From 45.4', Very dense, very dark gray (5Y 3/1), moderate cementation; no reaction with HCl; trace coarse sand and fine subround gravel, maximum dimension 3/8 inch.														Augers locked up.
-30	48				NSD												
	49																Felt like gravel as augers approached 50 feet, driller reported. Augers filled with 13 feet of slough.
	50		From 50.0 to 50.9', Coarse sand and fine gravel were absent.		SPT	100	15 28 60/4.5"										**S9-50.0-50.4 (50.0' to 51.4')**
	51																
	52	SP		Auger													
-35	53				NSD												
	54																
	55				SPT	100	25 36 55/4.5"								4		**S10-55.0-56.4 (55.0' to 56.4')** **At 55' [Lab] POORLY GRADED SAND (SP)**
	56																
	57				NSD												Sand locked up augers. Augered to 60 feet. Driller said soil was still dense sand.
-40	58																
	59																
	60	CL	59.5 to 60.0' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; dark greenish gray, wet; no reaction with HCl.			100											Driller reported seeing coarse gravel, maximum dimension 2 inches, in augers before clay layer was penetrated. Drilling ended 6/14/2021
	61	GP-GM	60.0 to 62.0' Poorly Graded GRAVEL with Silt and Sand, (GP-GM): About 55% fine to coarse, subrounded gravel, maximum size 1.3 inches; about 35% fine to coarse sand; about 10% nonplastic fines; very loose, dark gray, wet; no reaction with HCl.		SPT	100	5 2 1	3	4								**G1-59.5-60.0 (59.5' to 60.0')** Drilling began 6/15/2021 **S11-60.0-61.5 (60.0' to 61.5')** Pulled out augers to switch to mud rotary. Clay was at bottom of augers. Likely slough for sample S11
	62																
	63				SPT	80	8 10 9	19	26	0.3P							**S12-62.5-63.7 (62.5' to 63.7')**
-45	64	(CL)s	62.0 to 65.0' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 15% fine sand; soft, very dark gray, wet; no reaction with HCl.														
	65		From 63.0 to 63.1', Clayey sand. From 63.4 to 63.6', Clayey sand.	Rotary	SPT	67	6 6 14	20	27	2.2P		39	47	17			**S13-65.0-66.0 (65.0' to 66.0')**
	66																
	67	CL	65.0 to 71.5' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; very stiff, greenish gray, moist; no reaction with HCl.														
	68		From 67.7 to 67.8', Poorly graded sand. From 68.0 to 68.1', Poorly graded sand.		SPT	93	8 12 14	26	36	3.0P							**S14-67.5-68.9 (67.5' to 68.9')**
-50	69		*Description on next page.*														
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Transport Channel
Coordinates: North 2,039,204.18 East 6,665,350.39
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-109B
Sheet 4 of 4

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70																
	71	CL	From 68.5', About 95% medium to high plasticity fines with very high dry strength, no dilatancy, medium to high toughness; about 5% fine sand; borderline fat clay.	Rotary	SPT	73	6 8 12	20	27	3.0P							S15-70.0-71..1 (70.0' to 71.1')
	72		Tremie-grouted with 95% cement, 5% bentonite by weight														
-55	73																
	74																
	75																
	76																
	77																
	78																
-60	79																
	80																
	81																
	82																
	83																
-65	84																
	85																
	86																
	87																
	88																
-70	89																
	90																
	91																
	92																
	93																
-75	94																
	95																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge
Coordinates: North 2,038,569.17 East 6,665,258.48
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-110B
Sheet 1 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 5/27/21 — DATE COMPLETED 6/3/21	GROUND ELEVATION 27.80 ft — ELEVATION BASIS Ground Survey	TOTAL DEPTH OF BORING 126.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Javier Ruiz Rea — HELPER'S NAME Hugo Guzman	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 10 ft: HSA, 10 - 126.5 ft: RD	DRILL RIG MAKE AND MODEL Diedrich D-50	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger/PQ Rotary Bit	DRILLING ROD TYPE AND DIAMETER PQ and NWJ	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH 8" metal to 10.0'	FIELD LOG REVIEWER Mak Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod Cal, Punch Core	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 82%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING N/A due to rotary wash drilling method — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0	s(CL)	RECENT ALLUVIUM, (Qal) 0.0 to 126.5'														
	1		0.0 to 1.5' SANDY LEAN CLAY, s(CL): About 65% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 35% fine sand; yellowish brown, dry; no reaction with HCl.	Hand Auger	NSD												Hand auger 0 to 5.0 feet
	2																	Easy augering
25	3	s(CH)	1.5 to 5.0' SANDY FAT CLAY, s(CH): About 65% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 35% fine sand; gray, dry; weak cementation; no reaction with HCl; weak cementation by clay.														
	4																	
	5				SPT	100	8 8 9	17	23	4.5P								**S1-5.0-6.5 (5.0' to 6.5')**
	6		5.0 to 10.5' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 15% fine sand; hard, yellowish brown, dry; no reaction with HCl; plant root extended most of sample interval vertically.	Auger													
	7																	
20	8	(CL)s	From 7.5', About 85% low to medium plasticity fines with low to medium toughness; about 15% fine sand; very stiff, some plant roots.		SPT	100	6 8 9	17	23	2.5P		11	37	16	94		**S2-7.5-9.0 (7.5' to 9.0')** **At 7.5' [Lab] LEAN CLAY (CL)**
	9																	
	10																	**S3A-10.0-10.5 (10.0' to 10.5')**
	11		10.5 to 20.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, light olive brown (2.5Y 5/4), dry; no reaction with HCl; gradational change.		SPT	93	5 9 15	24	33	4.6P							**S3B-10.5-11.4 (10.5' to 11.4')**
	12					30											Pulled out hollow stem augers to switch to mud rotary **P1-11.5-11.8 (11.5' to 11.8')**
15	13		At 10.6', Weak reaction with HCl.		SPT	47	11 17 23	40	55	4.6P							**S4-12.5-13.2 (12.5' to 13.2')**
	14		From 12.5', About 100% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 0% sand; hard, olive brown (2.5Y 4/3), moist; weak reaction with HCl; 1/8-inch-by-1/8-inch white inclusion.	Rotary		0											All slough
	15	CH	At 12.6',														**T1-15.0-17.0 (15.0' to 17.0')**
	16		From 16.0', Stiff.		SHELBY	100						22	46	25		UC	500 psi downpressure, softer pushing after 16 inches, driller reported.
	17									1.6P							
10	18		From 17.5', Very stiff. From 18.0', Hard.		SPT	80	6 6 11	17	23	3.0P 4.4P							**S5-17.5-18.7 (17.5' to 18.7')**
	19					0											
	20																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge
Coordinates: North 2,038,569.17 East 6,665,258.48
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-110B
Sheet 2 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		20.0 to 23.2' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; stiff, brown, wet; no reaction with HCl.		SHELBY	0											**M1-20.0-22.0 (20.0' to 22.0')** No recovery; went in with Mod-Cal to recover lost sample. First foot, 300 psi downpressure, next foot 550 psi, driller reported. Sticky fat clay in Mod Cal sampler used to retrieve sample lost from Shelby tube likely slough.
	21	(ML)s															
	22																
5	23				SPT	100	7 7 14	21	29	1.1P							**S6A-22.5-23.2 (22.5' to 23.2')**
										1.3P							**S6B-23.2-24.0 (23.2' to 24.0')**
	24		23.2 to 25.9' LEAN CLAY, (CL)s: About 85% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 15% fine sand; stiff, brown, wet; no reaction with HCl.														
	25	(CL)s			SHELBY	0											
	26		25.9 to 28.7' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, dark grayish brown (2.5Y 4/2), moist; no reaction with HCl.		SPT	100	10 12 16	28	38								**S7A-25.0-25.9 (25.0' to 25.9')**
										4.2P							**S7B-25.9-26.5 (25.9' to 26.5')**
	27									3.5P							**P5-26.5-26.7 (26.5' to 26.7')**
0	28	CH	From 26.5', Very stiff, olive yellow (2.5Y 6/6).		SHELBY	20											**T3-27.5-29.5 (27.5' to 29.5')** 400 psi downpressure from 27.5-28.5 feet; 550 psi downpressure from 28.5-29.5 feet
	29		28.7 to 33.5' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, low to medium toughness; about 10% fine sand; very stiff, yellowish brown (10YR 5/6), moist; no reaction with HCl.			100						32	36	11		CN CU DS	
	30									2.6P							
	31	CL	From 30.7 to 30.8', About 85% fines; about 10% fine, subangular gravel, maximum size 0.25 inches; about 5% fine to medium sand.		SPT	87	4 5 7	12	16	2.2P							**S8-30.0-31.3 (30.0' to 31.3')**
	32			Rotary		0											Drilling ended 5/27/2021. Drilling began 5/28/2021. Felt like clay, driller reported.
-5	33				SHELBY	100						33	30	5		UC	**T4-32.5-34.5 (32.5' to 34.5')** 450 psi downpressure 32.5-33.5 feet; 550 psi downpressure 33.5-34.5 feet
	34		33.5 to 37.2' SILT, (ML): About 95% nonplastic fines with low to medium dry strength, slow dilatancy, low toughness; about 5% fine sand; stiff, brown, moist; no reaction with HCl.							2.3P							Soil in bottom of tube felt like clay with sand
	35	ML			SPT	80	7 11 20	31	42	1.3P							**S9-35.0-36.2 (35.0' to 36.2')**
	36																
	37					70											**P7-36.5-37.2 (36.5' to 37.2')**
-10	38		37.2 to 40.4' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; dense, olive brown (2.5Y 4/4), wet; no reaction with HCl; occasional coarse subrounded sand and fine subrounded gravel.		SPT	80	11 16 18	34	46								**S10A-37.5-37.7 (37.5' to 37.7')** **S10B-37.7-38.7 (37.7' to 38.7')**
	39	SP	At 38.3', 0.1 foot of lean clay.														
	40					100									26		**P8-39.0-40.0 (39.0' to 40.0')**
			At 40.4', 0.3 foot of brown silt.		SPT	100	8 20 21	41	56			24			12		**S11-40.0-41.5 (40.0' to 41.5')**
	41		40.7 to 49.5' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; dense, olive brown (2.5Y 4/4), wet; no reaction with HCl; occasional coarse subrounded sand and fine subrounded gravel.														Tagged to 41.0 feet below ground surface
	42																
-15	43	SP			PCORE	0											Punch-core barrel got stuck. Then retriever loop broke free. Driller needed to pull out PQ pipe before drilling 41.5-45.0 feet. Soft soil, PQ pipe sank under own weight.
	44																
	45																

Final Report Version 10/14/2021

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge
Coordinates: North 2,038,569.17 East 6,665,258.48
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-110B
Sheet 3 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45		40.7 to 49.5' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; dense, olive brown (2.5Y 4/4), wet; no reaction with HCl; occasional coarse subrounded sand and fine subrounded gravel. *(Continued)*		SPT	0	2 2 3	5	7								Large volumes of loose sand coming out during drill hole clean-out. Easy drilling, driller reported.
	46																
	47	SP	From 45.0', Loose.			0											Bit plugged with clay slough, retried, failed again. Slough kept clogging bit. Sent Mod-Cal sampler down to clear blockage. Cleared coarse sand slough at about 35 feet bgs.
-20	48		From 47.5', Very loose.		SPT	0	2 1 3	4	5								
	49																Driller recirculated mud and added bentonite to drilling fluid to clean out hole.
	50	(SP)g	49.5 to 50.6' Poorly Graded SAND with Gravel, (SP)g: About 50% coarse sand; about 45% fine to coarse, subrounded to subangular gravel, maximum size 1.1 inches; about 5% low plasticity fines; very dense, gray, wet; no reaction with HCl; with trace fine sand and trace medium sand.														Felt like gravel from 50.5-51.5 feet bgs, driller reported. Mod-Cal had sand catcher but no liners.
	51				MCAL	87	23 38 47										**M2A-50.0-50.6 (50.0' to 50.6')** **M2B-50.6-51.3 (50.6' to 51.3')**
	52		From 50.3', About 95% fine to medium sand; about 5% nonplastic fines; trace coarse sand.														
-25	53		50.6 to 57.5' Poorly Graded SAND, (SP): About 90% fine to medium sand; about 5% nonplastic fines; about 5% fine, subrounded gravel, maximum size 0.5 inches; very dense, olive brown, wet; no reaction with HCl; trace coarse sand.		SPT	80	18 23 27	50	68			18			6		**S14-52.5-53.7 (52.5' to 53.7')**
	54	SP															
	55		From 50.7', About 95% fine to medium sand; about 5% nonplastic fines.														**S15A-55.0-55.4 (55.0' to 55.4')**
	56		From 55.0 to 55.4', About 95 percent coarse sand and fine gravel, about 5 percent fines (slough?).		SPT	73	13 20 32	52	71						7		**S15B-55.4-56.1 (55.4' to 56.1')**
	57		From 55.4', About 95% fine sand; about 5% nonplastic fines; trace medium sand.														
-30	58	CL	57.5 to 57.9' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; soft, light olive brown (2.5Y 5/4), wet; no reaction with HCl.	Rotary	SPT	100	9 34 38	72	98	0.4P		11			14		**S16A-57.5-57.9 (57.5' to 57.9')** **S16B-57.9-59.0 (57.9' to 59.0')**
	59																
	60	(SP-SC)g	57.9 to 62.8' Poorly Graded SAND with Clay and Gravel, (SP-SC)g: About 75% fine to medium sand; about 15% fine to coarse, subrounded to subangular gravel, maximum size 1.0 inches; about 10% medium plasticity fines; very dense, light olive brown, wet; no reaction with HCl; trace coarse sand.		SPT	60	32 28 23	51	70								**S17-60.0-60.9 (60.0' to 60.9')**
	61																Drilling ended 5/28/2021. Drilling began 6/1/2021.
	62																
-35	63		62.8 to 69.6' LEAN CLAY, (CL): About 95% medium to high plasticity fines with very high dry strength, no dilatancy, medium to high toughness; about 5% fine sand; stiff, dark greenish gray, moist; no reaction with HCl.		SPT	100	9 6 9	15	21	1.6P							**S18-62.5-64.0 (62.5' to 64.0')**
	64																
	65		From 65.5', Stiff to very stiff.							2.2P 2.0P							**S19-65.0-66.2 (65.0' to 66.2')**
	66	CL			SPT	80	7 6 8	14	19								
	67																
-40	68				SHELBY	90						35	50	23		CU DS	**T5-67.5-69.3 (67.5' to 69.3')** 480 to 650 psi downpressure
	69									2.8P							
	70	s(CL)	*Description on next page.*														Bottom of tube dented

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge
Coordinates: North 2,038,569.17 East 6,665,258.48
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-110B
Sheet 4 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70	s(CL)	69.6 to 70.5' SANDY LEAN CLAY, s(CL): About 60% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 40% fine sand; very stiff, dark greenish gray, moist; no reaction with HCl. *(Continued)*	Rotary	SPT	100	9 10 11	21	29	2.7P							**S20A-70.0-70.5 (70.0' to 70.5')** **S20B-70.5-71.5 (70.5' to 71.5')**
	71																
	72																
-45	73		70.5 to 85.3' LEAN CLAY, (CL): About 90% low to medium plasticity fines with high dry strength, no dilatancy, low to medium toughness; about 10% fine sand; very stiff, dark greenish gray, wet; no reaction with HCl.		SPT	100	8 8 12	20	27	3.5P 2.0P							**S21-72.5-74.0 (72.5' to 74.0')**
	74																
	75		From 73.5', About 95% medium plasticity fines with medium toughness; about 5% fine sand; stiff to very stiff.														
	76		From 75.0', Stiff.		SHELBY	95											**T6-75.0-76.9 (75.0' to 76.9')** Push of Shelby tube pushed PQ pipe down; might be disturbed sample.
	77									1.9P							
-50	78	CL			PCORE	0											2 inches of obvious slough was all that was in core barrel.
	79																
	80		From 80.0', Medium stiff.														
	81		From 81.0', Soft.		SPT	100	4 4 6	10	14	0.9P 0.4P							**S22-80.0-81.5 (80.0' to 81.5')**
	82		From 82.0', Stiff to very stiff.														
-55	83				SHELBY	100						28	58	33		UC	**T7-82.5-84.5 (82.5' to 84.5')** 450 psi downpressure 82.5-83.5 feet; 550 psi downpressure 83.5-84.5 feet
	84									2.0P							
	85		From 85.0', Medium stiff.							0.8P							
	86		85.3 to 93.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, dark greenish gray, moist to dry; several 1-inch elongate zones of white coating with weak to strong HCl reaction.		SPT	60	8 19 23	42	57	4.1P							**S23A-85.0-85.3 (85.0' to 85.3')** **S23B-85.3-85.9 (85.3' to 85.9')**
	87																
-60	88		From 87.5', No reaction with HCl; no more white-coated zones or HCl reaction.		SPT	100	10 17 25	42	57	4.6P							**S24-87.5-89.0 (87.5' to 89.0')**
	89	CH															
	90																
	91				SPT	100	10 16 21	37	51								**S25-90.0-91.5 (90.0' to 91.5')** Drilling ended 6/1/2021. Drilling began 6/2/2021.
	92																
-65	93		From 92.5', Very stiff.							2.5P							**S26A-92.5-93.0 (92.5' to 93.0')**
			Description on next page.		SPT	93	4 16 17	33	45	2.0P							**S26B-93.0-93.9 (93.0' to 93.9')**
	94	(CL)s															
	95																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge
Coordinates: North 2,038,569.17 East 6,665,258.48
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-110B
Sheet 5 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95	s(ML)	93.0 to 95.2' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 15% fine sand; stiff to very stiff, very dark greenish gray, wet; no reaction with HCl; some white coating but no HCl reaction. *(Continued)*	SPT		100	12 17 21	38	52	1.5P 3.4P							S27A-95.0-95.2 (95.0' to 95.2') S27B-95.2-95.6 (95.2' to 95.6') S27C-95.6-97.0 (95.6' to 96.5')
	96	(ML)s															
	97																
-70	98	SP-SC	95.2 to 95.6' SANDY SILT, s(ML): About 70% low plasticity fines with low toughness; about 30% fine to medium sand; very dark greenish gray.	SPT		93	24 28 21	49	67								S28-97.5-98.9 (97.5' to 98.9')
	99		95.6 to 97.0' SILT with Sand, (ML)s: About 85% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 15% fine sand; very stiff, very dark greenish gray, moist.														
	100			SPT		80	14 21 25	46	63								S29-100.0-101.2 (100.0' to 101.2')
	101		97.0 to 100.0' Poorly Graded SAND with Clay, (SP-SC): About 90% fine sand; about 10% medium plasticity fines; dense, dark gray, wet; no reaction with HCl; trace medium sand and trace coarse sand; weak to moderate cementation in places by clay.														
	102																
-75	103	SP	From 97.7', Very dark gray.	SPT		80	20 30 26	56	77			23			15		S30-102.5-103.7 (102.5' to 103.7')
	104		From 98.0 to 98.3', About 80% fine sand; about 10% medium plasticity fines; about 10% fine to coarse, subrounded gravel, maximum size 1.0 inches.														
	105		100.0 to 107.7' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, very dark gray, wet; no reaction with HCl.	SPT		87	18 24 25	49	67								S31-105.0-106.3 (105.0' to 106.3')
	106		From 100.9 to 101.0', Clayey zone.														
	107		From 101.0', About 95% fine to medium sand; about 5% nonplastic fines.														
-80	108		From 102.5 to 103.7', About 85% fine to coarse sand; about 15% nonplastic fines; mostly fine to medium sand.	Rotary													S32A-107.5-107.7 (107.5' to 107.7')
	109		From 103.0', Very dense.	SPT		100	8 13 24	37	51	2.6P 3.4P							S32B-107.7-109.0 (107.7' to 109.0')
	110		At 103.3', 1/4-inch-thick clayey zone. From 105.0', Dense to very dense.														
	111	ML	107.7 to 113.0' SILT, (ML): About 95% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 5% fine sand; very stiff, dark greenish gray, moist; no reaction with HCl.	SPT		80	13 19 28	47	64	2.4P 4.2P							S33-110.0-111.2 (110.0' to 111.2')
	112		From 111.0', Hard.														Was going to push Shelby at 112.5 feet, but driller encountered gravel.
-85	113	SP	113.0 to 113.2' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; no reaction with HCl; trace fine subrounded gravel.	SPT		100	33 46 56	102	139	2.5P							S34A-112.5-113.0 (112.5' to 113.0') S34B-113.0-113.2 (113.0' to 113.2') S34C-113.2-114.0 (113.2' to 114.0')
	114																
	115		113.2 to 120.3' Poorly Graded SAND with Silt and Gravel, (SP-SM)g: About 70% fine sand; about 20% fine to coarse, subrounded gravel, maximum size 1.0 inches; about 10% low plasticity fines; very dense, very dark gray, wet; no reaction with HCl.	SPT		80	20 31 33	64	87								S35-115.0-116.2 (115.0' to 116.2')
	116	(SP-SM)g															
	117																
-90	118			SPT		73	27 50 47	97	133			13			12		S36-117.5-118.6 (117.5' to 118.6')
	119																
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Final Report Version 10/14/2021

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge
Coordinates: North 2,038,569.17 East 6,665,258.48
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-110B
Sheet 6 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	120	SP	120.3 to 120.8' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; very dense, very dark gray, wet.	SPT		80	28 25 54	79	108								S37-120.0-121.2 (120.0' to 121.2')
	121																
	122	(SP)g	120.8 to 126.5' Poorly Graded SAND with Gravel, (SP)g: About 75% fine sand; about 20% fine to coarse, subrounded gravel, maximum size 1.0 inches; about 5% low plasticity fines; very dense, very dark gray, wet; no reaction with HCl.														
-95	123			Rotary		33	52 50/4.5"										S38-122.5-122.8 (122.5' to 122.8') At 123.4' SPT Refusal
	124			NSD													
	125		From 125.0', About 70% fine to medium sand; about 25% fine to coarse, subrounded to subangular gravel; about 5% nonplastic fines.														
	126			SPT		73	29 49 55	104	142								S39-125.0-126.1 (125.0' to 126.1')
	127																
-100	128		Tremie-grouted with 95% cement, 5% bentonite by weight														
	129																
	130																
	131																
	132																
-105	133																
	134																
	135																
	136																
	137																
-110	138																
	139																
	140																
	141																
	142																
-115	143																
	144																
	145																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge abutment
Coordinates: North 2,038,539.12 East 6,665,515.09
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-111B
Sheet 1 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/20/20 — DATE COMPLETED 10/27/20	GROUND ELEVATION 20.04 ft — ELEVATION BASIS Ground Survey	TOTAL DEPTH OF BORING 126.3 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Poese Fuapau — HELPER'S NAME Murad Rashid/Navaro	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 126.3 ft: HSA	DRILL RIG MAKE AND MODEL CME 95 / 2nd Rig CME 95	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER 8" Hollow Stem Auger	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Soil Core, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 85% / 2nd Rig 76%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 10 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
20	0	SM	RECENT ALLUVIUM, (Qal) 0.0 to 126.3'	Hand Auger	CUTTINGS	100											
	1		0.0 to 2.0' SILTY SAND, (SM): About 85% fine sand; about 15% nonplastic fines; gray, dry; no reaction with HCl.														
	2	(CH)s															
	3		2.0 to 3.0' FAT CLAY with Sand, (CH)s: About 80% high plasticity fines; about 20% fine sand; dark brown, moist; no reaction with HCl.														
	4																Grab 1-3.5-4.5 (3.5' to 4.5')
15	5		3.0 to 12.5' LEAN CLAY, (CL): About 90% medium plasticity fines with very high dry strength, no dilatancy, medium toughness; about 10% fine sand; very stiff, dark brown, moist; no reaction with HCl.		SPT	53	2 3 5	8	11								Recovered sample may be slough S1-5.0-6.5 (5.0' to 5.8')
	6																
	7	CL								2.4P							Box 1 C1-6.5-10.0 (6.5' to 7.3')
	8				DCORE	23											
	9																
10	10		From 10.0', Stiff, reddish brown.		SPT	100	1 3 4	7	10	1.3P		26	33	14	91		S2-10.0-11.5 (10.0' to 11.5') At 10' [Lab] LEAN CLAY (CL)
	11		From 11.5 to 12.3', Thin interbeds of coarse sand.														
	12			Auger		100											Box 1 C2-11.5-12.5 (11.5' to 12.5')
	13		12.5 to 15.8' Well-Graded SAND with Silt, (SW-SM): About 90% fine sand; about 10% nonplastic fines; loose, gray, wet; no reaction with HCl.		SHELBY	100				2.3P					12		100 psi downpressure T1-12.5-14.5 (12.5' to 14.5')
	14	SW-SM															
5	15					0											
	16		15.8 to 16.9' SILT, (ML): About 90% nonplastic fines; about 10% fine sand; brown, moist; no reaction with HCl.		SPT	73	1 1 4	5	7								S3-15.0-16.5 (15.0' to 16.1')
	17	ML															
	18	SC	16.9 to 17.4' CLAYEY SAND, (SC): About 85% fine to medium sand; about 15% medium plasticity fines.		DCORE	43				4.7P							Box 1 C3-16.5-20.0 (16.5' to 18.0')
	19	CL	17.4 to 19.5' LEAN CLAY, (CL): About 95% medium plasticity fines with high toughness; about 5% fine sand; hard, brown.														
	20	CH	*Description on next page.*														

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge abutment
Coordinates: North 2,038,539.12 East 6,665,515.09
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-111B
Sheet 2 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
0	20	CH	19.5 to 21.4' FAT CLAY, (CH): About 95% high plasticity fines with high toughness; about 5% fine sand; brown. *(Continued)*	Auger	SPT	93	5 9 11	20	28								**S4-20.0-21.5 (20.0' to 21.4')**
	21																
	22	CL	21.4 to 27.5' LEAN CLAY with Sand, (CL): About 85% low plasticity fines with medium toughness; about 15% fine sand; very stiff, brown.		DCORE	63				3.0P		30	33	10	80		**Box 1 C4-21.5-25.0 (21.5' to 23.7')** **At 21.5' [Lab] LEAN CLAY with SAND (CL)**
	23																
	24																
-5	25		From 25.0 to 26.2', Stiff.		SPT	80	4 7 16	23	33	1.8P							**S5-25.0-26.5 (25.0' to 26.2')**
	26																
	27		From 26.5', Texture of fine to coarse angular gravel that breaks apart under moderate hand pressure.			0											
	28	SM	27.5 to 30.0' SILTY SAND, (SM): About 85% fine to medium sand; about 15% nonplastic fines; very dense, gray, wet.		SHELBY	100									8		**T2-27.5-29.0 (27.5' to 29.0')**
	29																Sand at top and bottom of Shelby tube.
-10	30					0											
	31	SP	30.0 to 45.6' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; very dense, gray, wet. At 30.9', 0.1-foot-thick clay bed.		SPT	100	8 20 39	59	84								**S6-30.0-31.5 (30.0' to 31.5')**
	32		At 31.3', 0.1-foot-thick clay bed.		DCORE	0											
	33																
	34																
-15	35				SPT	100	4 4 8	12	17								**S7-35.0-36.5 (35.0' to 36.5')**
	36																Lost SPT sample. Retrieved 1.5' with Mod Cal Sampler.
	37		From 36.5', About 90% fine to medium sand; about 5% nonplastic fines; about 5% fine gravel; medium dense, olive, wet; no reaction with HCl; trace coarse sand.		DCORE	31									7		**Box 2 C8-36.5-40.0 (36.5' to 37.6')** Drilling ended 15:30 hours 10/20/2020 Drilling began 09:00 hours 10/22/2020
	38																
	39																
-20	40		From 40.0', Very dense.		SPT	80	12 25 52	77	98								**S8-40.0-41.5 (40.0' to 41.2')**
	41																
	42					0											Heaving sands reported by driller to a depth of 1' bgs. Driller augered 15' through bottom of the sand and sampled through the augers.
	43		From 43.0', About 85% medium to coarse sand; about 10% fine to coarse, subrounded to subangular gravel, maximum size 1.5 inches; about 5% nonplastic fines.		SPT	67	0										**S9-42.5-44 (42.5' to 43.5')** SPT barrel was hitting the inside of the auger making the recorded blow counts (11/24/27) inaccurate.
	44																
	45				DCORE	46											**Box 2 C9-44.0-49.0 (44.0' to 46.3')**

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge abutment
Coordinates: North 2,038,539.12 East 6,665,515.09
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-111B
Sheet 3 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
-25	45	SP															
	46	s(CL)	45.6 to 46.0' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines; about 30% fine sand; olive, wet.		DCORE	46											
	47		46.0 to 56.5' Poorly Graded SAND, (SP): About 95% fine to coarse sand; about 5% low plasticity fines; very dense, dark olive gray, wet.														
	48																
	49					0											
-30	50				SPT	100	14 22 56	78	99						3		S10-50.0-51.5 (50.0' to 51.5') At 50' [Lab] POORLY GRADED SAND (SP)
	51	SP															
	52				NSD	0											SPT blow counts from within the auger and unreliable. Drilling ended 17:00 hours 10/22/2020 Drilling began 07:30 hours 10/23/2020
	53																
	54																
-35	55		From 55.0 to 55.4', 3" long root, undecayed.														
	56		At 55.3', 1" diameter lens of Sandy Lean Clay. From 55.7', Trace fine subrounded gravel.		SPT	87	3 18 19	37	47								S11-55.0-56.5 (55.0' to 56.3')
	57	(SC)g	From 56.3', Increasing fines.							3.5P							Box 2 C10-56.5-60.0 (56.5' to 58.0')
	58		56.5 to 57.2' CLAYEY SAND with Gravel, (SC)g: About 65% fine to coarse sand; about 20% fine to coarse, subrounded to subangular gravel, maximum size 1.2 inches; about 15% low plasticity fines; very dense, dark olive gray, wet; no reaction with HCl.	Auger	DCORE	43											
	59		57.2 to 67.4' LEAN CLAY, (CL): About 95% medium plasticity fines with slow dilatancy, low toughness; about 5% fine sand; very stiff, grayish green, moist; no reaction with HCl.														
-40	60				SPT	100	8 13 19	32	41								S12-60.0-61.5 (60.0' to 61.5')
	61		From 61.5', Medium stiff.														
	62	CL								0.7P			48	22	93		Box 2 C11-61.5-65.0 (61.5' to 63.7') At 61.5' [Lab] LEAN CLAY (CL)
	63				DCORE	63											
-45	65																
	66				SHELBY	100											500 psi downpressure T3-65.0-67.0 (65.0' to 67.0')
	67																
	68	CH	67.4 to 67.8' FAT CLAY, (CH): About 95% high plasticity fines with high toughness; about 5% fine sand; very stiff, grayish green, moist.							3.3P							Box 2 C12-67.0-70.0 (67.0' to 68.4')
	69	SC	67.8 to 69.0' CLAYEY SAND, (SC): About 85% fine to medium sand; about 15% medium plasticity fines; dark olive gray, wet.		DCORE	47											
	70	CH															

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge abutment
Coordinates: North 2,038,539.12 East 6,665,515.09
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-111B
Sheet 4 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
-50	70		69.0 to 80.4' FAT CLAY, (CH): About 95% high plasticity fines with high toughness; about 5% fine sand; very stiff, grayish green, moist. *(Continued)*	Auger	SPT	100	7 11 17	28	35	3.3P							**S13-70.0-71.5 (70.0' to 71.5')**
	71																
	72				DCORE	89				3.5P 3.9P 3.2P							Heaving sands. SPT sample may be slough. **Box 3 C13-71.5-74.6 (71.5' to 74.6')**
	73																
	74																
-55	75	CH			SPT	100	6 7 10	17	22	1.5P 0.8P							**S14-75.0-76.5 (75.0' to 76.5')**
	76																
	77					0											
	78				SHELBY	100											500 psi downpressure **T3-77.5-79.5 (77.5' to 79.5')**
	79									3.2P							
-60	80					0											
		(CH)s	80.4 to 81.8' FAT CLAY with Sand, (CH)s: About 85% high plasticity fines with high toughness; about 15% fine sand; hard, grayish green, moist; no reaction with HCl.		SPT	100	10 22 44	66	84	4.5P 4.5P							**S15A-80.0-80.4 (80.0' to 80.4')** **S15B-80.4-81.5 (80.4' to 81.5')**
	82	SC	81.8 to 86.3' CLAYEY SAND, (SC): About 80% coarse sand; about 20% low plasticity fines; very dark greenish gray, no reaction with HCl.		DCORE	51									23		**Box 3 C15-81.5-83.3 (81.5' to 83.3')**
	83																
	84																Drilling ended 17:00 hours 10/23/2020
-65	85																Drilling began 07:30 hours 10/24/2020
	86		At 85.7', 0.5" thick Sandy Lean Clay layer.		SPT	100	3 6 7	13	16								**S16-85.0-86.5 (85.0' to 86.5')**
	87	SC	86.5 to 89.0' CLAYEY SAND, (SC): About 70% fine to medium sand; about 30% low plasticity fines; dense, very dark greenish gray, wet; trace coarse sand.		DCORE	57											**Box 3 C16-86.5-90.0 (86.5' to 88.5')** Placed PVC tremie to clear out heave
	88		From 87.7 to 88.1', About 70% fine to medium sand; about 25% low plasticity fines; about 5% fine gravel.														
	89		89.0 to 126.3' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; trace coarse sand.														
-70	90				SPT	93	6 14 25	39	49								**S17-90.0-91.5 (90.0' to 91.4')**
	91																
	92	SP				0											Drilling ended 14:45 hours 10/24/2020
	93		From 92.5', About 90% fine to medium sand; about 5% nonplastic fines; about 5% fine, subrounded gravel.		SPT	100	9 25 34	59	75								Drilling began 07:30 hours 10/26/2020 **S18-92.5-94.0 (92.5' to 94.0')**
	94																
	95					0											

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge abutment
Coordinates: North 2,038,539.12 East 6,665,515.09
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-111B
Sheet 5 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
-75	95	SP	89.0 to 126.3' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; trace coarse sand. *(Continued)*	Auger	SPT	100	4 7 11	18	23								S19-95.0-96.5 (95.0' to 96.5')
	96																
	97		From 95.0', About 95% fine to coarse sand; about 5% nonplastic fines; medium dense.		NSD	0											
	98		From 97.5', About 90% fine to coarse sand; about 5% medium plasticity fines; about 5% fine to coarse, subrounded gravel, maximum size 7/8 inches; very dense, occasional plant roots.		SPT	100	18 53 50/3"										S20-97.5-98.8 (97.5' to 98.8')
	99		From 98.6 to 98.7', No reaction with HCl; weak clay cementation.		NSD	0											Poured water down the augers
-80	100		From 100.2 to 100.3', No reaction with HCl; moderate clay cementation.			100	26 50/3"										S21-100.0-100.8 (100.0' to 100.8')
	101				NSD	0											At 100.8' SPT Refusal
	102																
	103		From 102.5', Occasional 1" thick clay layers.			100	44 50/5"										S22-102.5-103.5 (102.5' to 103.5')
	104				NSD	0											At 103.5' SPT Refusal
-85	105				SPT	100	6 32 50	82	104								S23-105.0-106.6 (105.0' to 106.5')
	106																
	107				NSD	0											
	108					100	15 50										S24-107.5-108.5 (107.5' to 108.5')
	109				NSD	0											
-90	110					100	37 50/4"										S25-110.0-110.9 (110.0' to 110.9')
	111				NSD	0											At 110.9' SPT Refusal
	112																
	113				SPT	100	9 17 50/2"										S26-112.5-113.7 (112.5' to 113.7')
	114				NSD	0											
-95	115					100	13 50/4"										S27-115.0-115.8 (115.0' to 115.8')
	116				NSD	0											At 115.8' SPT Refusal
	117																
	118				SPT	100	6 11 50/4"										S28-117.5-118.8 (117.5' to 118.8')
	119				NSD	0											
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Pedestrian Bridge abutment
Coordinates: North 2,038,539.12 East 6,665,515.09
Survey Method: Ground Survey Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-111B
Sheet 6 of 6

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
-100	120		89.0 to 126.3' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; very dense, very dark greenish gray, wet; trace coarse sand. *(Continued)*	Auger		100	12 50/5"										**S29-120.0-120.8 (120.0' to 120.9')**
-100	121				NSD	0											**At 120.9' SPT Refusal**
	122		From 120.0', About 95% fine to medium sand; about 5% medium plasticity fines; very dense, dark gray, wet; no reaction with HCl; interbedded with 1" to 2" thick clay layers.														
	123	SP				100	10 50/4"										**S30-122.5-123.3 (122.5' to 123.3')**
	124				NSD	0											**At 123.3' SPT Refusal**
-105	125																
	126				SPT	100	7 26 50/3"										**S31-125.0-126.3 (125.0' to 126.3')**
	127		Tremie-grouted with 95% cement, 5% bentonite by weight														Total depth 126.3' at 15:00 hours 10/26/2020
	128																
	129																
-110	130																
	131																
	132																
	133																
	134																
-115	135																
	136																
	137																
	138																
	139																
-120	140																
	141																
	142																
	143																
	144																
	145																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / RD 1600
Coordinates: North 2,038,514.00 East 6,665,749.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

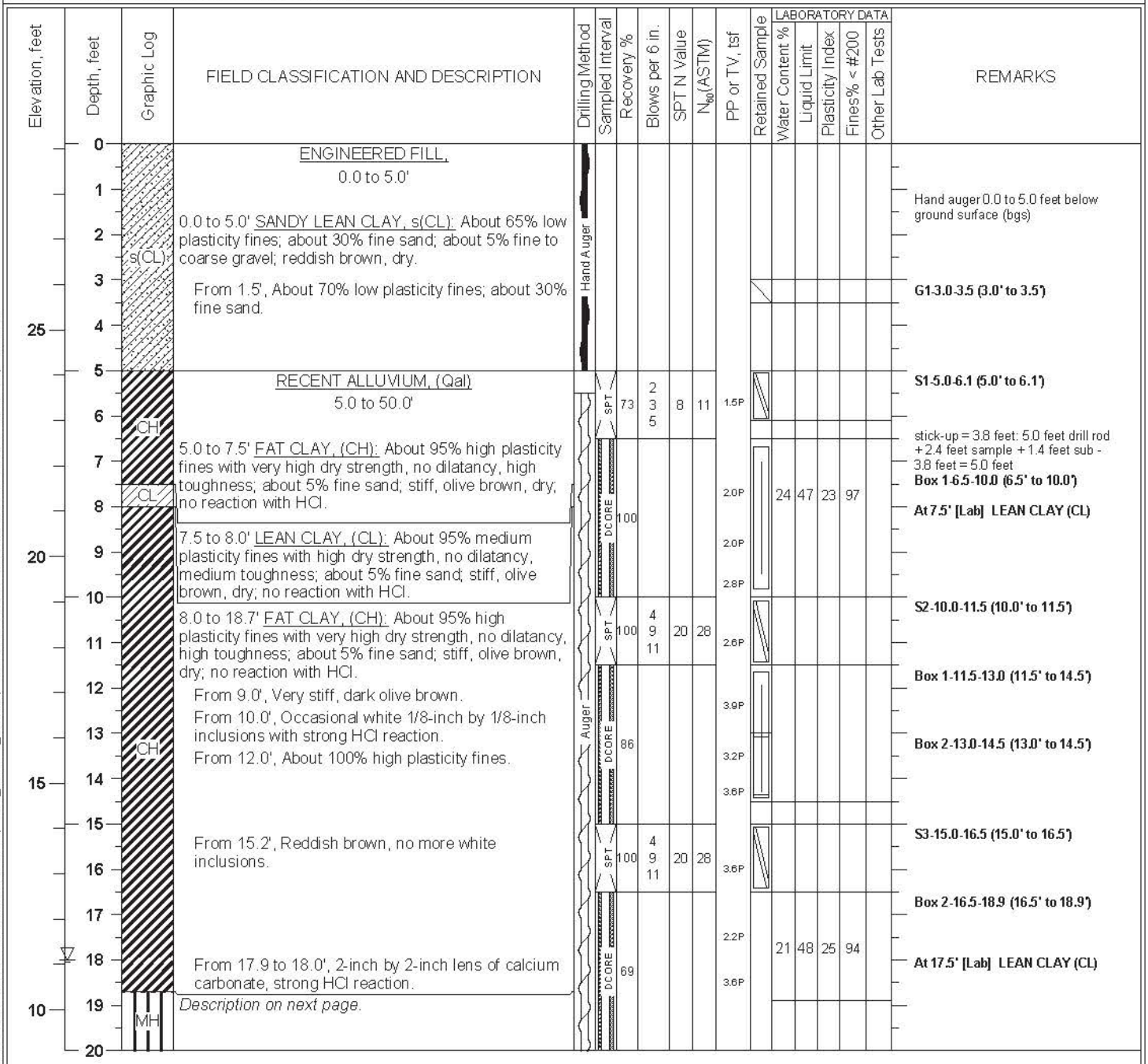
DRILL HOLE LOG

FW-113B

Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/15/20 — DATE COMPLETED 10/16/20	GROUND ELEVATION 29.10 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 50.0 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Tyler Rouse — HELPER'S NAME Murad Rashid	TOTAL DEPTH OF FILL 5 ft
DRILLING METHOD 0 - 5 ft: HA, 5.5 - 50 ft: HSA	DRILL RIG MAKE AND MODEL CME 01-LAR02	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER X (0.0 to 45.0'), NWJ (45.0-50')	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, core barrel	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 84%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 18.0 ft — AFTER DRILLING (DATE-TIME)	



1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / RD 1600
Coordinates: North 2,038,514.00 East 6,665,749.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-113B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		18.7 to 22.0' ELASTIC SILT, (MH): About 95% nonplastic fines with medium dry strength, slow dilatancy, low toughness; about 5% fine sand; stiff to very stiff, reddish brown, moist; no reaction with HCl. *(Continued)*														
	21	MH			SPT	100	5 9 12	21	29	2.3P 1.6P 2.2P							**S4-20.0-21.5 (20.0' to 21.5')**
	22																	**Box 3-21.5-25.0 (21.5' to 25.0')**
		(ML)s	22.0 to 23.0' SILT with Sand, (ML)s: About 80% nonplastic fines with low dry strength, slow dilatancy, low toughness; about 20% fine sand; hard, olive brown, moist; no reaction with HCl.		DCORE	100				2.6P 2.5P 4.6P		27	41	11	82		**At 22' [Lab] SILT with SAND (ML)**
5	24		23.0 to 27.9' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, olive brown, moist; no reaction with HCl.														
	25		From 25.0', Very stiff, reddish brown.		SPT	100	3 4 5	9	13	2.1P 1.3P							**S5-25.0-26.5 (25.0' to 26.5')**
	26	CH	From 25.6', Stiff.														Tagged to 26.5 feet bgs, 10:50 hours
	27		From 26.0', Sand content increased.														
	28				DCORE	94				1.1P 1.8P							**Box 4-26.5-29.8 (26.5' to 29.8')**
0	29	s(ML)	27.9 to 29.5' SANDY SILT, s(ML): About 70% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 30% fine sand; stiff, olive brown, moist; no reaction with HCl.														
	30	SM	29.5 to 30.7' SILTY SAND, (SM): About 60% fine sand; about 40% nonplastic fines; loose, olive brown, wet; no reaction with HCl.		SPT	100	2 3 5	8	11			34					**S6-30.0-31.5 (30.0' to 31.5')**
	31	s(ML)	30.7 to 32.3' SANDY SILT, s(ML): About 70% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 30% fine sand; stiff, olive brown, moist; no reaction with HCl; trace fine gravel.	Auger													
	32				DCORE	37											**Box 4-31.5-32.8 (31.5' to 32.8')**
	33	SM	32.3 to 34.5' SILTY SAND, (SM): About 70% fine sand; about 30% nonplastic fines; medium dense, olive brown, wet; no reaction with HCl.														
-5	34																
	35		34.5 to 38.0' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium sand; about 10% nonplastic fines; medium dense, reddish brown, wet; no reaction with HCl; numerous 1-inch-thick layers of yellowish brown silt or lean clay.		SPT	80	7 12 12	24	34								**S7-35.0-36.2 (35.0' to 36.2')**
	36	SP-SM															
	37				DCORE	57											**Box 4-36.5-38.5 (36.5' to 38.5')** Run conducted in two stages. First run went to approximately 38 feet and was tagged to 38 feet bgs at 13:00 hours. Second run went to 40 feet bgs but recovered only half a foot. Driller reported heaving sand.
	38	SM	38.0 to 38.5' SILTY SAND, (SM): About 65% fine to medium sand; about 35% nonplastic fines; reddish brown, wet; no reaction with HCl.									23			33		
-10	39		38.5 to 50.0' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% low plasticity fines; very dense, dark olive brown, wet; no reaction with HCl; trace coarse sand.														
	40				SPT	100	8 25 50/4"										**S8-40.0-41.4 (40.0' to 41.4')**
	41																
	42	SP	From 41.5 to 42.7', Lenses of clayey material.												4		**Box 5-41.5-42.6 (41.5' to 42.6')** **At 41.5' [Lab] POORLY GRADED SAND (SP)** 41.5 to 42.6 feet bgs sample could be slough. Heaving sand prevented core barrel progress. Because LAR can't do mud rotary, decided to do SPTs every 2.5 feet.
	43				DCORE	31											
-15	44																
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / RD 1600
Coordinates: North 2,038,514.00 East 6,665,749.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-113B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
-45	45	SP	38.5 to 50.0' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% low plasticity fines; very dense, dark olive brown, wet; no reaction with HCl; trace coarse sand. *(Continued)*	Auger	SPT	100	9 16 16	32	45								**S9-45.0-46.5 (45.0' to 46.5')**
	46		From 45.0', Dense, trace subrounded fine gravel.														
	47				NSD												Heaving sand filled augers; driller needed to clean out. Used PVC tremie pipe and poured water to clean out. Reported problem to Geotechnical Engineering Section, who directed to declare total depth at 50.0 feet.
	48																
-20	49				MCAL	0	7 12 13										Augered to 50.0 feet bgs; tagged to 45.5 feet bgs. Used Mod-Cal to clean out sloughed sample. **Box 5-48.5-50.0 (48.5' to 50.0')**
	50																
	51		Tremie-grouted with 95% cement, 5% bentonite by weight														
	52																
	53																
-25	54																
	55																
	56																
	57																
	58																
-30	59																
	60																
	61																
	62																
	63																
-35	64																
	65																
	66																
	67																
	68																
-40	69																
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,037,176.00 East 6,665,778.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-115B
Sheet 1 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 11/5/20 — DATE COMPLETED 11/7/20	GROUND ELEVATION 43.80 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 103.0 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Tyler Rouse	TOTAL DEPTH OF FILL 29.5 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 103 ft: HSA	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER 8" Hollow Stem Auger	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 37.6 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0	GP	LEVEE FILL, (Qaf) 0.0 to 29.5'														Hand Auger to 5 feet
	1	s(CL)	0.0 to 0.7' Poorly Graded GRAVEL, (GP):	Hand Auger	CUTTINGS	100											
	2																
	3		0.7 to 3.0' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines; about 30% fine sand; brown, moist to dry.														
40	4	SM	3.0 to 4.5' SILTY SAND, (SM): About 75% fine sand; about 25% nonplastic fines; brown, moist to dry.														G1-4.0-5.0 (4.0' to 5.0')
	5		4.5 to 8.5' FAT CLAY, (CH): About 90% high plasticity fines; about 10% fine sand; brown, moist.		SPT	73	1 2 1	3	4								S1-5.0-6.5 (5.0' to 6.5')
	6		From 5.5 to 5.7', FAT CLAY with Sand, (CH)s: About 80% high plasticity fines; about 10% fine sand; about 10% fine to coarse gravel; brown, moist.														
	7	CH	From 5.9 to 6.0', SILTY SAND, (SM): About 75% fine sand; about 25% nonplastic fines; brown, moist.		SPT	80	1 2 3	5	6	2.6P 2.6P							S2-6.5-8.0 (6.5' to 8.0') Pocket penetrometer indicted very stiff consistancy but the SPT blow count suggest a medium consistancy
	8		From 6.0 to 8.5', About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff.														
35	9		8.5 to 11.5' SANDY SILT, s(ML): About 60% low plasticity fines with low dry strength, rapid dilatancy, low toughness; about 40% fine sand; brown, moist; variable fines-sand content.		SPT	80	1 1 1	2	2						60		S3-9.0-10.2 (9.0' to 10.2')
	10	s(ML)															
	11																
	12		11.5 to 29.5' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; stiff, brown, moist.	Auger	SPT	100	0 1 2	3	4	2.0P		24	44	26			S4-11.5-13.0 (11.5' to 13.0')
	13																
30	14		From 14.0', Dark olive gray.		SPT	100	1 2 2	4	5	1.5P							S5-14.0-15.5 (14.0' to 15.5')
	15	CL															
	16																
	17		From 16.6', Brown. From 16.9', Dark olive gray.		SPT	93	1 3 3	6	7	1.1P 2.2P							S6-16.5-18.0 (16.5' to 18.0')
	18																
25	19																
	20				SHELBY	90							43	20	99		350 psi downpressure T1-19.0-20.8 (19.0' to 20.8') At 19' [Lab] LEAN CLAY (CL)

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,037,176.00 East 6,665,778.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-115B
Sheet 2 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60} (ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20	CL	11.5 to 29.5' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; stiff, brown, moist. *(Continued)*	Auger	SHELBY	90				1.4P			43	20	99		
	21																
	22				SPT	100	1 2 2	4	5	1.7P							S7-21.5-23.0 (21.5' to 23.0')
20	23																
	24				SPT	100	2 3 4	7	8	2.1P 1.0P		27	41	19	97		S8-24.0-25.5 (24.0' to 25.5') At 24' [Lab] LEAN CLAY (CL)
	25																
	26																
	27				SPT	100	1 3 4	7	8	1.3P 2.0P		26				PD	S9-26.5-28.0 (26.5' to 28.0')
15	28																
	29																
	30	CL	RECENT ALLUVIUM, (Qal) 29.5 to 103.0'		SPT	100	3 7 10	17	20	3.0P 4.0P							S10-29.0-30.5 (29.0' to 30.5')
	31		29.5 to 31.0' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; very stiff to hard, dark olive gray, moist.														
	32				SPT	100	5 9 13	22	26	3.5P 3.8P							S11-31.5-33.0 (31.5' to 33.0')
	33	CH	31.0 to 36.5' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, brown, moist; occasional white inclusions that stongly react to HCl.														
10	34				SPT	100	5 11 21	32	38	4.4P 4.6P							S12-34.0-35.5 (34.0' to 35.5')
	35		From 34.0', Hard.														
	36																
	37	(CL)s	36.5 to 38.5' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 15% fine sand; very stiff to hard, brown, moist; occasional white inclusions with strong reaction to HCl.		SPT	100	6 11 13	24	28	4.2P 2.8P		20	43	26	84		S13-36.5-38.0 (36.5' to 38.0') At 36.5' [Lab] LEAN CLAY with SAND (CL)
	38																Rig chatter
5	39		From 37.7 to 37.9', Soft.														
	40		38.5 to 45.3' SILT with Sand, (ML)s: About 85% nonplastic fines; about 15% fine sand; stiff, yellowish brown, moist; numerous veins of white material that don't react to HCl.		SPT	100	10 27 39	66	78	1.5P							S14-39.0-40.5 (39.0' to 40.5')
	41																End Day 11/5/2020 Begin Day 11/6/2020
	42	(ML)s	From 41.5', Very stiff to hard.		MCAL	67	10 19 29			2.9P 4.6P							Liners for strength test M1B-42.0-42.5 (42.0' to 42.5') M1C-42.5-43.0 (42.5' to 43.0')
	43																
0	44		44.0', Increased plasticity and a decrease in sand content.		SPT	100	3 6	13	15			25	28	8		PD	S15-44.0-45.5 (44.0' to 45.5')
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,037,176.00 East 6,665,778.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-115B
Sheet 3 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45				SPT	100	7	13	15			25	28	8		PD	
	46		45.3 to 56.0' LEAN CLAY, (CL): About 90% low plasticity fines with high dry strength, slow dilatancy, low toughness; about 10% fine sand; very stiff, reddish brown, moist; no reaction with HCl.														
	47				SPT	100	2 6 7	13	15	2.5P							S16-46.5-48.0 (46.5' to 48.0')
	48																
-5	49				SPT	100	2 2 6	8	9	2.4P							S17-49.0-50.5 (49.0' to 50.5')
	50																
	51	CL															
	52				SPT	100	5 8 11	19	22	2.4P		28	40	17			S18-51.5-53.0 (51.5' to 53.0')
	53																
-10	54		54.0' Stiff, borderline silt.		SPT	100	4 9 12	21	25	1.5P							S19-54.0-55.5 (54.0' to 55.5')
	55																
	56		56.0 to 60.4' SILT with Sand, (ML)s: About 85% nonplastic fines; about 15% fine sand; stiff, yellowish brown, moist; numerous veins of white material that don't react to HCl.														
	57		At 57.3', 0.1' thick sand layer.	Auger	SPT	87	7 14 19	33	39	1.8P							S20-56.5-58.0 (56.5' to 58.0')
	58	(ML)s	At 57.6', 0.1' thick sand layer.														
-15	59																
	60		From 59.7', Increased sand content.		SPT	100	6 15 23	38	45						57		S21-59.0-60.5 (59.0' to 60.5')
	61		60.4 to 73.5' Poorly Graded SAND with Gravel, (SP)g: About 75% fine to medium sand; about 20% fine, subrounded gravel; about 5% nonplastic fines; very dense, dark olive gray, wet; no reaction with HCl; some flat gravels.														
	62					100	40 50/5"										S22-61.5-62.4 (61.5' to 62.4') At 62.4' SPT Refusal
	63				NSD												
-20	64					75	35 62/4"										S23-64.0-64.8 (64.0' to 64.8')
	65	(SP)g															At 64.8' SPT Refusal
	66				NSD												
	67		From 66.5', About 20% fine to coarse gravel, maximum size 1.7 inches.		SPT	79	27 46 50/5"								0		S24-66.5-67.9 (66.5' to 67.9') At 66.5' [Lab] POORLY GRADED SAND with GRAVEL (SP)
	68																
-25	69				NSD												
	70				SPT	60	10 30	56	66								S25-69.0-70.5 (69.0' to 70.5')

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,037,176.00 East 6,665,778.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-115B
Sheet 4 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70	(SP)g	60.4 to 73.5' Poorly Graded SAND with Gravel, (SP)g: About 75% fine to medium sand; about 20% fine, subrounded gravel; about 5% nonplastic fines; very dense, dark olive gray, wet; no reaction with HCl; some flat gravels. *(Continued)*		SPT	60	26	56	66								
	71																
	72				SPT	67	11 30 42	72	85								**S26-71.5-73.0 (71.5' to 73.0')**
	73																
-30	74	SP	73.5 to 77.5' Poorly Graded SAND, (SP): About 90% fine to coarse sand; about 5% nonplastic fines; about 5% fine, subrounded gravel; medium dense, dark gray, wet. At 74.2', 0.25" thick band of iron oxide staining. At 74.5', 0.25" thick band of iron oxide staining. At 74.6', 1" thick band of iron oxide staining.		SPT	53	0										Unreliable blow counts (11/0/67). Inside auger.
	75																**S27-74.0-75.5 (74.0' to 75.5')**
	76																
	77				SPT	87	3 12 16	28	33								**S28-76.5-78.0 (76.5' to 78.0')**
	78	SP-SM	77.5 to 79.3' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium sand; about 10% nonplastic fines; medium dense, olive, wet.														
-35	79																
	80	CH	79.3 to 83.5' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, brown, moist. From 79.9', Dark bluish gray. 81.5' Medium plasticity fines with medium toughness.		SPT	100	5 8 11	19	22	3.7P 3.0P							**S29-79.0-80.5 (79.0' to 80.5')**
	81																
	82			Auger	SPT	60	7 10 13	23	27	3.8P							**S30-81.5-83 (81.5' to 83.0')**
	83																
-40	84	ML	83.5 to 86.0' SILT, (ML): About 90% low plasticity fines with medium dry strength, slow dilatancy, low toughness; about 10% fine sand; very stiff, dark bluish gray, moist.		SPT	93	7 14 20	34	40	3.7P							**S31-84.0-85.5 (84.0' to 85.5')**
	85																Clay plugged holes on NWJ rod
	86																
	87	SM	86.0 to 91.0' SILTY SAND, (SM): About 85% fine sand; about 15% nonplastic fines; dense, dark bluish gray, moist. From 86.7', Interbedded with Sandy Silt, s(ML).		SPT	100	12 23 24	47	56								**S32-86.5-88 (86.5' to 88.0')**
	88																
-45	89				SPT	73	8 27 49	76	90	3.1P					50		**S33-89.0-90.1 (89.0' to 90.1')**
	90																
	91																
	92	SP	91.0 to 93.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; dense, dark bluish gray, wet; no reaction with HCl; trace medium sand.		SPT	53	5 12 25	37	44								**S34-91.5-93 (91.5' to 93.0')**
	93																
-50	94	CL	*Description on next page.*		SPT	100	7 12	28	33	3.2P			37	16			**S35-94.0-95.5 (94.0' to 95.5')**
	95																

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,037,176.00 East 6,665,778.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-115B
Sheet 5 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95		93.5 to 99.0' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, dark bluish gray, moist; no reaction with HCl. *(Continued)*		SPT	100	16	28	33				37	16			
	96																
	97	CL			SPT	100	12 21 25	46	54								S36-96.5-98 (96.5' to 98.0')
-55	98																
	99		99.0 to 101.9' SANDY LEAN CLAY, s(CL): About 60% low plasticity fines; about 40% fine sand; dark bluish gray, moist.	Auger													
	100	s(CL)			SPT	80	13 18 18	36	43								S37-99.0-100.5 (99.0' to 100.5')
	101																
	102																S38-101.5-103.0 (101.5' to 103.0')
	103	SP	101.9 to 103.0' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% low plasticity fines; dense, dark bluish gray, wet; no reaction with HCl.		SPT	80	16 21 20	41	49								
-60	104		Tremie-grouted with 95% cement, 5% bentonite by weight														Total Depth of 103 feet on 11/6/2020 at 1510
	105																
	106																
	107																
	108																
-65	109																
	110																
	111																
	112																
	113																
-70	114																
	115																
	116																
	117																
	118																
-75	119																
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,035,456.00 East 6,665,785.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-116B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/19/20 — DATE COMPLETED 10/20/20	GROUND ELEVATION 22.50 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Poese Fuapau — HELPER'S NAME Murad Rashid	TOTAL DEPTH OF FILL
DRILLING METHOD 0 - 5 ft: HA, 5 - 61.5 ft: HSA	DRILL RIG MAKE AND MODEL CME 95	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER 8" Hollow Stem Auger	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Soil Core, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 85%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 17.1 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		RECENT ALLUVIUM, (Qal) 0.0 to 61.5'														Hand auger to 5 feet
	1																
20	2	s(CL)	0.0 to 5.0' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines; about 30% fine sand; dark brown, dry.	Hand Auger	CUTTINGS	100											
	3		From 3.5', Decrease in sand content.														
	4																
	5		5.0 to 9.7' LEAN CLAY, (CL): About 90% medium plasticity fines with no dilatancy, medium toughness; about 10% fine sand; hard, dark brown, dry; no reaction with HCl.		SPT	73	3 3 5	8	11	4.5P 2.0P							S1-5.0-6.5 (5.0' to 6.1')
	6																
	7	CL	From 5.7', Stiff to very stiff.			100				2.0P			48	26	88		Box 1 C1-6.5-7.5 (6.5' to 7.5') At 6.5' [Lab] LEAN CLAY (CL)
15	8		From 8.0', Hard.		SHELBY	100						20	44	23	92		500 psi down pressure T1-7.5-9.5 (7.5' to 9.5') At 7.5' [Lab] LEAN CLAY (CL)
	9									4.5P							
	10		9.7 to 12.5' FAT CLAY, (CH): About 90% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 10% fine sand; very stiff, dark brown, dry.		SPT	80	1 3 4	7	10	1.9P		25	52	31	89		S2-10.0-11.5 (10.0' to 11.2') At 10' [Lab] FAT CLAY (CH)
	11	CH															
	12																
10	13		12.5 to 14.7' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; very stiff, dark brown, dry; no reaction with HCl.	Auger	SHELBY	100						30	47	22	97	DS	T2-12.5-14.5 (12.5' to 14.5') At 12.5' [Lab] LEAN CLAY (CL)
	14	CL															
	15		14.7 to 17.1' FAT CLAY with Sand, (CH)s: About 80% high plasticity fines with high toughness; about 20% fine sand; brown, dry.														
	16	(CH)s			SPT	87	3 6 9	15	21	4.5P							300 psi down pressure S3-15.0-16.5 (15.0' to 16.3')
	17																Box 1 C4-16.5-20.0 (16.5' to 19.4')
5	18	(SC)g	17.1 to 19.7' CLAYEY SAND with Gravel, (SC)g: About 45% medium to coarse sand; about 40% fine, angular gravel; about 15% medium plasticity fines; dense, brown, wet; weak to strong reaction with HCl; HCL reaction strong on whitish material cemented by CaCO3.		DCORE	83									16		
	19																
	20	s(CL)															

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,035,456.00 East 6,665,785.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-116B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		19.7 to 24.5' SANDY LEAN CLAY, s(CL): About 65% low plasticity fines with low toughness; about 35% fine sand; very stiff, brown, wet; no reaction with HCl. *(Continued)*		SPT	73	9 12 20	32	45								S4-20.0-21.5 (20.0' to 21.1')
	21																
	22	s(CL)	From 21.9 to 22.3', About 40% fine, angular gravel; 0.4-foot layer of poorly graded medium to coarse sand with clay and gravel.		DCORE												Box 1 C5-21.5-25.0 (21.5' to 24.4')
0	23					83											
	24		From 23.6 to 24.0', About 40% fine, angular gravel; 0.4-foot layer of poorly graded medium to coarse sand with clay and gravel.														
	25	(SP-SC)g	24.5 to 25.0' Poorly Graded SAND with Clay and Gravel, (SP-SC)g: About 40% medium to coarse sand; about 40% fine, angular gravel; about 10% medium plasticity fines.		SPT	100	1 3 4	7	10						81		S5-25.0-26.5 (25.0' to 26.5')
	26	(CL)s															
	27		25.0 to 26.5' LEAN CLAY with Sand, (CL)s: About 80% low plasticity fines with medium dry strength, no dilatancy, low toughness; about 20% fine sand; very stiff, brown, wet; no reaction with HCl.		DCORE								29	11	64		Box 1 C6-26.5-30.0 (26.5' to 27.7') At 26.5' [Lab] SANDY LEAN CLAY (CL)
-5	28	s(CL)	26.5 to 30.7' SANDY LEAN CLAY, s(CL): About 65% low plasticity fines with low toughness; about 35% fine sand; very stiff, brown, wet; no reaction with HCl.			34											
	29																
	30				SPT	100	4 7 3	10	14								S6-30.0-31.5 (30.0' to 31.5')
	31		30.7 to 34.0' SILTY SAND, (SM): About 80% fine sand; about 20% nonplastic fines; medium dense, black, wet; no reaction with HCl.	Auger													
	32	SM			DCORE												Box 1 C7-31.5-35.0 (31.5' to 32.5')
-10	33					29											
	34		34.0 to 37.7' Poorly Graded SAND, (SP): About 95% fine sand; about 5% low plasticity fines; loose, dark gray, wet.														
	35				SPT	73	1 2 4	6	9								S7-35.0-36.5 (35.0' to 36.1')
	36	SP															
	37		From 36.7 to 37.1', Trace coarse sand and trace fine gravel.		DCORE												Box 2 C8-36.5-40.0 (36.5' to 37.9')
-15	38		37.7 to 40.1' SILT, (ML): About 90% nonplastic fines; about 10% fine sand; very stiff, brown.			40				3.8P							
	39	ML															
	40		40.1 to 42.5' Well-Graded SAND with Silt, (SP-SM): About 80% fine to coarse sand; about 10% nonplastic fines; about 10% fine to coarse, subrounded to subangular gravel, maximum size 1 inches; medium dense, dark gray, wet; no reaction with HCl; occasional 1" diameter brown silt lenses.		SPT	100	5 10 17	27	38						10		S8-40.0-41.5 (40.0' to 41.5')
	41	SP-SM															
	42				DCORE												Box 2 C9-41.5-45.0 (41.5' to 43.3')
-20	43		42.5 to 47.5' Poorly Graded SAND with Silt and Gravel, (SP-SM)g: About 50% fine to coarse sand; about 40% fine to coarse, subrounded to subangular gravel; about 10% nonplastic fines; very dense, dark gray, wet; no reaction with HCl.			51											Severe heaving sands. Driller poured water down the augers, which controlled the heaving allowed continued augering.
	44	(SP-SM)g															
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,035,456.00 East 6,665,785.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-116B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45	(SP-SM)g	From 42.9 to 43.1', Moderate cementation. 42.5 to 47.5' Poorly Graded SAND with Silt and Gravel, (SP-SM)g: About 50% fine to coarse sand; about 40% fine to coarse, subrounded to subangular gravel; about 10% nonplastic fines; very dense, dark gray, wet; no reaction with HCl. *(Continued)*		SPT	100	6 21 44	65	92								**S9-45.0-46.5 (45.0' to 46.5')**
	46																
	47																Heaving sands continued. Cable unspooled and was repaired. Obstruction occurred in auger and was cleared. Augering continued but with SPTs performed every 2.5 feet instead of every 5 feet with dry core between.
-25	48	(CH)s	From 45.0', Variable gravel content. From 46.3 to 46.5', Moderate cementation.		SPT	60	5 12 14	26	37	4.7P							
	49		47.5 to 50.0' FAT CLAY with Sand, (CH)s: About 85% high plasticity fines with high toughness; about 15% fine sand; hard, olive, moist; moderate cementation; no reaction with HCl; occasional irom oxide staining, trace fine to coarse gravel.														**S10-47.5-49.0 (47.5' to 48.4')**
	50				SPT	53	4 10 14	24	34	3.5P							**S11-50.0-51.5 (50.0' to 50.8')**
	51	CH	50.0 to 52.5' FAT CLAY, (CH): About 95% high plasticity fines; about 5% fine sand; hard, olive, moist; no reaction with HCl.							4.1P							
	52																
-30	53	ML	52.5 to 55.0' SILT, (ML): About 90% nonplastic fines with medium dry strength, slow dilatancy, low toughness; about 10% fine sand; medium stiff, olive, moist; no reaction with HCl.	Auger	SPT	80	8 14 15	29	41	.7P 4.7P		32	48	20	89		**S12-52.5-54.0 (52.5' to 53.7')** **At 52.5' [Lab] SILT (ML)**
	54																
	55	(CH)s	55.0 to 57.0' FAT CLAY with Sand, (CH)s: About 85% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 15% fine sand; very stiff, olive, moist; no reaction with HCl.		SPT	100	11 14 15	29	41	2.4P 2.1P					80		**S13-55.0-56.5 (55.0' to 56.5')**
	56																
	57	SP	57.0 to 58.0' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% nonplastic fines; brown, wet; no reaction with HCl.														**S14A-57.5-58.0 (57.5' to 58.0')**
-35	58	SM	58.0 to 58.8' SILTY SAND, (SM): About 75% fine sand; about 25% nonplastic fines; medium dense, dark bluish gray, wet; no reaction with HCl.		SPT	100	4 7 11	18	26								**S14B-58.0-58.8 (58.0' to 58.8')**
	59	CL	58.8 to 59.5' LEAN CLAY, (CL): About 90% medium plasticity fines; about 10% fine sand; dark bluish gray, moist; no reaction with HCl.														**S14C-58.8-59.0 (58.8' to 59.0')**
	60	(CL)s	59.5 to 61.5' LEAN CLAY with Sand, (CL)s: About 85% nonplastic fines; about 15% fine sand; stiff, dark bluish gray, moist; no reaction with HCl.		SPT	100	7 10 17	27	38	1.8P			49	24	87		**S15-60.0-61.5 (60.0' to 61.5')** **At 60.3' [Lab] LEAN CLAY (CL)**
	61																
-40	62		Tremie-grouted with 95% cement, 5% bentonite by weight														Drilling ended on 10/19/2020 at 16:15. Total depth of hole 61.5'
	63																
	64																
	65																
	66																
	67																
-45	68																
	69																
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,034,097.00 East 6,665,834.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-118B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/30/20 — DATE COMPLETED 10/30/20	GROUND ELEVATION 21.20 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Eric Ramey — HELPER'S NAME Patrick Siegler	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 61.5 ft: HSA	DRILL RIG MAKE AND MODEL CME 95	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER NWJ	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 76%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 12.0 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
20	0		RECENT ALLUVIUM, (Qal) 0.0 to 61.5'														
	1	(CH)s	0.0 to 3.5' FAT CLAY with Sand, (CH)s: About 80% high plasticity fines; about 20% fine sand; olive, dry.	Hand Auger													Hand auger 0.0-5.0' bgs
	2																
	3																
	4		3.5 to 17.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, olive, moist.														
	5																
15	6																
	7																
	8		From 8.0', Occasional white inclusions with weak HCL reaction.		SPT	100	3 5 8	13	16	2.7P			55	37	98		**S1-7.5-9.0 (7.5' to 9.0')** **At 7.5' [Lab] FAT CLAY (CH)**
	9																
	10	CH			SHELBY	55						24	54	34	98	UW CN UC	**T1-10.0-11.1 (10.0' to 11.1')** **At 10' [Lab] FAT CLAY (CH)** 500 psi downpressure; tube slipped off NWJ rod, so drilled around tube to retrieve.
10	11									2.9P							
	12																
	13			Auger	SPT	100	2 6 9	15	19	2.7P							**S2-12.5-14.0 (12.5' to 14.0')**
	14																
	15		From 15.0 to 15.3', Yellowish brown, cemented by calcium carbonate. From 15.3', About 90% high plasticity fines; about 10% fine sand.		SPT	100	5 12 19	31	39	3.5P							**S3-15.0-16.5 (15.0' to 16.5')**
5	16																
	17		17.0 to 19.5' LEAN CLAY with Sand, (CL)s: About 80% medium plasticity fines; about 20% fine sand; hard, yellowish brown, moist; strong reaction with HCl.														
	18	(CL)s			SPT	100	12 20 22	42	53	4.8P							**S4-17.5-19.0 (17.5' to 19.0')**
	19																
	20	s(CL)	*Description on next page.*														

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,034,097.00 East 6,665,834.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-118B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
0	20	s(CL)	19.5 to 22.0' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines; about 30% fine sand; hard, reddish brown, moist. *(Continued)*	Auger	SPT	87	6 9 11	20	25	4.8P							**S5-20.0-21.3 (20.0' to 21.3')**
	21																
	22	CL	22.0 to 30.3' LEAN CLAY, (CL): About 90% low plasticity fines; about 10% fine sand; soft to medium stiff, brown, wet.		SPT	100	0 2 3	5	6	0.5P 0.5P							**S6-22.5-24.0 (22.5' to 24.0')**
	23																
	24																
	25		From 25.0', Medium stiff, weak reaction with HCl; occasional 1-inch thick sections cemented by calcium carbonate.		SPT	87	3 5 6	11	14	1.5P 1.2P							**S7-25.0-26.3 (25.0' to 26.3')**
-5	26																
	27																
	28				SHELBY	100											**T2-27.5-29.5 (27.5' to 29.5')** 500 psi downpressure soft at top, hard at bottom
	29									4.8P							
	30		From 30.0', Transition from clay to silt.														
-10	31	ML	30.3 to 37.9' SILT, (ML): About 90% nonplastic fines with medium dry strength, rapid dilatancy, low toughness; about 10% fine sand; reddish brown, wet; no reaction with HCl.		SPT	100	3 5 8	13	16	1P		32	8	79		**S8-30.0-31.5 (30.0' to 31.5')** **At 30' [Lab] SILT with SAND (ML)**
	32																
	33		From 32.5', Low plasticity fines; soft, interbedded silt/elastic silt/lean clay, 0.5-inch layers of high fine sand content.		SPT	100	3 6 10	16	20	0.6P							**S9-32.5-34.0 (32.5' to 34.0')**
	34																
	35				SPT	100	4 12 16	28	35	0.8P							**S10-35.0-36.5 (35.0' to 36.5')**
-15	36																
	37																
	38	(SW-SM)g	37.9 to 45.6' Poorly Graded SAND with Silt and Gravel, (SW-SM)g: About 70% fine to coarse sand; about 20% fine to coarse, subangular to subrounded, hard gravel, maximum size 1.0 inches; about 10% nonplastic fines; dark gray, wet; no reaction with HCl.		SPT	60	14 50/6										**S11-37.5-38.4 (37.5' to 38.4')** **At 39' SPT Refusal**
	39																
-20	40				SPT	87	24 39 31	70	89						7		**S12-40.0-41.3 (40.0' to 41.3')**
	41																
	42																
	43				SPT	87	5 17 34	51	65								**S13-42.5-44.0 (42.5' to 43.8')**
	44		At 43.6',														Driller poured water down inside of auger.
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,034,097.00 East 6,665,834.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-118B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45	(SW-SM)g															
		CL	45.6 to 49.5' LEAN CLAY, (CL): About 95% medium plasticity fines with high to very high dry strength, no dilatancy, high toughness; about 5% fine sand; stiff to very stiff, olive, moist; no reaction with HCl; occasional 1-inch layers with dark brown organic material, no organic odor.		SPT	67	5 6 5	11	14								S14A-45.0-45.6 (45.0' to 45.6') S14B-45.6-46.0 (45.6' to 46.0')
-25	46																
	47																
	48				SPT	100	8 11 12	23	29	2.3P 3.0P							S15-47.5-49.0 (47.5' to 49.0')
	49																
	50	ML	49.5 to 51.0' SILT, (ML): About 90% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 10% fine sand; soft, brown, wet.		SPT	100	4 6 9	15	19	0.6P 2.6P							S16-50.0-51.5 (50.0' to 51.5')
-30	51	CL	51.0 to 52.0' LEAN CLAY, (CL): About 95% medium plasticity fines with high to very high dry strength, no dilatancy, high toughness; about 5% fine sand; stiff to very stiff, olive, moist.														
	52	ML	52.0 to 53.2' SILT, (ML): About 90% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 10% fine sand; very soft, brown, wet.		SPT	100	1 8 10	18	23	0.2P							S17A-52.5-53.2 (52.5' to 53.2') S17B-53.2-54.0 (53.2' to 54.0')
	53	SC															
	54	s(CL)	53.2 to 53.9' CLAYEY SAND, (SC): About 75% fine sand; about 25% low plasticity fines; medium dense, very dark greenish gray, wet.														
	55		53.9 to 56.2' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines with medium dry strength, no dilatancy, medium toughness; about 30% fine sand; medium stiff, very dark greenish gray, wet.		SPT	100	2 3 8	11	14	0.7P					66		S18-55.0-56.5 (55.0' to 56.5')
-35	56	SC															
	57	CL	56.2 to 57.5' CLAYEY SAND, (SC): About 75% fine sand; about 25% low plasticity fines; medium dense, very dark greenish gray, wet.		SPT	100	3 7 13	20	25	0.7P							S19A-57.5-58.3 (57.5' to 58.3') S19B-58.3-59.0 (58.3' to 59.0')
	58	SC															
	59		57.5 to 58.3' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand.														
	60	SP	58.3 to 60.0' CLAYEY SAND, (SC): About 75% fine sand; about 25% low plasticity fines; medium dense, very dark greenish gray, wet.		SPT	100	4 8 11	19	24								S20A-60.0-60.9 (60.0' to 60.9') S20B-60.9-61.5 (60.9' to 61.5')
-40	61	s(CL)															
	62		60.0 to 60.9' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% low plasticity fines; medium dense, very dark greenish gray, wet.														
	63		60.9 to 61.5' SANDY LEAN CLAY, s(CL): About 70% low plasticity fines with low toughness; about 30% fine sand; very dark greenish gray, wet.														
	64																
	65		Tremie-grouted with 95% cement, 5% bentonite by weight														
-45	66																
	67																
	68																
	69																
	70																

Total depth of 61.5' reached 10/30/2020

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,034,054.00 East 6,665,949.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-119B
Sheet 1 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 11/9/20 — DATE COMPLETED 11/19/20	GROUND ELEVATION 44.20 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 100.0 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Gary Whitley — HELPER'S NAME Robert Allen	TOTAL DEPTH OF FILL 27 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 100 ft: HSA	DRILL RIG MAKE AND MODEL CME 85	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER NWJ	FIELD LOGGER S. Sochar, C. Silva
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby, Mod-Cal	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 71%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 39.0 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		LEVEE FILL, 0.0 to 28.5'														
	1		0.0 to 0.5' Gravel Road Base.	Hand Auger													Hand auger 0.0-5.0' bgs
	2	s(CL)	0.5 to 4.9' SANDY LEAN CLAY, s(CL): About 65% low plasticity fines; about 35% fine sand; brown, dry.														
40	3																
	4																
	5		4.9 to 24.1' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, brown, dry; no reaction with HCl; occasional white inclusions, 1/8-inch maximum dimension, strong HCl reaction; some blackish material like charcoal, no organic odor.		SPT	13	2 2 4	6	7								S1-5.0-5.2 (5.0' to 5.2')
	6																
	7				SPT	73	1 3 4	7	8	2.4P							S2-7.0-8.1 (7.0' to 8.1')
	8																
35	9		From 9.0', Stiff.		SPT	93	2 3 5	8	9	1.5P		23	50	31	93		S3-9.0-10.4 (9.0' to 10.4') At 9' [Lab] FAT CLAY (CH)
	10																
	11																
	12	CH		Auger	SPT	80	2 4 6	10	12	1.3P							S4-11.5-12.7 (11.5' to 12.7')
30	13																
	14																
	15				SHELBY	65				1.7P			58	33	94	UC	T1-14.0-15.3 (14.0' to 15.3') At 14' [Lab] FAT CLAY (CH) 300 psi downpressure; one of four tube bolts missing.
	16																
	17		From 16.5', Very stiff.		SPT	100	2 5 8	13	15	3.3P 3.2P							S5-16.5-18.0 (16.5' to 18.0')
	18																
25	19																
	20				SPT	100	3 4	11	13	2.7P							S6-19.0-20.5 (19.0' to 20.5')

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,034,054.00 East 6,665,949.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-119B
Sheet 2 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		4.9 to 24.1' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, brown, dry; no reaction with HCl; occasional white inclusions, 1/8-inch maximum dimension, strong HCl reaction; some blackish material like charcoal, no organic odor. *(Continued)*		SPT	100	7	11	13	2.1P							
	21		From 20.1', Dark brown.														
	22	CH			SPT	93	2 5 8	13	15	2.9P 2.5P		26	53	30			S7-21.5-22.9 (21.5' to 22.9')
	23																
20	24		24.1 to 28.5' LEAN CLAY, (CL): About 95% high plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; stiff, very dark bluish gray, moist; earthy odor; no reaction with HCl.														
	25				SPT	100	0 3 5	8	9	1.3P							S8-24.0-25.5 (24.0' to 25.5')
	26	CL	24.2 to 24.5', Charcoal-like substance fills vertical column half the sampler diameter width.														
	27				SPT	93	1 4 9	13	15	2.7P 2.4P		34				PD	S9-26.5-27.9 (26.5' to 27.9')
	28																
	29		RECENT ALLUVIUM, (Qal) 28.5 to 100.0'														
15	30		28.5 to 39.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, dark brown, moist; no reaction with HCl; strong HCl reaction on occasional 1/8-inch white inclusions of calcium carbonate.		SPT	100	1 4 9	13	15	3.2P 2.9P							S10-29.0-30.5 (29.0' to 30.5')
	31																
	32		From 31.5', Very stiff to hard.	Auger	SPT	100	4 10 14	24	28	3.9P 4.6P		22	54	33	97		S11-31.5-33.0 (31.5' to 33.0') At 31.5' [Lab] FAT CLAY (CH)
	33	CH															
10	34		34.0' Brown.		SPT	100	4 10 16	26	31	4.1P 4.1P							S12-34.0-35.5 (34.0' to 35.5')
	35																
	36																
	37				SPT	100	5 9 17	26	31	4.6P 4.6P		19				PD	S13-36.5-38.0 (36.5' to 38.0')
	38																
	39																Drilling ended 11/9/2020 Drilling began 11/17/2020
5	40		39.0 to 44.2' SILT with Sand About 85% nonplastic fines with low dry strength, slow dilatancy, low toughness; about 15% fine sand; hard, brown (7.5YR 4/3), moist; no reaction with HCl.		MCAL	100	16 31 39			4.5P 4.5P 4.5P							M1A-39.0-39.5 (39.0' to 39.5') M1B-39.5-40.0 (39.5' to 40.0') M1C-40.0-40.5 (40.0' to 40.5')
	41																
	42					0											Attempted Shelby tube from 41.5' to 43.5; only pushed 0.7', no recovery.
	43				NSD												
0	44				SPT	100	16 21 39	60	71	4.5P 4.5P 4.5P		26	32	6	74		S14-43.5-45.0 (43.5' to 45.0') At 43.5' [Lab] SILT with SAND (ML)
	45	s(ML)	*Description on next page.*														

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,034,054.00 East 6,665,949.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-119B
Sheet 3 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45	s(ML)	44.2 to 46.3' SANDY SILT, s(ML): About 60% nonplastic fines with low dry strength, no dilatancy, low toughness; about 40% fine to medium, subangular to subrounded sand; hard, brown (7.5YR 4/3), moist; no reaction with HCl. *(Continued)*	Auger	SPT	100	6 10 12	22	26	2.6P 3.4P 3.6P							S15-46.0-47.5 (46.0' to 47.5')
	46																
	47	(ML)s	46.3 to 48.5' SILT with Sand, (ML)s: About 85% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 15% fine sand; very stiff, brown (7.5YR 4/3), moist; no reaction with HCl.														
	48																
-5	49	s(ML)	48.5 to 49.1' SILT About 95% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 5% fine sand; very stiff, brown (7.5YR 4/3), moist; no reaction with HCl.		SPT	100	6 16 30	46	54	2.3P 4.5P 4.5P							S16-48.5-50.0 (48.5' to 50.0')
	50																
	51		49.1 to 51.2' SANDY SILT, s(ML): About 60% nonplastic fines with low dry strength, no dilatancy, low toughness; about 40% fine to medium, subangular to subrounded sand; hard, brown (7.5YR 4/3), moist; no reaction with HCl. At 51.0', 0.2' lens of silty sand.		SPT	100	8 16 24	40	47	4.3P 3.8P 4.5P							S17-51.0-52.5 (51.0' to 52.5')
	52																
	53																
-10	54		51.2 to 54.9' SILT About 95% low plasticity fines with low dry strength, slow dilatancy, low toughness; about 5% fine sand; very stiff, brown (7.5YR 4/3), moist; no reaction with HCl. From 53.7', Grades to saturated.		SPT	100	7 47 50/2"			2.4P 4.5P 4.5P					86		S18-53.5-54.7 (53.5' to 54.7')
	55	SW-SM															
	56		54.9 to 56.2' Well-Graded SAND with Silt, (SW-SM): About 90% fine to coarse, subangular to subrounded sand; about 10% nonplastic fines; brown (7.5YR 4/3), wet; no reaction with HCl; trace subrounded to subangular fine gravel.		SPT	100	2 25 50/5"										S19-56.0-57.4 (56.0' to 57.4')
	57	SP															
	58	(GW)g	56.2 to 57.1' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; very dense, dark grayish brown (10YR 4/2), wet; no reaction with HCl.															
-15	59				SPT	100	4 9 18	27	32								S20-58.5-60.0 (58.5' to 60.0')
	60	g(ML)	57.1 to 59.7' Well-Graded SAND with Gravel, (GW)g: About 75% fine to coarse, subangular to subrounded sand; about 20% fine, subangular to subrounded gravel; about 5% nonplastic fines; very dense, very dark gray (7.5YR 3/1), wet; no reaction with HCl. From 58.5', Medium dense.														
	61	SW-SM															
	62				SPT	100	7 17 40	57	67								S21-61.0-62.5 (61.0' to 62.5')
	63	(GW)g	59.7 to 60.1' GRAVELLY CLAYEY SILT, g(ML): About 50% nonplastic fines with low dry strength, slow dilatancy, low toughness; about 40% fine to coarse, subangular gravel, maximum size 1.0 inches; about 10% fine to medium, subangular to subrounded sand; brown (7.5YR 4/3), wet; no reaction with HCl.														
-20	64	SM			SPT	100	8 37 50/5"										S22-63.5-64.9 (63.5' to 64.9')
	65		60.1 to 61.5' Well-Graded SAND with Silt, (SW-SM): About 90% fine to coarse, subangular to subrounded sand; about 10% nonplastic fines; brown (7.5YR 4/3), wet; no reaction with HCl; trace subrounded to subangular fine gravel.														
	66																
	67	SP			SPT	100	8 33 35	68	80								S23-66.0-67.5 (66.0' to 67.5')
	68		61.5 to 63.5' Well-Graded SAND with Gravel, (GW)g: About 75% fine to coarse, subangular to subrounded sand; about 20% fine, subangular to subrounded gravel; about 5% nonplastic fines; very dense, very dark gray (7.5YR 3/1), wet; no reaction with HCl.														
-25	69		*Description on next page.*		SPT	100	4 13 21	34	40								S24-68.5-70.0 (68.5' to 70.0')
	70																

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,034,054.00 East 6,665,949.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-119B
Sheet 4 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	70	SP	63.5 to 64.3' SILTY SAND, (SM): About 65% fine sand; about 35% nonplastic fines; brown (7.5YR 4/3), wet; no reaction with HCl.														
	71		From 69.6', About 95% fine sand; about 5% nonplastic fines; dense, trace subrounded to subangular fine gravel.	Auger	SPT	100	16 14 18	32	38								S25-71.0-72.5 (71.0' to 72.5')
	72		64.3 to 72.2' Poorly Graded SAND, (SP): About 95% fine to medium, subangular to subrounded sand; about 5% nonplastic fines; very dense, dark grayish brown (10YR 4/2), wet; no reaction with HCl. *(Continued)*														
-30	73																
	74				SPT	100	3 5 10	15	18			35	41	14			S26-73.5-75.0 (73.5' to 75.0')
	75		72.2 to 81.7' SILT, (ML): About 95% nonplastic fines with low dry strength, slow dilatancy, low toughness; about 5% fine sand; very stiff, brown (7.5YR 4/3), moist; no reaction with HCl.														
	76																
	77	ML			SPT	100	8 12 13	25	30	2.7P 3.3P 3.9P							S27-76.0-77.5 (76.0' to 77.5')
	78																
-35	79		From 79.2', Very dark gray (7.5YR 3/1), gradational change.		SPT	100	8 8 11	19	22								S28-78.5-80.0 (78.5' to 80.0')
	80																
	81																
	82	SP	81.7 to 91.0' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; medium dense, very dark gray (7.5YR 3/1), wet; no reaction with HCl.		SPT	100	10 23 29	52	62								S29-81.0-82.5 (81.0' to 82.5')
	83																
-40	84				SPT	100	5 8 19	27	32								S30-83.5-85.0 (83.5' to 85.0')
	85																
	86		From 86.0', Dense.														
	87				SPT	100	3 12 22	34	40								S31-86.0-87.5 (86.0' to 87.5')
	88																
-45	89				SPT	100	11 17 21	38	45						5		S32-88.5-90.0 (88.5' to 90.0')
	90																
	91	CH	91.0 to 100.0' FAT CLAY, (CH): About 100% high plasticity fines with high dry strength, no dilatancy, high toughness; hard, bluish gray, moist; no reaction with HCl.		SPT	100	1 7 11	18	21	4.2P 4.4P 4.5P							S33-91.0-92.5 (91.0' to 92.5')
	92																
	93																
-50	94				SPT	100	7 14 18	32	38	4.3P 4.4P 4.5P		34	54	26			S34-93.5-95.0 (93.5' to 95.0')
	95																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Crest
Coordinates: North 2,034,054.00 East 6,665,949.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-119B
Sheet 5 of 5

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	95		91.0 to 100.0' FAT CLAY, (CH): About 100% high plasticity fines with high dry strength, no dilatancy, high toughness; hard, bluish gray, moist; no reaction with HCl. *(Continued)*														
	96			Auger	SPT	100	9	42	50	4.5P							S35-96.0-97.5 (96.0' to 97.5')
	97	CH					20			4.5P							
	98						22			4.5P							
-55	99				SPT	100	10	35	41	4.3P							S36-98.5-100.0 (98.5' to 100.0')
	100						17			4.5P							
							18			4.5P							
			Tremie-grouted with 95% cement, 5% bentonite by weight														Total depth of 100.0' reached at 15:55 hours on 11/17/2020.
	101																
	102																
	103																
-60	104																
	105																
	106																
	107																
	108																
-65	109																
	110																
	111																
	112																
	113																
-70	114																
	115																
	116																
	117																
	118																
-75	119																
	120																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Landside Toe
Coordinates: North 2,034,030.00 East 6,666,019.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-120B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/13/20 — DATE COMPLETED 10/14/20	GROUND ELEVATION 24.70 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 60.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Tyler Rouse — HELPER'S NAME Murad Rashid	TOTAL DEPTH OF FILL 2 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 60.5 ft: HSA	DRILL RIG MAKE AND MODEL CME 01-LAR02	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER X (0.0-50'), NWJ	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) DCore(2.5"), MCal(2"), Shelby(2.87"), SPT(1.375")	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 84%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 10.0 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		LEVEE FILL, 0.0 to 2.0'														
	1	SC	0.0 to 2.0' CLAYEY SAND, (SC): About 70% fine sand; about 30% low plasticity fines.														Hand auger 0.0-5.0' bgs.
	2																
	3	s(CL)	RECENT ALLUVIUM, (Qal) 2.0 to 60.5'														
	4																
20	5	(CH)s	2.0 to 4.5' SANDY LEAN CLAY, s(CL): About 65% low plasticity fines; about 35% fine sand. From 3.5', About 5% organics. 4.5 to 5.0' FAT CLAY with Sand, (CH)s: About 85% high plasticity fines; about 15% fine sand; dark brown, moist; no reaction with HCl.	Hand Auger	SPT	100	3 2 5	7	10	1.7P							S1-5.0-6.5 (5.0' to 6.5')
	6																
	7		5.0 to 19.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; stiff, dark brown, moist.							2.7P							Box 1-6.5-9.9 (6.5)
	8				DCORE	97				1.6P							
	9		At 7.0', Very stiff, strong reaction with HCl; occasional white, hard nodules.							1.7P		23	67	44	99		At 8.5' [Lab] FAT CLAY (CH)
15	10																
	11		From 11.0', Brown.		SHELBY	100						26	50	25	99	UW DS	T1-10.0-12.0 (10.0' to 12.0') At 10' [Lab] FAT CLAY (CH) 350 to 490 psi downpressure
	12	CH	From 12.0', About 90% fines; about 10% sand; medium stiff to stiff.							2.5P							Box 1-12.0-13.3 (12.0' to 13.3') At 12' [Lab] FAT CLAY (CH)
	13			Auger						1.3P							
	14		From 14.0', Very stiff, strong reaction with HCl; occasional white, hard nodules.		DCORE	77				0.7P		22	54	33	99		Box 2-13.3-14.3 (13.3' to 14.3')
10	15									3.0P							
	16				SPT	100	3 5 9	14	20	2.6P 3.0P					94		S2-15.0-16.5 (15.0' to 16.5')
	17																
	18				SHELBY	100											T2-17.5-19.0 (17.5' to 19.0') 395 to 550 psi downpressure
	19									3.2P							
5	20	(CL)s	*Description on next page.*			100											Box 2-19.0-20.0 (19.0' to 20.0')

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Landside Toe
Coordinates: North 2,034,030.00 East 6,666,019.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-120B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		19.0 to 24.0' LEAN CLAY with Sand, (CL)s: About 85% high plasticity fines; about 15% fine to medium sand; very stiff, brown, wet; no reaction with HCl. *(Continued)*	Auger	SPT	100	4 7 7	14	20				37	13	86		**S3-20.0-21.5 (20.0' to 21.5')** At 20' [Lab] LEAN CLAY (CL) Tagged to 20.0' bgs
	21																
	22	(CL)s	From 20.0', Medium stiff.							0.7P							**Box 2-21.5-22.5 (21.5' to 22.5')**
	23				DCORE	100											**Box 3-22.5-25.0 (22.5' to 25.0')**
	24		24.0 to 28.5' SANDY LEAN CLAY, s(CL): About 60% medium plasticity fines with medium dry strength, slow dilatancy, low toughness; about 40% sand; medium stiff, brown, wet; no reaction with HCl; occasional platey, coarse sand grains.														
0	25				SPT	100	2 4 3	7	10	0.5P							**S4-25.0-26.5 (25.0' to 26.5')**
	26	s(CL)															
	27				DCORE	100											**Box 3-26.5-29.0 (26.5' to 29.0')**
	28																
	29		28.5 to 31.0' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines; about 30% fine sand; medium stiff, brown, wet; no reaction with HCl.														Drilled to 30' bgs, pulled barrel out, tagged to 26.9' bgs. Sample fell out, driller said. Drilled to 32.5' to clean out.
-5	30	s(CL)															**Box 4-29.0-30.0 (29.0' to 30.0')**
	31		31.0 to 32.5' SILTY SAND, (SM): About 70% fine sand; about 30% nonplastic fines; loose, brown, wet; no reaction with HCl.		DCORE	100				0.5P							**Box 4-30.0-32.5 (30.0' to 32.5')** Sample likely slough.
	32	SM															
	33	s(ML)	32.5 to 34.0' SANDY SILT, s(ML): About 70% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 30% fine sand; brown, wet; no reaction with HCl.		SPT	100	3 5 4	9	13			36			69		**S5-32.5-34.0 (32.5' to 34.0')**
	34				DCORE	100											**Box 4-34.0-35.0 (34.0' to 35.0')**
-10	35		34.0 to 40.3' SILTY SAND, (SM): About 70% fine sand; about 30% nonplastic fines; loose, brown, wet; no reaction with HCl. From 35.0', Medium dense.		SPT	100	4 7 9	16	22								**S6-35.0-36.5 (35.0' to 36.5')**
	36		At 36.0', Two elongate pieces of fine gravel, maximum dimension 0.25-inches.														
	37	SM															**Box 5-36.5-38.1 (36.5' to 38.1')**
	38		From 37.6', About 65% sand; about 25% fines; about 10% fine to coarse gravel, maximum size 0.9 inches.		DCORE	46											
	39																
-15	40																Tagged to 40.0' bgs
	41		40.3 to 46.0' SILTY SAND with Gravel, (SM)g: About 55% fine sand; about 25% nonplastic fines; about 20% fine to coarse gravel, maximum size 1.0 inches; no reaction with HCl.		SPT	60	7 59 50/5										**S7-40.0-40.9 (40.0' to 40.9')** Last SPT with X rod Drilling ended 10/13/2020
	42		From 41.0', Olive brown.		DCORE	29											**Box 5-41.5-42.5 (41.5' to 42.5')** Drilling began 10/14/2020
	43	(SM)g															Tagged to 36' bgs; cleaned out to 40.0' bgs. Much of the sample fell out.
-20	44																
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Landside Toe
Coordinates: North 2,034,030.00 East 6,666,019.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-120B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45	(SM)g															**Box 5-45.0-46.1 (45.0' to 46.1')** Driller couldn't get SPT split-spoon down to 45' bgs. Cleaned out to 50' bgs.
	46		46.0 to 50.3' SILTY SAND, (SM): About 60% fine to medium sand; about 40% nonplastic fines; loose, olive brown, wet; no reaction with HCl.		DCORE	22						13			22		
	47	SM															
	48																"Really nasty sand," driller reported.
-25	49																
	50																**S8A-50.0-50.3 (50.0' to 50.3')**
	51	CL	50.3 to 51.3' LEAN CLAY, (CL): About 95% high plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% fine sand; stiff, light olive brown, moist; no reaction with HCl.		SPT	100	5 6 8	14	20	1.8P							**S8B-50.3-51.3 (50.3' to 51.3')** NWJ rod
	52	SP	At 51.0', Sub-horizontal rust colored band.	Auger													Because core barrel was preventing recovery, driller switched to doing SPTs every 2.5'.
	53		51.3 to 53.1' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% low plasticity fines; loose, brown, wet.		SPT	100	4 3 6	9	13	0.8P							**S9-52.5-54.0 (52.5' to 54.0')** NWJ rod
	54	(CL)s	53.1 to 55.9' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with low toughness; about 15% fine sand; no reaction with HCl.														
-30	55				SPT	100	4 11 13	24	34								**S10-55.0-56.5 (55.0' to 56.5')**
	56	SP-SC	55.9 to 57.2' Poorly Graded SAND with Clay, (SP-SC): About 90% fine sand; about 10% low plasticity fines; loose, dark gray, wet; no reaction with HCl.														
	57		57.2 to 60.5' Poorly Graded SAND, (SP): About 95% fine to medium sand; about 5% low plasticity fines; loose, dark greenish gray, wet; no reaction with HCl; trace coarse sand.		SPT	100	5 4 6	10	14			25			8		**S11-57.5-59.0 (57.5' to 59.0')**
	58																
	59	SP			MCAL	100	14 15 13										**Box 5-59.0-60.5 (59.0' to 60.5')**
-35	60																
	61		Tremie-grouted with 95% cement, 5% bentonite by weight														Total depth of 60.5' reached at 11:40 hours on 10/14/2020.
	62																
	63																
	64																
-40	65																
	66																
	67																
	68																
	69																
-45	70																

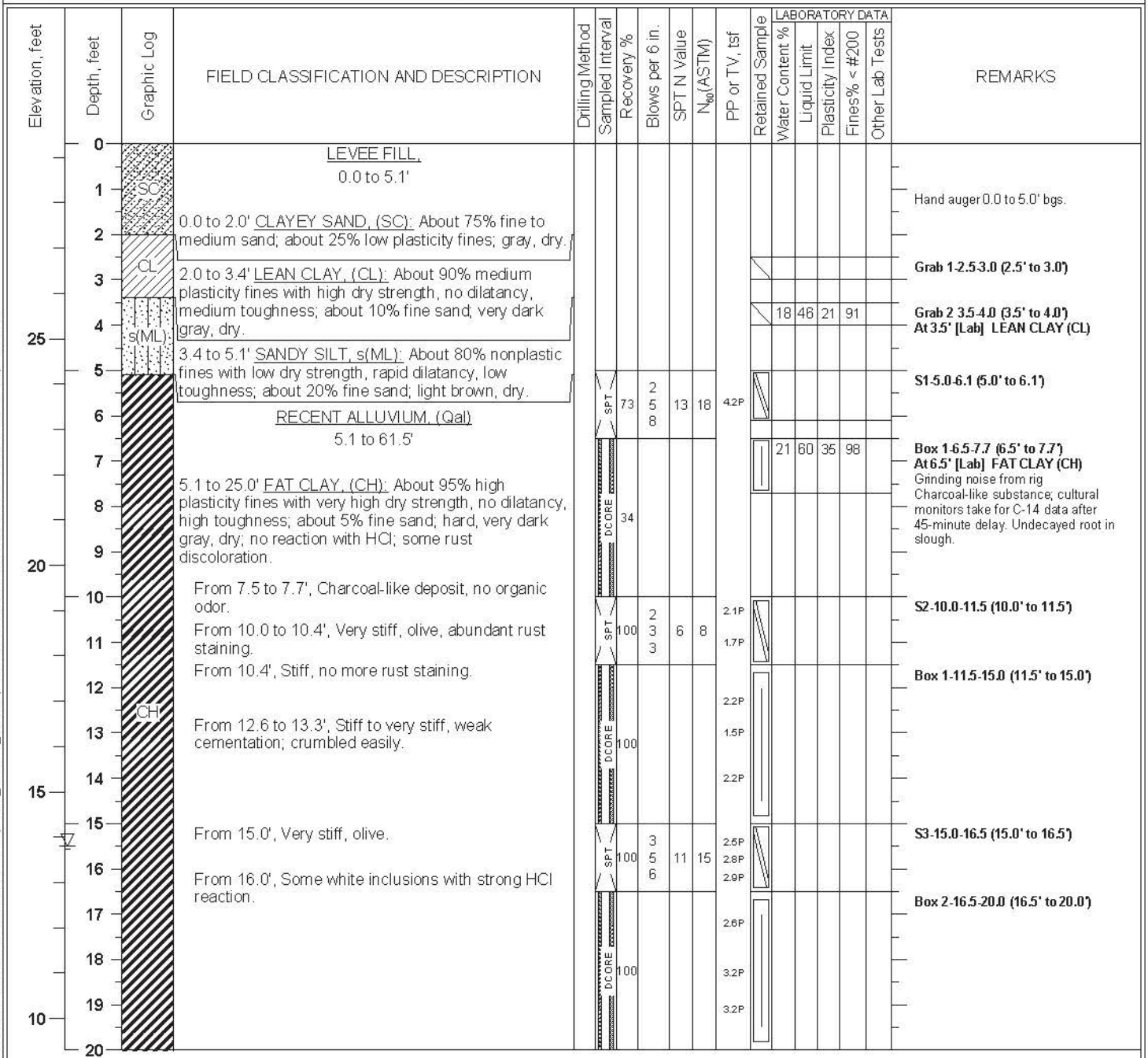
1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,032,350.00 East 6,665,971.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-121B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/16/20 — DATE COMPLETED 10/17/20	GROUND ELEVATION 29.30 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Tyler Rouse — HELPER'S NAME Murad Rashid	TOTAL DEPTH OF FILL 2 ft
DRILLING METHOD Hollow Stem Auger	DRILL RIG MAKE AND MODEL CME 01-LAR02	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER X (0.0-50'), NWJ	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Dry Core Barrel	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 84%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 15.5 ft — AFTER DRILLING (DATE-TIME)	



1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,032,350.00 East 6,665,971.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-121B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		RECENT ALLUVIUM, (Qal) 5.1 to 61.5'		SPT	100	5 7 9	16	22	2.8P 3.5P							**S4-20.0-21.5 (20.0' to 21.5')**
	21																
	22	CH	5.1 to 25.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, very dark gray, dry; no reaction with HCl; some rust discoloration. *(Continued)*														**Box 2-21.5-23.0 (21.5' to 23.0')**
	23				DCORE	100											
	24		From 20.0', Brown.							3.0P							**Box 3-23.0-25.0 (23.0' to 25.0')**
5			At 20.4', White inclusion, 1" maximum dimension, with strong HCl reaction.							2.9P							
	25				SPT	100	6 10 12	22	31	4.2P 3.2P 3.7P							**S5-25.0-26.5 (25.0' to 26.5')**
	26	(CL)s	25.0 to 27.0' LEAN CLAY with Sand, (CL)s: About 85% medium plasticity fines with high dry strength, medium toughness; about 15% fine sand; hard, yellowish brown, moist.														
	27				DCORE	100				3.8P		20	35	17	83		**Box 3-26.5-29.0 (26.5' to 29.0')** **At 26.5' [Lab] LEAN CLAY with SAND (CL)**
	28	CH	27.0 to 30.0' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, yellowish brown, moist; no odor; no reaction with HCl; numerous black organic-like inclusions.							3.9P							
0	29																**Box 4-29.0-30.0 (29.0' to 30.0')**
	30									3.8P							
	31	(CL)s	30.0 to 31.3' LEAN CLAY, (CL)s: About 80% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 20% fine sand; yellowish brown, wet; no reaction with HCl; gradational increase in sand content.		SPT	100	7 12 18	30	42								**S6-30.0-31.5 (30.0' to 31.5')**
	32		From 31.0', White streaks with strong HCl reaction.														**Box 4-31.5-34.7 (31.5' to 34.7')**
	33	CH	31.3 to 34.4' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff to hard, brown, wet; no reaction with HCl; occasional whitish inclusions with weak HCl reaction.		DCORE	91				3.2P 4.5P 3.2P							
-5	34																
	35		34.4 to 39.6' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; medium stiff to stiff, brown, wet; no reaction with HCl.		SPT	100	3 4 5	9	13	0.9P 1.5P							**S7-35.0-36.5 (35.0' to 36.5')**
	36																
	37	CL	From 37.3', Very stiff.		DCORE	97				3.0P							Drilling ended 10/16/2020. Drilling began 10/17/2020. **Box 5-36.5-39.9 (36.5' to 39.9')** Tagged to 36.5' bgs.
	38		From 38.2', Stiff.							1.6P							
-10	39		From 39.0', Medium stiff.							0.9P							Sand catcher on
	40		39.6 to 49.0' SILT with Sand, (ML)s: About 85% nonplastic fines with medium dry strength, rapid dilatancy, low toughness; about 15% fine sand; medium stiff, brown, wet; no reaction with HCl.		SPT	100	4 7 9	16	22								**S8-40.0-51.5 (40.0' to 41.5')**
	41																No sand catcher
	42	(ML)s			DCORE	60				0.5P		31	31	5	85		**Box 5-41.5-42.9 (41.5' to 42.9')** **At 41.5' [Lab] SILT with SAND (ML)**
	43		From 42.8', Very stiff, some half-inch layers of coarse sand and medium sand.							2.7P 2.1P							**Box 6-42.9-43.6 (42.9' to 43.6')**
-15	44																
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / Waterside Toe
Coordinates: North 2,032,350.00 East 6,665,971.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-121B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45		39.6 to 49.0' SILT with Sand, (ML)s: About 85% nonplastic fines with medium dry strength, rapid dilatancy, low toughness; about 15% fine sand; medium stiff, brown, wet; no reaction with HCl. *(Continued)*		SPT	93	5 11 13	24	34								**S9-45.0-46.4 (45.0' to 46.4')**
	46		From 45.0', Olive.														
	47	(ML)s	From 46.1 to 46.3', Abundant rust staining.		DCORE	57				1.1P							**Box 6-46.5-48.5 (46.5' to 48.5')**
	48		From 46.6 to 46.8', Abundant rust staining.														
-20	49		From 47.4 to 47.5', About 80% no to low plasticity fines; about 15% fine, rounded gravel; about 5% fine sand; dark rust staining.														
	50	(GP)s	49.0 to 50.8' Poorly Graded GRAVEL with Sand, (GP)s: About 65% fine, rounded to subrounded gravel, maximum size 1.2 inches; about 30% fine to coarse sand; about 5% nonplastic fines; dense, dark gray, wet; no reaction with HCl.		SPT	87	9 25 25	50	70						31		Tagged to 50.0' bgs. **S10A-50.0-50.8 (50.0' to 50.8')** **S10B-50.8-51.3 (50.8' to 51.3')**
	51																
	52	SM	50.8 to 54.0' SILTY SAND, (SM): About 65% fine sand; about 35% nonplastic fines; dense, olive, wet; no reaction with HCl; occasionally fine to medium sand.		DCORE	20									43		**Box 6-51.5-52.2 (51.5' to 52.2')**
	53																
	54																Driller to try a more-robust sand catcher.
-25	55	SP-SM	54.0 to 56.3' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium sand; about 10% nonplastic fines; medium dense, dark grayish brown, wet; no reaction with HCl.														Tagged to 55.0' bgs.
	56				SPT	100	11 13 9	22	31						13		**S11-55.0-56.5 (55.0' to 56.5')**
	57	CH	56.3 to 60.7' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; very stiff, olive, wet; no reaction with HCl.		DCORE	74				2.4P 3.4P 2.3P							**Box 6-56.5-58.7 (56.5' to 58.7')**
	58																
	59		From 59.5', Gradational increase in sand content.														**Core-58.7-59.1 (58.7' to 59.1')**
-30	60																
	61	SM	60.7 to 61.5' SILTY SAND, (SM): About 80% fine sand; about 20% nonplastic fines; medium dense, olive brown, wet; no reaction with HCl.		SPT	100	4 8 13	21	29								**S12-60.0-61.5 (60.0' to 61.5')**
	62																Total depth of 61.5' reached at 12:30 hours on 10/17/2020.
	63		Tremie-grouted with 95% cement, 5% bentonite by weight														
-35	64																
	65																
	66																
	67																
	68																
	69																
-40	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside Toe
Coordinates: North 2,039,900.00 East 6,665,946.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-126B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/29/20 — DATE COMPLETED 10/29/20	GROUND ELEVATION 32.10 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Eric Ramey — HELPER'S NAME Patrick Siegler/Rayshawn Bentley	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 61.5 ft: HSA	DRILL RIG MAKE AND MODEL CME 95	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Spade/Bullet	DRILLING ROD TYPE AND DIAMETER 8" Hollow Stem Auger	FIELD LOGGER Teresa Butler
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 76%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 23 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		RECENT ALLUVIUM, (Qal) 0.0 to 61.5'														Begin drilling at 0800 on 10/29/20 Hand augered to 5 feet and then switched over to hollow stem augers
30	1																
	2	SM	0.0 to 4.0' SILTY SAND, (SM): About 60% fine sand; about 40% nonplastic fines; dark brown (7.5YR 3/2), moist to dry.	Hand Auger													
	3																
	4	SP	4.0 to 5.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; loose, very dark grayish brown (10YR 3/2), moist to dry; micaceous.														
	5				SPT	67	1 4 2	6	8								
	6	(CL)o	5.5 to 6.5' LEAN CLAY with Organics, (CL)o: About 90% medium plasticity fines with high dry strength, medium toughness; about 10% organics, fibrous; medium stiff, dark brown (10YR 3/3), moist to dry; earthy odor.									29	47	21	92		S1-5.5-6.5 (5.5' to 6.5') At 5.5' [Lab] LEAN CLAY (CL)
25	7																
	8	(CL)s	6.5 to 10.0' LEAN CLAY with Sand and Organics, (CL)s: About 80% medium plasticity fines with medium to high dry strength, slow dilatancy, low toughness; about 10% fine sand; about 10% organics, fibrous; soft, very dark gray (10YR 3/1), moist; earthy odor.		SPT	67	1 1 2	3	4								S2-8.0-9.0 (8.0' to 9.0')
	9																
	10	CL	10.0 to 17.5' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy; about 5% fine sand; medium stiff, brown (10YR 4/3), moist; weak reaction with HCl; oxidized.		SPT	100	1 2 3	5	6			25	36	15			S3-10.0-11.5 (10.0' to 11.5')
20	11			Auger													
	12																
	13				SHELBY	100				1.5P							T4-12.5-14.5 (12.5' to 14.5')
	14																
	15																
15	16				SPT	100	2 6 7	13	16								S5-15.0-16.5 (15.0' to 16.5')
	17																
	18	(CL)s	17.5 to 29.5' LEAN CLAY with Sand, (CL)s: About 90% medium plasticity fines with high dry strength, medium toughness; about 10% fine to medium sand; medium stiff, dark yellowish brown (10YR 3/6), moist; laminated; weak reaction with HCl; trace organics, micaceous, manganese oxide staining, blocky.		SPT	100	0 3 6	9	11								S6-17.5-19.0 (17.5' to 19.0')
	19																
	20																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside Toe
Coordinates: North 2,039,900.00 East 6,665,946.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-126B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	20		17.5 to 29.5' LEAN CLAY with Sand, (CL)s: About 90% medium plasticity fines with high dry strength, medium toughness; about 10% fine to medium sand; medium stiff, dark yellowish brown (10YR 3/6), moist; laminated; weak reaction with HCl; trace organics, micaceous, manganese oxide staining, blocky. *(Continued)*		SPT	100	2 9 15	24	30			21	40	19	90		**S7-20.0-21.5 (20.0' to 21.5') At 20' [Lab] LEAN CLAY (CL)**
10	22																
	23				SPT	100	2 5 7	12	15			18	39	11	96		**S8-22.5-24.0 (22.5' to 24.0') At 22.5' [Lab] SILT (ML)**
	24																
	25	(CL)s.			SPT	100	5 12 14	26	33								**S9-25.0-26.5 (25.0' to 26.5')**
	26																
5	27																
	28				SPT	100	3 12 21	33	42								**S10-27.5-29.0 (27.5' to 29.0')**
	29																
	30		29.5 to 32.5' SANDY SILT, s(ML): About 80% low plasticity fines with low dry strength, slow to rapid dilatancy, low toughness; about 20% fine sand; very dark brown (7.5YR 2.5/3), laminated; oxidized.														Rig Chatter
	31	s(ML)			SPT	100	3 7 10	17	22			41			92		**S11-30.0-31.5 (30.0' to 31.5')**
0	32																
	33	(ML)s.	32.5 to 34.0' SILT with Sand, (ML)s: About 85% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 15% fine sand; dark yellowish brown, wet.	Auger	SPT	100	3 7 13	20	25						85		**S12-32.5-34.0 (32.5' to 34.0')**
	34		34.0 to 40.0' SILTY SAND, (SM): About 60% fine sand; about 40% nonplastic fines; medium dense, dark yellowish brown (10YR 3/4) mottled with very dark brown, wet; laminated; micaceous.														
	35				SPT	100	3 9 18	27	34								**S13-35.0-36.5 (35.0' to 36.5')**
	36		From 35.0 to 37.5', About 70% fine sand; about 30% nonplastic fines.														
-5	37	SM															
	38		From 37.5', About 85% fine sand; about 15% nonplastic fines.		SPT	50	5 10 16	26	33								**S14-37.5-39.0 (37.5' to 38.3')**
	39																
	40																Driller added water down augers
	41		40.0 to 45.4' Poorly Graded SAND with Silt, (SP-SM): About 90% fine sand; about 10% nonplastic fines; medium dense, very dark grayish brown (10YR 3/2), wet; laminated.		SPT	87	5 9 11	20	25								**S15-40.2-41.5 (40.2' to 41.5')**
-10	42	SP-SM															
	43																
	44				NSD												
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside Toe
Coordinates: North 2,039,900.00 East 6,665,946.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-126B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45	SP-SM															
	46		45.4 to 50.0' SILTY SAND, (SM): About 70% fine to medium sand; about 30% nonplastic fines; dark grayish brown (10YR 4/2) mottled with dark reddish brown (5YR 3/4), stratified fine and medium sand.		SPT	73	5 10 12	22	28								S16-45.4-46.5 (45.4' to 46.5')
-15	47	SM															
	48				NSD												
	49																
	50		50.0 to 55.0' Well-Graded SAND with Gravel, (SW)g: About 85% fine to coarse, subrounded to subangular sand; about 15% fine, subrounded to subangular gravel; very dense, very dark gray (10YR 3/1) to very dark brown (10YR 2/2), wet; weak reaction with HCl; oxidized.		SPT	87	20 27 26	53	67								S17-50.2-51.5 (50.2' to 51.5')
-20	51	(SW)g															
	52			Auger													
	53				NSD												
	54																
	55		55.0 to 60.0' Poorly Graded SAND, (SP): About 90% fine to coarse, subrounded to subangular sand; about 5% nonplastic fines; about 5% fine, subrounded to subangular gravel; very dense, very dark gray (10YR 3/1) to very dark brown (10YR 2/2), wet.		SPT	87	6 17 23	40	51								S18-55.2-56.5 (55.2' to 56.5')
-25	56	SP															
	57				NSD												
	58																
	59																
	60		60.0 to 61.5' Well-Graded SAND, (SW): About 95% fine to coarse, subrounded to subangular sand; about 5% nonplastic fines; dense, very dark gray (10YR 3/1), wet.		SPT	100	6 11 10	21	27								S19-60.0-61.5 (60.0' to 61.5')
	61	SW															End Drilling at 1430 on 10/29/20
-30	62		Tremie-grouted with 95% cement, 5% bentonite by weight														
	63																
	64																
	65																
	66																
-35	67																
	68																
	69																
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside Toe
Coordinates: North 2,035,472.00 East 6,665,990.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-128B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 10/31/20 — DATE COMPLETED 10/31/20	GROUND ELEVATION 26.80 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Eric Ramey — HELPER'S NAME Robert Allen	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 61.5 ft: HSA	DRILL RIG MAKE AND MODEL CME 95	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER NWJ	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 76%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 22.5 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	0		RECENT ALLUVIUM, (Qal) 0.0 to 61.5'														
	1	s(ML)	0.0 to 2.5' SANDY SILT, s(ML): About 65% nonplastic fines; about 35% fine sand; dark brown, dry.	Hand Auger													Hand auger 0.0 to 5.0' bgs.
25	2																
	3	(CL)s	2.5 to 5.2' LEAN CLAY with Sand, (CL)s: About 80% low plasticity fines with low toughness; about 20% fine sand; dark brown, moist.														
	4																
	5				SPT	87	3 4 6	10	13				43	20	98		S1-5.0-6.3 (5.0' to 6.3') At 5' [Lab] LEAN CLAY (CL)
	6	CL	5.2 to 7.0' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; dark brown, moist; no reaction with HCl.														
20	7																
	8		7.0 to 11.0' SILT, (ML): About 90% nonplastic fines with medium dry strength, rapid dilatancy, low toughness; about 10% fine sand; medium stiff to stiff, dark brown, moist; no reaction with HCl.		SPT	87	0 1 2	3	4	1.0P			34	16			S2-7.5-8.8 (7.5' to 8.8')
	9	ML															
	10																T1-10.0-11.6 (10.0' to 11.6')
	11		11.0 to 19.5' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; stiff, olive, moist; no reaction with HCl.		SHELBY	80				1.2P							Shelby was disturbed; no end caps until hours later; clay at top and bottom of tube.
15	12			Auger													
	13				NSD												
	14																
	15	CH			SPT	100	0 3 3	6	8	1.9P 1.6P			56	36	98		S3-15.0-16.5 (15.0' to 16.5') At 15' [Lab] FAT CLAY (CH)
10	16																
	17																
	18		From 17.5', Reddish brown, some white inclusions, 1/4-inch maximum dimension, with strong HCl reaction.		SPT	100	0 4 5	9	11	1.9P							S4-17.5-19.0 (17.5' to 19.0')
	19																
	20	(CH)s	*Description on next page.*														

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside Toe
Coordinates: North 2,035,472.00 East 6,665,990.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-128B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	LABORATORY DATA: Liquid Limit	LABORATORY DATA: Plasticity Index	LABORATORY DATA: Fines% < #200	LABORATORY DATA: Other Lab Tests	REMARKS
	20		19.5 to 24.5' FAT CLAY with Sand, (CH)s: About 80% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 20% fine sand; very stiff, reddish brown, moist; some white inclusions with weak HCl reaction. *(Continued)*														
	21																
5	22	(CH)s			SPT	100	2 6 13	19	24	3.7P			34	15			S5-20.0-21.5 (20.0' to 21.5')
			From 22.5', 1-inch zones of moderate cementation by calcium carbonate with strong HCl reaction.														Grinding noise from augers
	23				SPT	100	24 50/4"			4.1P							S6-22.5-23.3 (22.5' to 23.3')
	24				NSD												At 23.3' SPT Refusal
	25		24.5 to 29.5' SANDY SILT, s(ML): About 70% nonplastic fines with low dry strength, rapid dilatancy, low toughness; about 30% fine sand; very stiff, yellowish brown, wet; no reaction with HCl.		SPT	100	7 15 24	39	49	2.6P			26	4	83		S7-25.0-26.5 (25.0' to 26.5') At 25' [Lab] SILT with SAND (ML)
0	27	s(ML)															
	28				SPT	67	4 3 4	7	9								S8-27.5-28.5 (27.5' to 28.5')
	29																
	30		29.5 to 32.7' LEAN CLAY, (CL): About 90% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 10% fine sand; stiff, yellowish brown, wet; no reaction with HCl.														
	31	CL			SPT	20	0 0 2	2	3	1.3P							S9-30.0-30.3 (30.0' to 30.3')
-5	32			Auger													
	33		32.7 to 37.6' SILTY SAND, (SM): About 60% fine sand; about 40% nonplastic fines with low dry strength, slow dilatancy, low toughness; loose, brown, wet; no reaction with HCl; variable sand:fines ratio.		SPT	100	3 2 4	6	8						50		S10-32.7-34.0 (32.7' to 34.0')
	34		From 33.0', Silty sand is interbedded with sandy silt and sandy lean clay.														
	35	SM			SPT	100	3 3 5	8	10								S11-35.0-36.5 (35.0' to 36.5')
-10	36																
	37																
	38		37.6 to 45.2' FAT CLAY, (CH): About 95% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 5% fine sand; hard, olive, dry; occasional 1/8-inch inclusions or veins of white material with weak HCl reaction.		SPT	87	6 11 18	29	37	4.7P 4.7P							S12-37.6-38.8 (37.6' to 38.8')
	39																
	40		From 40.8', Numerous spots of rust staining.														
	41	CH			SPT	100	5 12 14	26	33				39	13			S13-40.0-41.5 (40.0' to 41.5')
-15	42																
	43				NSD												
	44																
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside Toe
Coordinates: North 2,035,472.00 East 6,665,990.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-128B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
	45																
	46		45.2 to 50.3' Poorly Graded SAND, (SP): About 95% fine sand; about 5% low plasticity fines; medium dense, olive, wet; no reaction with HCl; several 1/8- to 1/4-inch-thick bands of clay within.		SPT	93	6 11 15	26	33								S14-45.0-46.4 (45.0' to 46.4')
-20	47	SP															
	48				NSD												
	49																
	50																
	51		50.3 to 55.2' Poorly Graded SAND with Clay and Gravel, (SP-SC)g: About 75% fine to medium sand; about 15% fine to coarse, subrounded gravel, maximum size 1.1 inches; about 10% medium plasticity fines; very dense, dark gray, wet; no reaction with HCl.		SPT	100	16 36 50/4"									S15-50-51.3 (50.0' to 51.3')
-25	52	(SP-SC)g															
	53			Auger	NSD												
	54																
	55																
	56		55.2 to 61.0' FAT CLAY, (CH): About 90% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 10% fine sand; very stiff, olive, wet; no reaction with HCl.		SPT	100	5 12 14	26	33	2.3P							S16-55.0-56.5 (55.0' to 56.5')
-30	57		From 55.3 to 55.8', No to strong cementation and strong HCl reaction in areas with white staining (cemented by calcium carbonate).														
	58	CH	From 55.8 to 56.1', Strong cementation with no HCl reaction.		NSD												
	59		At 56.0', Two pieces of fine gravel.														
	60		From 60.0', Increased fine-sand content in clay.														S17A-60.0-61.0 (60.0' to 61.0')
	61	SP	61.0 to 61.5' Poorly Graded SAND, (SP): About 95% fine sand; about 5% nonplastic fines; medium dense, dark gray, wet; occasional streaks of rust staining.		SPT	100	3 6 9	15	19								S17B-61.0-61.5 (61.0' to 61.5')
-35	62																Total depth of 61.5' reached at 15:30 hours 10/31/2020.
	63		Tremie-grouted with 95% cement, 5% bentonite by weight														
	64																
	65																
	66																
-40	67																
	68																
	69																
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside
Coordinates: North 2,034,664.00 East 6,666,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-129B
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 11/2/20 — DATE COMPLETED 11/3/20	GROUND ELEVATION 25.10 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Eric Ramey — HELPER'S NAME Robert Allen	TOTAL DEPTH OF FILL 0 ft
DRILLING METHOD 0 - 5 ft: HA, 5 - 61.5 ft: HSA	DRILL RIG MAKE AND MODEL CME 95	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER NWJ	FIELD LOGGER Teresa Butler
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT, Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 76%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 23.5 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
25	0	SM	RECENT ALLUVIUM, (Qal) 0.0 to 61.5' 0.0 to 2.0' SILTY SAND, (SM): About 60% fine sand; about 40% nonplastic fines; dark brown, dry.	Hand Auger													Hand auger 0.0 to 5.0' bgs
	1																
	2																
	3	s(CL)	2.0 to 5.0' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines with no dilatancy, medium toughness; about 30% fine sand; dark brown, moist to dry.														
	4																
20	5	(CL)o	5.0 to 12.5' LEAN CLAY with Organics, (CL)o: About 90% medium plasticity fines with no dilatancy, medium toughness; about 5% fine sand; about 5% organics; medium stiff, very dark brown (10YR 2/2) mottled with dark grayish brown (10YR 4/2), moist; no reaction with HCl; oxidized.		SPT	67	2 3 5	8	10						98		S1-5.5-6.5 (5.5' to 6.5')
	6																
	7																
	8				SPT	73	0 3 4	7	9			28	55	33	98		S2-7.9-9.0 (7.9' to 9.0') At 7.9' [Lab] FAT CLAY (CH)
	9																
15	10																T3-10.1-11.3 (10.1' to 11.3')
	11				SHELBY	60				0.7P							Bottom 0.7' fell out.
	12			Auger													Auger fell into hole. Driller retrieved auger.
	13	CL	12.5 to 17.5' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% medium to coarse, subangular sand; stiff, very dark gray (10YR 3/1), moist; no reaction with HCl.		SPT	100	0 4 5	9	11								S4-12.5-14.0 (12.5' to 14.0')
	14																
10	15				SPT	100	1 3 6	9	11								S5-15.0-16.5 (15.0' to 16.5')
	16																
	17																
	18	CH	17.5 to 19.0' FAT CLAY, (CH): About 90% high plasticity fines with very high dry strength, no dilatancy, high toughness; about 10% fine sand; dark yellowish brown (10YR 4/4), moist; trace organics, fissured with weak reaction to HCl on fissure planes, oxidized.		SPT	100	2 4 6	10	13			24	58	41	91		S6-17.5-19.0 (17.5' to 19.0') At 17.5' [Lab] FAT CLAY (CH)
	19	CL	*Description on next page.*														
	20																

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside
Coordinates: North 2,034,664.00 East 6,666,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-129B
Sheet 2 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
5	20	CL	19.0 to 23.5' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% medium to coarse, subangular sand; stiff, very dark gray (10YR 3/1), moist; no reaction with HCl. *(Continued)*	Auger	SPT	100	1 7 4	11	14								**S7-20.0-21.5 (20.0' to 21.5')**
	21																
	22		From 20.0', Bedded with coarse sand, trace fine subangular gravel.														
	23				SPT	100	4 8 9	17	22								**S8-22.5-24.0 (22.5' to 24.0')**
	24	SM	23.5 to 25.0' SILTY SAND, (SM): About 80% fine to medium, subangular sand; about 20% nonplastic fines; very loose, dark yellowish brown (10YR 4/4), wet; no reaction with HCl; micaceous.														
0	25				SPT	100	1 2 2	4	5				32	13	74		**S9-25.0-26.5 (25.0' to 26.5')** **At 25' [Lab] LEAN CLAY with SAND (CL)**
	26		25.0 to 32.5' SANDY LEAN CLAY, s(CL): About 70% medium plasticity fines; about 30% fine sand; dark yellowish brown (10YR 4/4), wet; no reaction with HCl; micaceous.														
	27																Driller added water to hole.
	28	s(CL)			SPT	100	1 1 1	2	3						68		**S10-27.5-29.0 (27.5' to 29.0')**
	29																
-5	30		From 30.0', About 70% fine sand; about 30% nonplastic fines.		SPT	100	3 4 6	10	13			29	33	12	68		**S11-30.0-31.5 (30.0' to 31.5')** **At 30' [Lab] SANDY LEAN CLAY (CL)**
	31																
	32																Driller added water to hole.
	33		32.5 to 37.5' SANDY SILT, s(ML/SM): About 55% nonplastic fines; about 45% fine to medium sand; very loose, very dark brown (7.5YR 2.5/3) mottled with gray (7.5YR 5/1), wet; no reaction with HCl; oxidized, trace organics, micaceous, metamorphic lithics.		SPT	100	1 1 2	3	4				27	7	49		**S12-32.5-34.0 (32.5' to 34.0')** **At 32.5' [Lab] SILTY, CLAYEY SAND (SC-SM)**
	34																
-10	35	s(ML/SM)															
	36		From 35.5', Medium dense.		SPT	67	3 5 8	13	16								**S13-35.5-36.5 (35.5' to 36.5')**
	37																
	38	SP	37.5 to 40.0' Poorly Graded SAND, (SP): About 95% fine to coarse sand; about 5% low plasticity fines; medium dense, very dark gray (10YR 3/1), wet; no reaction with HCl; angular to subangular fine to medium sand, subangular to subrounded coarse sand, trace fine subrounded gravel.		SPT	87	1 3 8	11	14								**S14-37.7-39.0 (37.7' to 39.0')**
	39																
-15	40																
	41	SM	40.0 to 41.5' SILTY SAND, (SM): About 85% fine to coarse sand; about 15% nonplastic fines; medium dense, very dark gray (10YR 3/1), wet; no reaction with HCl.		SPT	100	1 5 6	11	14						28		**S15-40.0-41.5 (40.0' to 41.5')**
	42																
	43	SP	41.5 to 46.0' Poorly Graded SAND, (SP): About 95% fine to coarse sand; about 5% low plasticity fines; medium dense, very dark gray (10YR 3/1), wet; no reaction with HCl; angular to subangular fine to medium sand, subangular to subrounded coarse sand, trace fine subrounded gravel.		NSD													
	44																Driller added water to hole because of heaving sands.
	45																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Project: FREMONT WEIR BIG NOTCH
Feature: Big Notch / East Levee Landside
Coordinates: North 2,034,664.00 East 6,666,309.00
Survey Method: GPS Datum: NAD83
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-129B
Sheet 3 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Drilling Method	Sampled Interval	Recovery %	Blows per 6 in.	SPT N Value	N_{60}(ASTM)	PP or TV, tsf	Retained Sample	LABORATORY DATA: Water Content %	Liquid Limit	Plasticity Index	Fines% < #200	Other Lab Tests	REMARKS
-20	45	SP			SPT	100	24 38 49	87	110								**S16-45.0-46.5 (45.0' to 46.5')**
	46		46.0 to 55.5' Well-Graded SAND, (SW): About 95% fine to coarse, subangular to subrounded sand; about 5% nonplastic fines; very dense, very dark gray (10YR 3/1), wet; no reaction with HCl; sand percentage (f:m:c = 30:40:30), trace fine rounded gravel.														
	47				NSD												
	48																
	49																
-25	50																Driller added water to hole.
	51	SW			SPT	67	4 12 27	39	49						5		**S17-50.5-51.5 (50.5' to 51.5')**
	52																
	53			Auger	NSD												
	54																
-30	55																
	56		55.5 to 60.5' LEAN CLAY, (CL): About 95% medium plasticity fines with high dry strength, no dilatancy, medium toughness; about 5% medium sand; stiff, dark yellowish brown (10YR 4/4) mottled with yellowish red (5YR 4/6), wet; no reaction with HCl; trace black organics, oxidation exhibited in yellowish red.		SPT	100	3 4 8	12	15			39	51	18	89		**S18-55.5-56.5 (55.5' to 56.5')** **At 55.5' [Lab] ELASTIC SILT (MH)**
	57				NSD												
	58	CL															
	59																
-35	60																
	61	SM	60.5 to 61.5' SILTY SAND, (SM): About 85% fine to medium, subangular sand; about 15% nonplastic fines; medium dense, dark yellowish brown (10YR 4/4), wet; no reaction with HCl; micaceous.		SPT	100	3 8 12	20	25								**S19-60.0-61.5 (60.0' to 61.5')**
	62																Total depth of 61.5' reached 11/2/2020.
	63		Tremie-grouted with 95% cement, 5% bentonite by weight														
	64																
-40	65																
	66																
	67																
	68																
	69																
	70																

1 PROJECT GEOLOGY DRILL HOLE LOG; BIG_NOTCH_12.GPJ; DWR PROJECT GEOLOGY LIBRARY 20200505.GLB; 12/14/21

Historical Explorations

Project:
Feature:
Coordinates: North 2,040,582.00 East 6,665,434.00
Survey Method: GIS/LiDAR Datum: GPS
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-DH-01
Sheet 1 of 3

State of California
California Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

DATE STARTED 4/18/16 — DATE COMPLETED 4/18/16	GROUND ELEVATION 32.00 ft — ELEVATION BASIS GIS/LiDAR	TOTAL DEPTH OF BORING 51.5 ft
DRILLING CONTRACTOR Cascade Drilling	DRILLER'S NAME Sam Vasquez — HELPER'S NAME Jason Klipfel	TOTAL DEPTH OF FILL 5.2 ft
DRILLING METHOD 0 - 3 ft: Hand Auger, 3 - 4 ft: Auger, 4 - 5 ft: Hand Auger, 5 - 51.5 ft: Hollow Stem Auger	DRILL RIG MAKE AND MODEL CME-75	DWR/CONSULTANT COMPANY DWR
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 8-inch Auger	DRILLING ROD TYPE AND DIAMETER 8" Hollow Stem Auger	FIELD LOGGER Scott Sochar
☒ VERTICAL ☐ INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH	FIELD LOG REVIEWER Mark Pagenkopp
SAMPLER TYPE(S) SPT/Soil Core/Shelby	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic, 140 lbs / 30-inch drop	HAMMER EFFICIENCY 69%
BOREHOLE BACKFILL OR COMPLETION Tremie-grouted with 95% cement, 5% bentonite by weight	GROUNDWATER READING: DURING DRILLING 16.5 ft — AFTER DRILLING (DATE-TIME)	

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Sample Location	Sample Type / Sample Number / Recovery %	Blows per 6 in.	SPT N Value N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA: Water Content / Liquid Limit / Plasticity Index	LABORATORY DATA: Fines % < #200	LABORATORY DATA: Other Lab Tests	Drilling Method	REMARKS
30	0	(CL)sc	0 to 5.2' LEAN CLAY with Sand and Cobbles, (CL)sc: About 80% low plasticity fines; About 20% fine sand; About 10% cobbles or boulders; About 10%; dark brown, dry; no reaction with HCl.		NSD							Hand Auger	Hand-auger 0.0' to 3.0' bgs, hit cobble. Drilled from 3.0' to 4.0' bgs through cobbles. Hand-auger 4.0' to 5.0' bgs. Hollow stem auger from 5.0' to 51.5' bgs.
	1												
	2												
	3											Hand Auger	
	4												
	5	CL	5.2 to 13.1' LEAN CLAY, (CL): About 90% medium plasticity, high dry strength, slow dilatancy, low toughness fines; About 10% fine sand; stiff to very stiff, very dark brown, moist; no reaction with HCl; trace woody organics at the top.		SPT	0 13 7	**20** **23**		15 35	82	HD PA		
25	6		medium toughness fines.										
	7				DCORE								Sand catcher inadvertently left in core barrel
	8												
	9												
	10	SC	9.9 to 10.5' CLAYEY SAND, (SC): .		SHELBY								100 psi downpressure Driller said soil was probably too soft to be retained in tube From 10.0' to 12.0': Slough from the no-recovery Shelby recovered in top of clean-out core barrel.
	11												
20	12											Auger	
	13				DCORE								
	14	CL	13.1 to 16.7' LEAN CLAY, (CL): About 90% high plasticity, very high dry strength, no dilatancy, medium toughness fines; About 10% fine sand; stiff to very stiff, bluish black, moist; no reaction with HCl; trace fine gravel.										
	15				SPT	2 3 3	**6** **7**		21 38	90	HD PA		
	16		dark olive brown.										
15	17		very dark bluish gray.		DCORE								Water table at 16.5' bgs
	18	SP	16.7 to 21' Poorly Graded SAND, (SP): About 95% fine to medium sand; About 5% low plasticity fines; medium dense, dark olive brown, wet; no reaction with HCl; micaceous.		DCORE								
	19												
	20												

DWR GEOLOGY SOIL & LAB; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Project: FREMONT WEIR BIG NOTCH
Feature:
Coordinates: North 2,040,582.00 East 6,665,434.00
Survey Method: GIS/LiDAR Datum: GPS
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-DH-01
Sheet 2 of 3

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Sample Location	Sample Type Sample Number Recovery %	Blows per 6 in.	SPT N Value N_{60} (ASTM)	PP or TV, tsf	LABORATORY DATA: Water Content / Liquid Limit / Plasticity Index	LABORATORY DATA: Fines% < #200	LABORATORY DATA: Other Lab Tests	Drilling Method	REMARKS
	20	SP											
	21	CH	21 to 21.5' FAT CLAY, (CH): About 95% high plasticity, very high dry strength, no dilatancy, high toughness fines; About 5% fine sand; very stiff, dark brown, wet; no reaction with HCl.		SPT	3 6 14	**20** **23**						
10	22												
	23	SP	21.5 to 25.4' Poorly Graded SAND, (SP): About 95% fine to medium sand; About 5% low plasticity fines; medium dense, dark olive brown, wet; no reaction with HCl; micaceous. dark olive gray.		DCORE								
	24												
	25												
	26	SC	25.4 to 27.5' CLAYEY SAND, (SC): About 55% fine to medium sand; About 45% low plasticity, medium dry strength, slow dilatancy, low toughness fines; medium dense, dark reddish brown, wet; moderate cementation; no reaction with HCl.		SPT	7 15 11	**26** **30**						
5	27				DCORE				8 25	44	HD PA		Cored 1 foot to prepare for Shelby but sand was encountered
	28	SP	27.5 to 28.1' Poorly Graded SAND, (SP): About 95% fine to medium sand; About 5% non plasticity fines; dark bluish gray, wet; could be slough.		DCORE								
	29	s(ML)	28.1 to 34.5' SANDY SILT, s(ML): About 60% low plasticity, medium dry strength, slow dilatancy, low toughness fines; About 40% fine to medium sand; very stiff, dark reddish brown, wet; moderate cementation; no reaction with HCl; variable sand content. 30.6' numerous layers of Poorly Graded Sand (SP) from 0.1' to 0.5' thick.		SPT	7 14 21	**35** **40**						
	30												
	31												
0	32				DCORE							Auger	
	33												
	34												
	35	SP-SM	34.5 to 36.5' Poorly Graded SAND with Silt, (SP-SM): About 90% fine to medium sand; About 10% non plasticity fines; dense, very dark gray, wet; no reaction with HCl. 35.4' two inch-long root-like grass blades. 35.9' About 90% fine to coarse sand; About 10% non plasticity fines; with abundant quartz sand.		SPT	4 12 23	**35** **40**			5	PA		
	36												
-5	37				DCORE								
	38		36.5 to 51.5' Poorly Graded SAND, (SP): About 100% fine to medium sand; dense, very dark gray, wet; no reaction with HCl; some coarse sand. dark olive gray.							7	HD PA		Some chattering from drill rig - driller attributed it to play in rods.
	39												
	40	SP			SPT	3 5 8	**13** **15**						
-10	41												
	42				DCORE								Driller tagged hole to 36.5' bgs, concluded he had 5' sand in the auger, driller then cleaned it out. Heaving sands First clean-out unsuccessful; second clean-out successful.
	43												
	44												
	45												

DWR GEOLOGY SOIL & LAB; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Project: FREMONT WEIR BIG NOTCH
Feature:
Coordinates: North 2,040,582.00 East 6,665,434.00
Survey Method: GIS/LiDAR Datum: GPS
GPS: Latitude Longitude
County: Yolo

DRILL HOLE LOG
FW-DH-01
Sheet 3 of 3

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

Elevation, feet	Depth, feet	Graphic Log	FIELD CLASSIFICATION AND DESCRIPTION	Sample Location	Sample Type Sample Number Recovery %	Blows per 6 in.	SPT N Value N_{60} (ASTM)	PP or TV, tsf	LABORATORY DATA: Water Content / Liquid Limit / Plasticity Index	LABORATORY DATA: Fines% < #200	LABORATORY DATA: Other Lab Tests	Drilling Method	REMARKS
	46	SP	About 100% fine sand. 36.5 to 51.5' Poorly Graded SAND, (SP): About 100% fine to medium sand; dense, very dark gray, wet; no reaction with HCl; some coarse sand. *(Continued)*		SPT	6 21 27	48 55						
-15	47												
	48				DCORE							Auger	Water that driller had poured down the hole flowed out of hole during augering. Driller tagged hole to 49.5' bgs, concluded 6" sand fell back in.
	49												
	50												
	51		50.4 to 50.6' trace fine gravel. 50.6' About 100% fine sand; medium dense, dark olive gray, wet; no reaction with HCl; micaceous, no quartz.		SPT	6 8 7	15 17						
-20	52		Tremie-grouted with 95% cement, 5% bentonite by weight										
	53												
	54												
	55												
	56												
-25	57												
	58												
	59												
	60												
	61												
-30	62												
	63												
	64												
	65												
	66												
-35	67												
	68												
	69												
	70												

DWR GEOLOGY SOIL & LAB; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

DocuSign Envelope ID: B1793F00-BCC8-489A-B86F-796CBAFBF4FF

CORPS OF ENGINEERS

U. S. ARMY

GENERAL SURVEY NOTES:
ELEVATIONS REFER TO C. OF E. DATUM + 3.0 FT. BELOW SEA LEVEL
TRAVERSE PLOTTED GRAPHICALLY. \ DATUM 1929.
DATE OF SURVEY: 11-12 APR 1960.
ORIG. SURVEY SHOWN ON DRAWING FILE Nº 50-13-3687.
ALL TYPICAL SECTIONS SHOWN ON PLAN ARE ON A SHEET NUMBER REFERENCE THUS (Nº)

STRUCTURE NOTES

Sta 0+35 to 16+00 — Remove and save 1590 lin ft 0' fence including gate on ramp waterside. Reconstruct 1565 lin ft, and construct 30 lin ft of new fence 5' west of the waterside levee toe. Reconstruct gate across toe of waterside ramp at Sta. 3+18

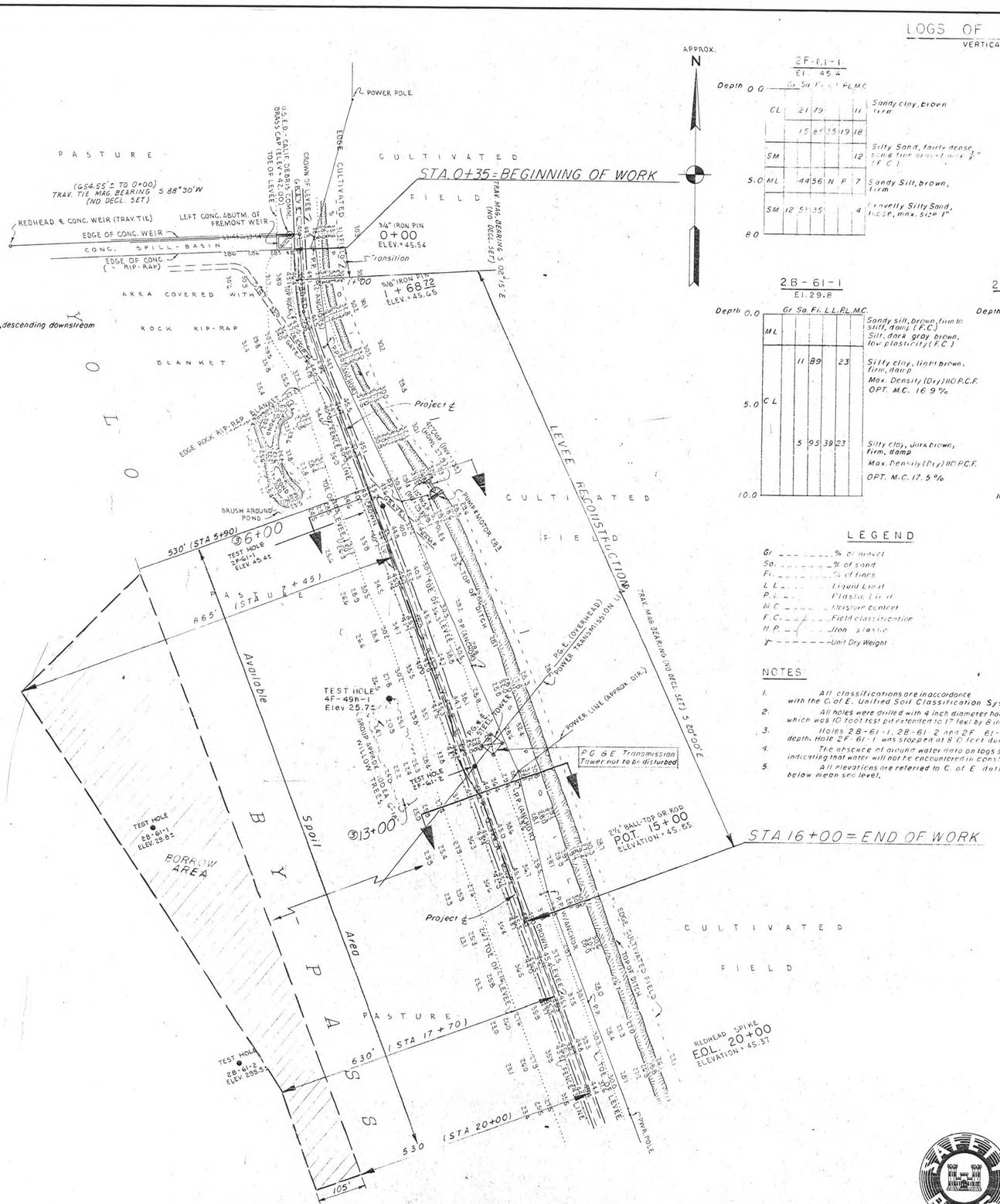
Sta 0+35 to 16+00 — Surface levee crown (3' x 16'). See detail sheet 3696/3.

Sta 0+35 to 3+30 — Remove, stockpile and reuse existing rock, waterside.

Sta 3+18 ——— Construct S-type ramp, waterside, descending upstream

Sta 3+70 ——— Construct S-type 16' wide 8% grade, side slope 1on2, landside, descending downstream Surface (4" x 12"). See detail sheet 3696/3

Sta 16+00 ——— Construct 120 lin ft of cross fence, waterside Tie to existing fence on waterside levee slope. See detail sheet 3696/3



LOGS OF EXPLORATION HOLES

VERTICAL SCALE: 2" - 5'

2F-61-1 El. 45.4

Depth	Gr	Sa	Fi	LL	PL	MC		
0.0								
	CL	21	79			11		Sandy clay, brown firm
		15	64	35	19	18		
	SM					12		Silty Sand, fairly dense some fine gravel, max. 3/4" (F.C.)
5.0	ML	44	56	N	P	7		Sandy Silt, brown, firm
	SM	12	53	35		4		Gravelly Silty Sand, loose, max. size 1"
8.0								

2F-61-2 El. 44.8

Depth	Gr	Sa	Fi	LL	PL	MC		
0.0	ML							Silt, brown and fine gravel
		91	9		20	12		
	ML							Silt, brown, firm to stiff
						11		
3.0	CL	8	92	39	21	16		Lean clay, brown, soft
7.0	ML	34	66			11		Sandy silt, brown, soft to firm

2B-61-1 El. 29.8

Depth	Gr	Sa	Fi	LL	PL	MC		
0.0	ML							Sandy silt, brown, firm to stiff, damp (F.C.)
								Silt, dark gray brown, low plasticity (F.C.)
		11	89			23		Silty clay, light brown, firm, damp
5.0	CL							Max. Density (Dry) 110 P.C.F.
		5	95	39	23			OPT. M.C. 16.9%
10.0								

2B-61-2 El. 29.5

Depth	Gr	Sa	Fi	LL	PL	MC		
0.0								Silt, brown with some fine sand (F.C.)
								Silt gray brown, damp, firm, low plasticity (F.C.)
								Silt, light brown, damp, firm, non plastic, (F.C.)
	ML							
5.0								Silt, dark brown, damp, low plasticity, firm (F.C.)
9.1								Ground water, 13 April 1961
10.0	CL							Clay, brown, moist, medium plasticity (F.C.)

4F-49H-1 El. 25.7

Depth	Gr	Sa	Fi	LL	PL	Sp	MC	
0.0								
	CL	15	85	31	18	82	8	Sandy Clay, light tan, firm
			29	71	N	P		
	ML		43	57	N	P	92	6	Sandy Silt, tan to brown, soft
5.0								
	SP	1	97	2				Sand, black, fine to medium grained very loose
	ML		47	53	N	P	91	8	Sandy silt, tan, soft
			37	63	29	15	92	15	Sandy clay, tan to brown, soft to firm
	CL							
15.0								
17.0								

LEGEND

Gr ——— % of gravel
Sa ——— % of sand
Fi ——— % of fines
L L ——— Liquid Limit
P L ——— Plastic Limit
M C ——— Moisture content
F C ——— Field classification
N P ——— Non plastic
γ ——— Unit Dry Weight

NOTES

1. All classifications are in accordance with the C. of E. Unified Soil Classification System.
2. All holes were drilled with 4 inch diameter hand auger, except 4F-49h-1 which was 10 foot test pit extended to 17 feet by 8 inch diameter hand auger.
3. Holes 2B-61-1, 2B-61-2 and 2F-61-2 were drilled to specified depth. Hole 2F-61-1 was stopped at 8.0 feet due to caving.
4. The absence of ground water data on logs shall not be construed as indicating that water will not be encountered in construction operations.
5. All elevations are referred to C. of E. datum equals 3.0 feet below mean sea level.

PLAN

GRAPHIC SCALE
1" = 100'
0 50' 100' 200' 300' 400' 500'

REVISION	DATE	DESCRIPTION	BY	BY

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

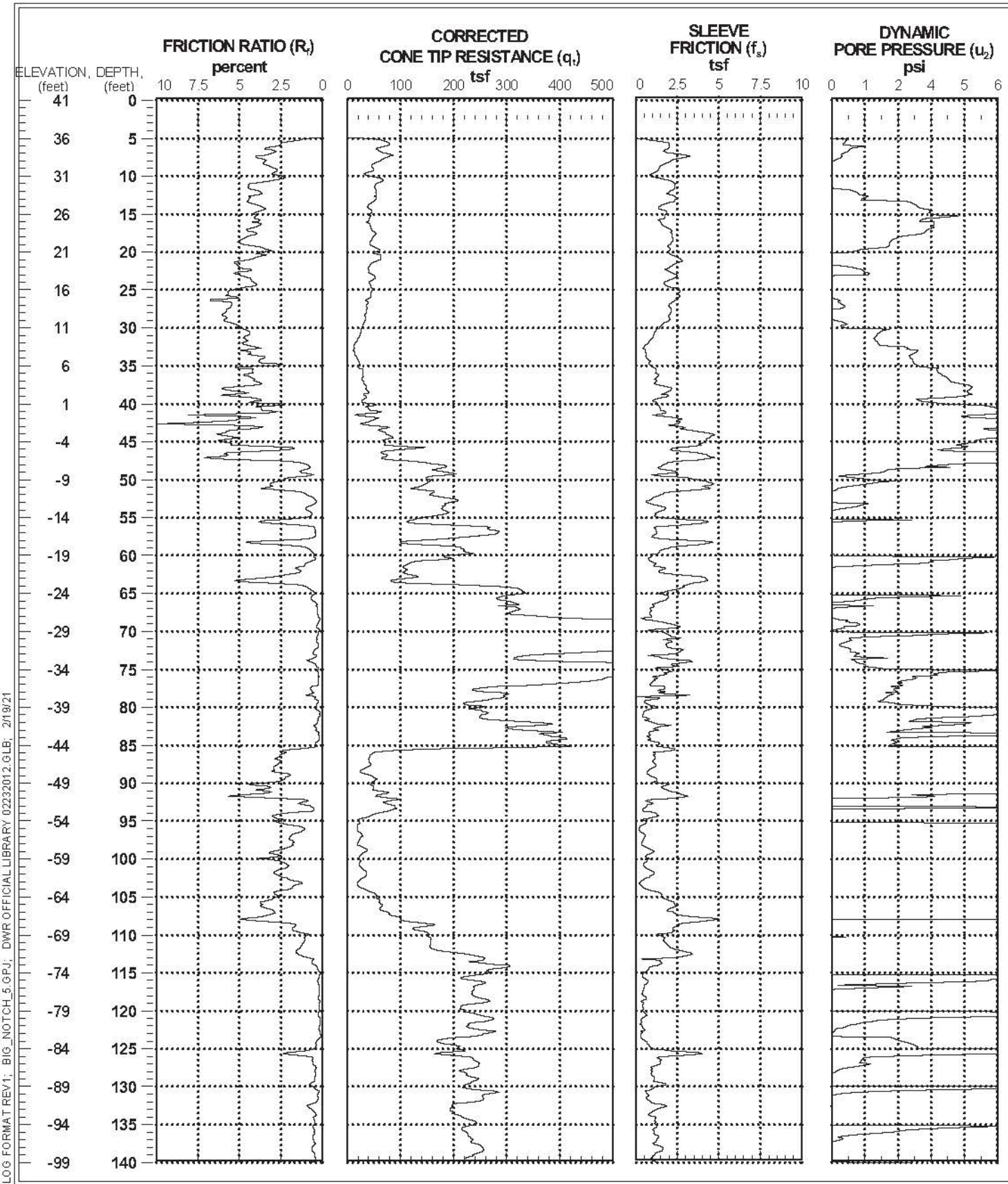
DRAWN BY: W.W.B.
CHECKED BY: M.A.S.
PREPARED BY: J.A.S.
SUBMITTED BY: K.U.E. Chief, E.&C. Br.
APPROVAL RECOMMENDED: H.J. Bittner Chief, Design Branch
PREPARED UNDER THE DIRECTION OF H. N. TURNER, Col., Corps of Engineers, U.S.A., District Engineer

SACRAMENTO RIVER, CALIFORNIA
FLOOD CONTROL PROJECT
LEVEE CONSTRUCTION
LEFT BANK YOLO BY-PASS
VICINITY OF FREMONT WEIR

APPROVED: H.J. Bittner, Asst. Chief, Engineering Division
DATE: 31 January 1963

SCALE: AS SHOWN | SPEC. NO. 2771
FILE NO. 50-4-3696
SHEETS 3696/1 to 3696/3 | SHEET NO. 3696/2

CPT Sounding Plots

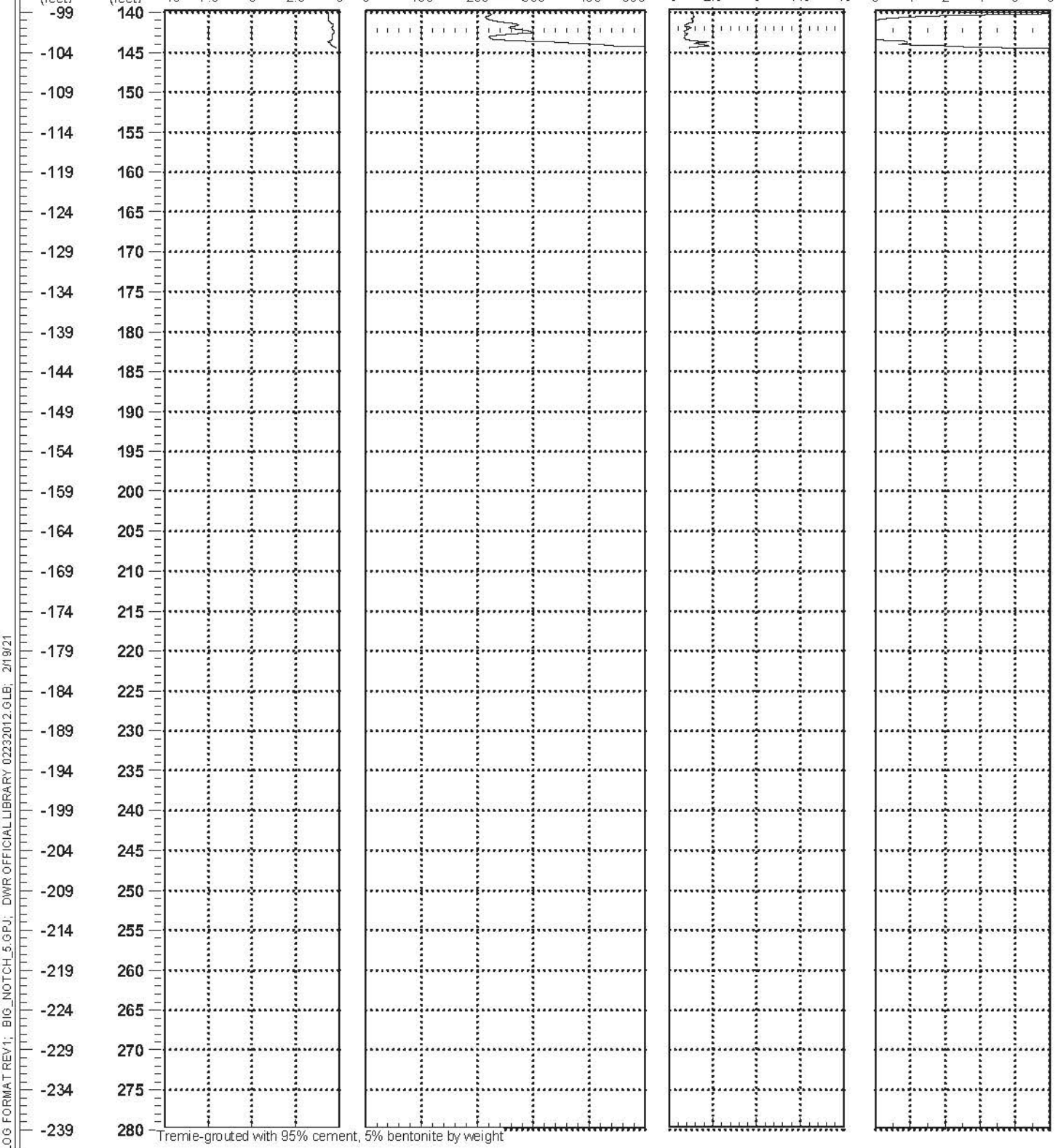


DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Borehole Location: Control Building **County:** Yolo
Performed By: Cascade Drilling **Date:**
Ground Elevation: 41.10 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,040,470.00 **Easting:** 6,665,611.00
Latitude: **Longitude:**
Levee Station or Milepost: **Levee Mile:**
Levee Segment:
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature:

CPT Sounding
FW-107C

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT

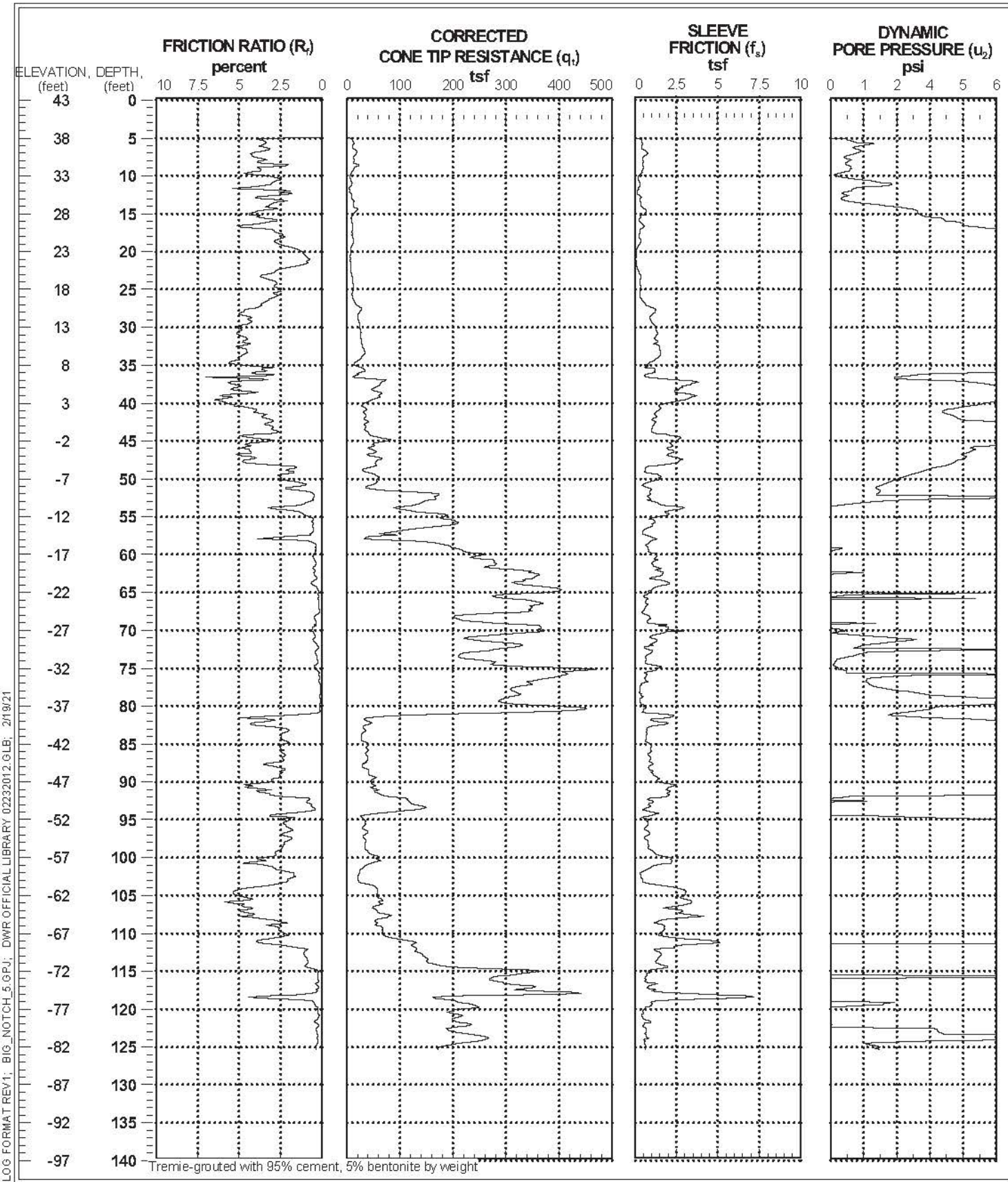


DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Borehole Location: Control Building **County:** Yolo
Performed By: Cascade Drilling **Date:**
Ground Elevation: 41.10 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,040,470.00 **Easting:** 6,665,611.00
Latitude: **Longitude:**
Levee Station or Milepost: **Levee Mile:**
Levee Segment:
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature:

CPT Sounding
FW-107C

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT



DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

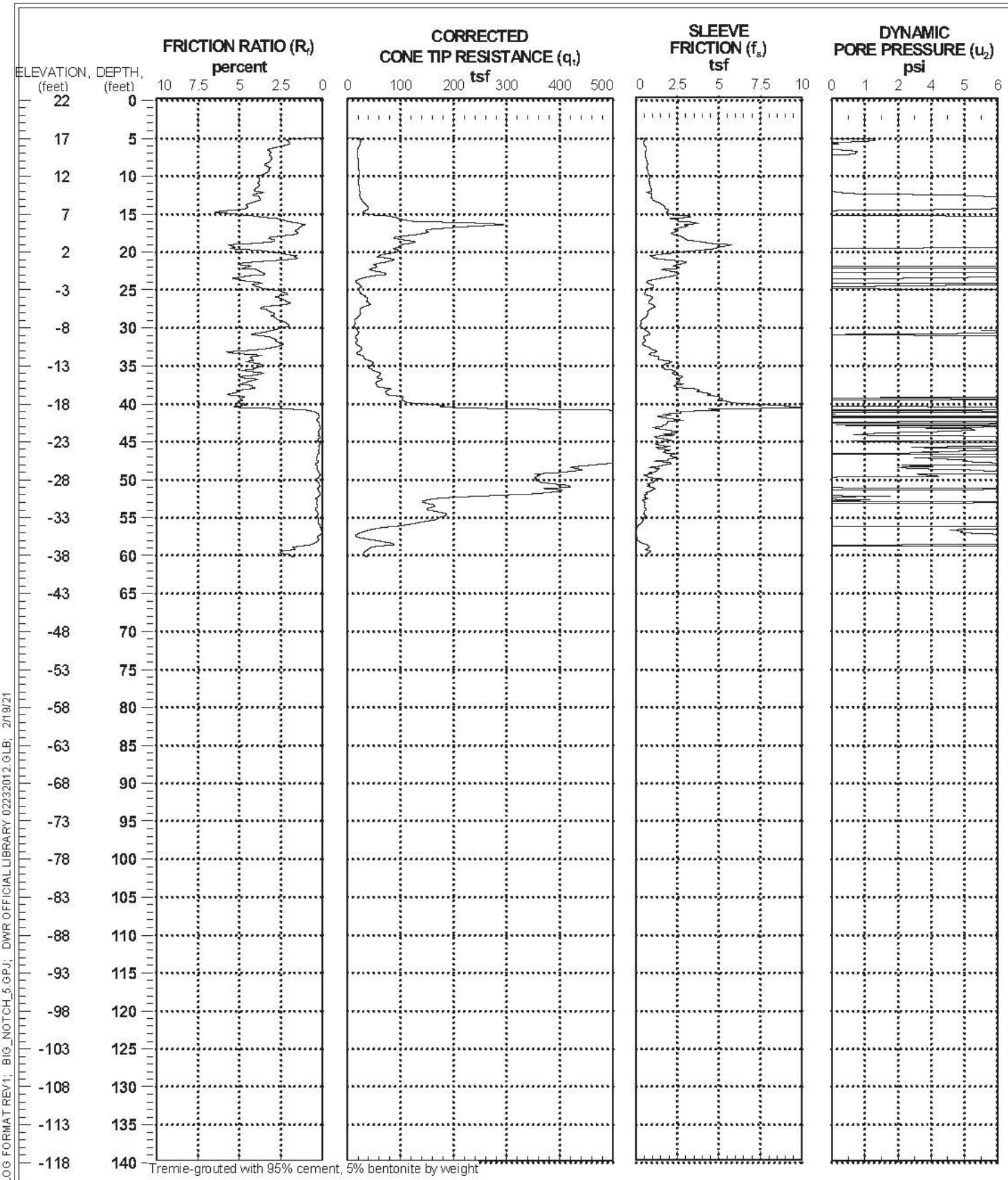
DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

Borehole Location: _____ **County:** Yolo
Performed By: Cascade Drilling **Date:** _____
Ground Elevation: 43.30 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,038,525.00 **Easting:** 6,665,678.00
Latitude: _____ **Longitude:** _____
Levee Station or Milepost: _____ **Levee Mile:** _____
Levee Segment: _____
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: _____

CPT Sounding
FW-112C

Sheet 1 of 1

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT



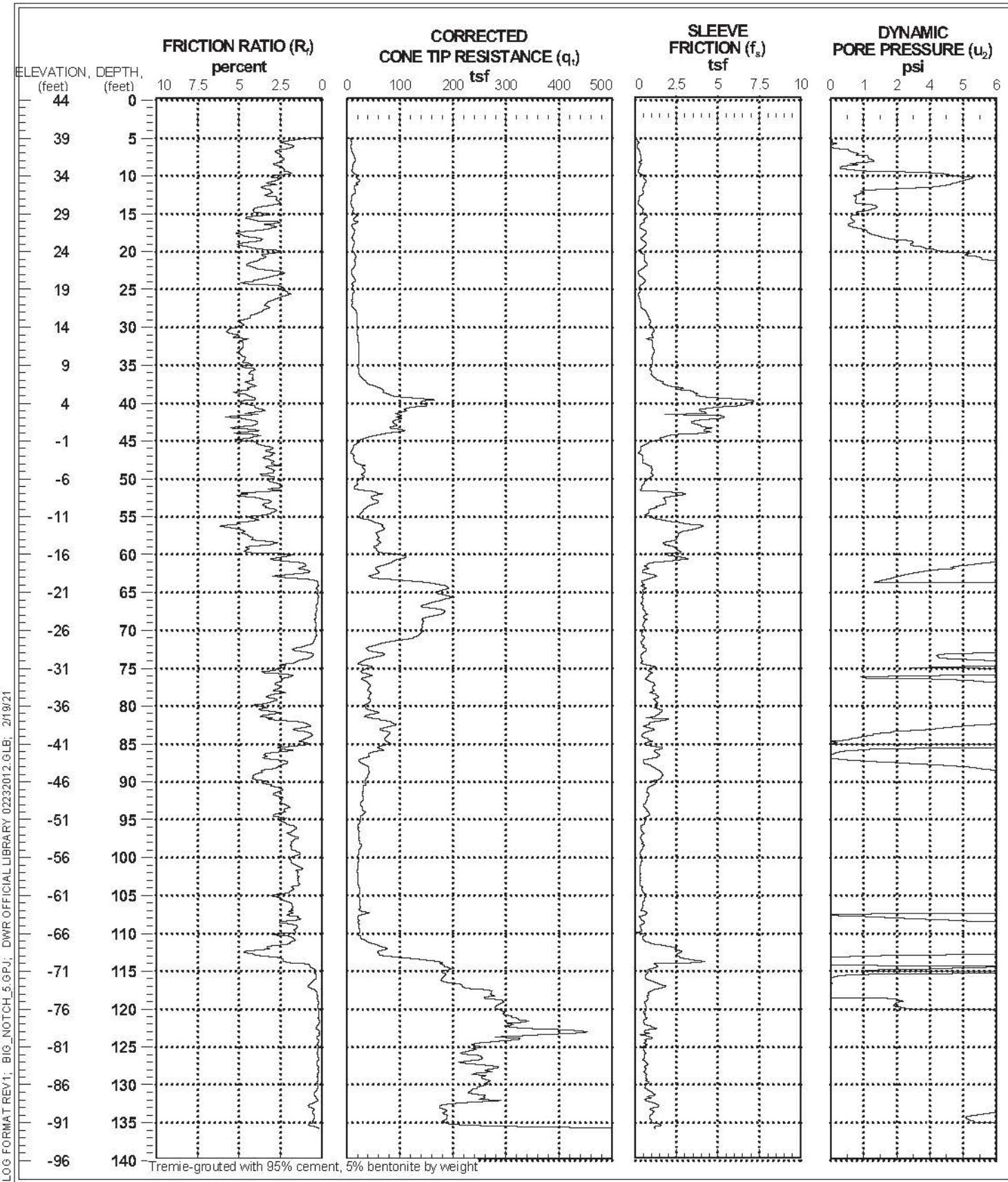
DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Borehole Location: _____ **County:** Yolo
Performed By: Cascade Drilling **Date:** _____
Ground Elevation: 22.30 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,037,175.00 **Easting:** 6,665,664.00
Latitude: _____ **Longitude:** _____
Levee Station or Milepost: _____ **Levee Mile:** _____
Levee Segment: _____
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: _____

CPT Sounding
FW-114C

Sheet 1 of 1

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT



DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

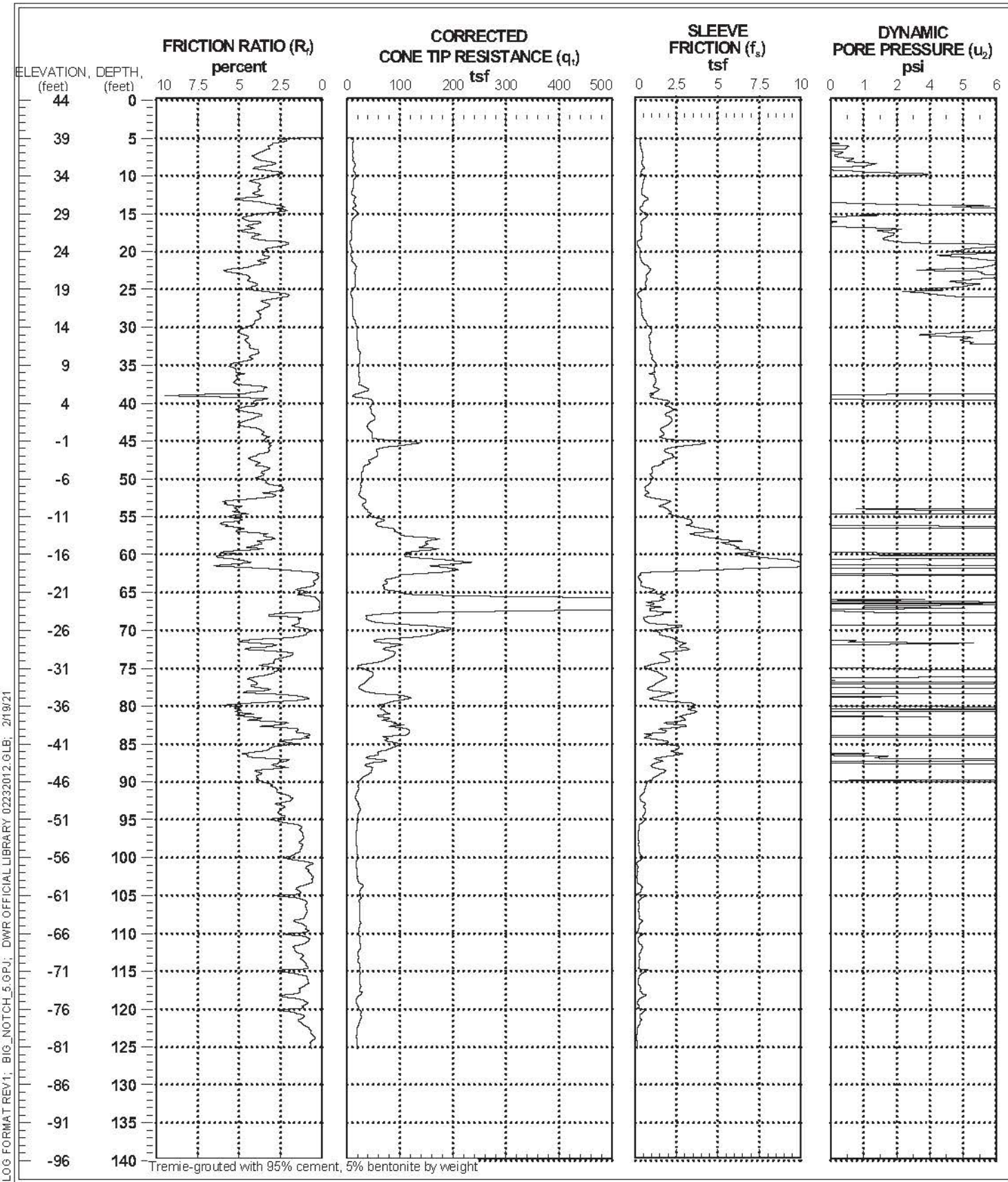
DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

Borehole Location: _____ **County:** Yolo
Performed By: Cascade Drilling **Date:** _____
Ground Elevation: 43.60 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,035,414.00 **Easting:** 6,665,877.00
Latitude: _____ **Longitude:** _____
Levee Station or Milepost: _____ **Levee Mile:** _____
Levee Segment: _____
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: _____

CPT Sounding
FW-117C

Sheet 1 of 1

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT



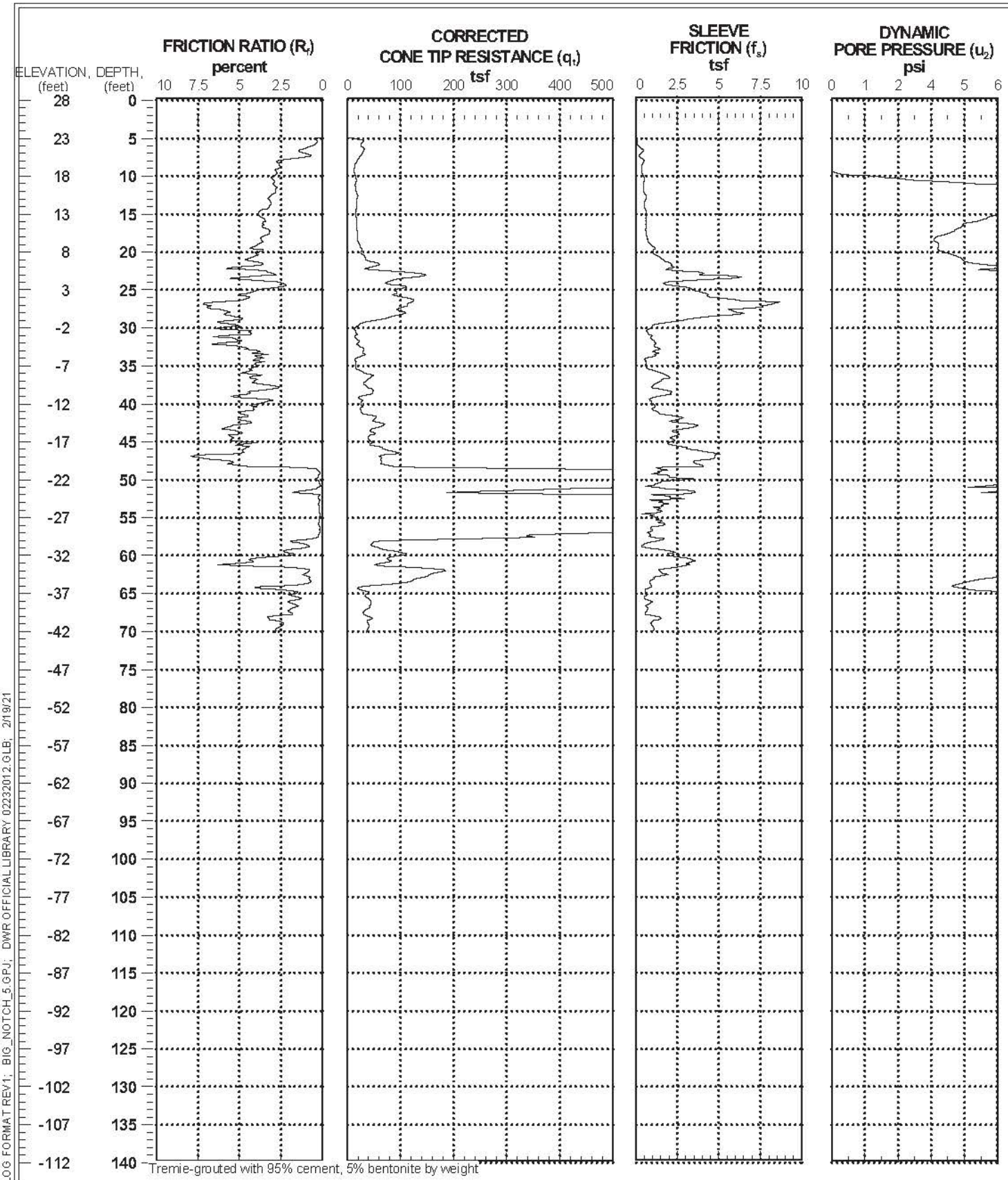
DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Borehole Location: _____ **County:** Yolo
Performed By: Cascade Drilling **Date:** _____
Ground Elevation: 43.80 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,032,430.00 **Easting:** 6,666,038.00
Latitude: _____ **Longitude:** _____
Levee Station or Milepost: _____ **Levee Mile:** _____
Levee Segment: _____
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: _____

CPT Sounding
FW-122C

Sheet 1 of 1

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT



DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

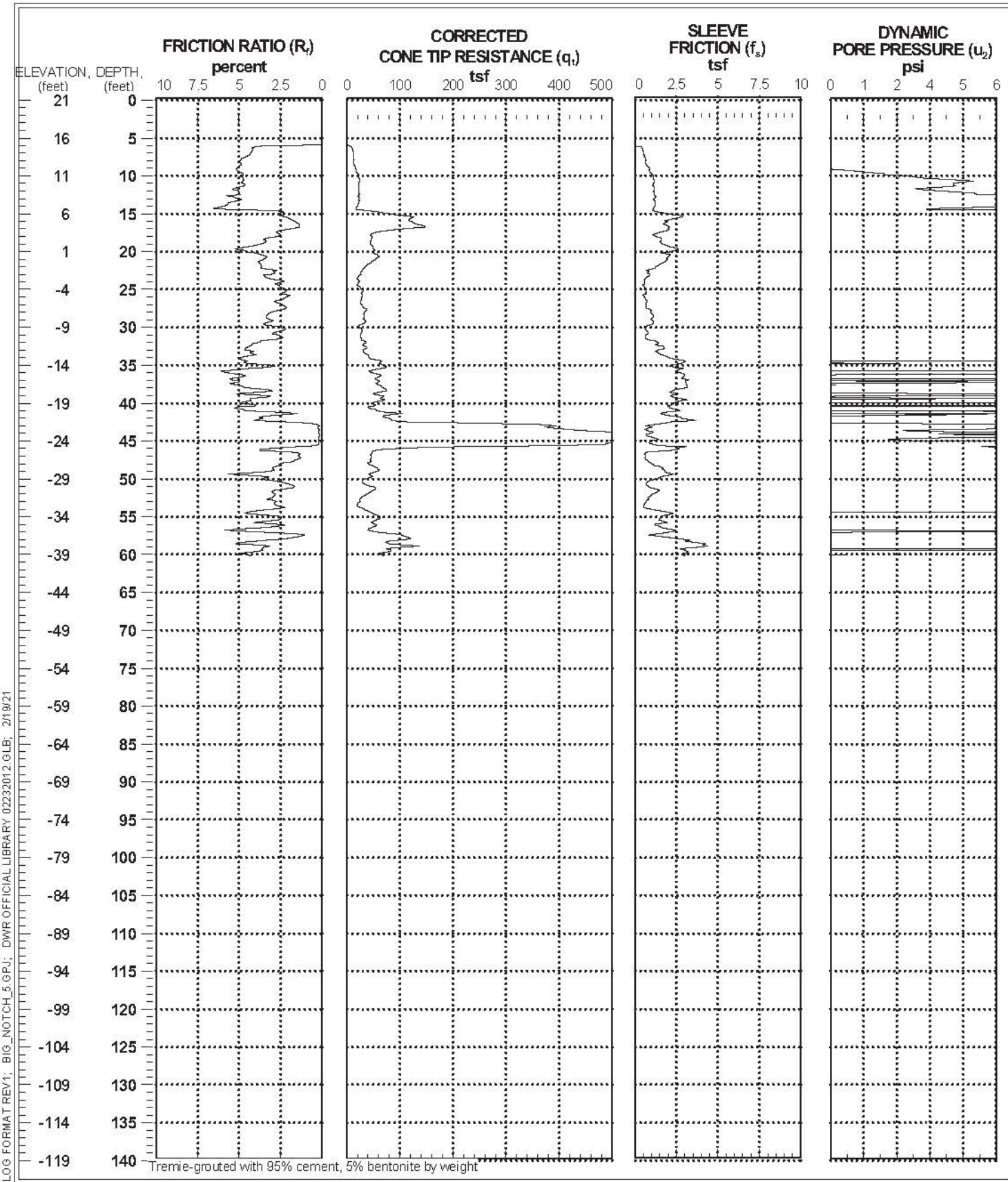
DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

Borehole Location: _____ **County:** Yolo
Performed By: Cascade Drilling **Date:** _____
Ground Elevation: 28.10 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,037,140.00 **Easting:** 6,666,022.00
Latitude: _____ **Longitude:** _____
Levee Station or Milepost: _____ **Levee Mile:** _____
Levee Segment: _____
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: _____

CPT Sounding
FW-127C

Sheet 1 of 1

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT



DWR LEVEE U/NU CPT IN LOG FORMAT REV1; BIG_NOTCH_5.GPJ; DWR OFFICIAL LIBRARY 02232012.GLB; 2/19/21

Borehole Location: _____ **County:** Yolo
Performed By: Cascade Drilling **Date:** _____
Ground Elevation: 20.60 ft **Datum:** NAVD88
Coordinates: **Northing:** 2,032,441.00 **Easting:** 6,666,170.00
Latitude: _____ **Longitude:** _____
Levee Station or Milepost: _____ **Levee Mile:** _____
Levee Segment: _____
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: _____

CPT Sounding
FW-130C

Sheet 1 of 1

FREMONT WEIR BIG NOTCH
YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

APPENDIX C
Laboratory Test Results

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Description

Attached are the results of laboratory testing performed under Test Request No. 2020-18: Big Notch Project. The samples were received at our laboratory in months October and November 2020. Testing was performed according to the Test Request Forms submitted.

Samples

The samples delivered to Bryte Lab included Shelby tubes, jar samples and sealed plastic bag samples. Testing was requested on 158 of the soil samples received.

Tests

The tests performed are listed below:

- ASTM D2487: Classification
- ASTM D4318: Atterberg Limits
- ASTM D422: Particle Size Analysis
- ASTM D854: Specific Gravity
- ASTM D2216: Water Content
- ASTM D2974: Organic Content
- ASTM D4647: Identification of Dispersive Clays-Pinhole
- ASTM D2435: One Dimensional Consolidation
- ASTM D3080: Direct Shear
- ASTM D4767: Consolidated Undrained Triaxial Compression
- ASTM D2166: Unconfined Compressive Strength of Soils

Results

Classification Testing:

The samples were collected from Boring holes FW-104B, 113B, 116B, 120B, 121B, 103B, 106B, 111B, 129B, 105B, 118B, 128B, 115B, 119B, 126B and 108B. Classification testing performed on the samples included particle size analysis (ASTM D422), Atterberg Limits (ASTM D4318), Organic content test (ASTM 2974) and Pinhole testing (ASTM D4646). Soil classifications were performed according to ASTM D2487. A summary of classification test results is attached.

Gradation test were performed according to ASTM D422. Based on the laboratory test results, the materials varied significantly from sand to fine grained soils.

Plasticity Index testing indicated that the soil was generally Low to Medium Plastic with Plasticity Indexes (PI) ranging from 5 to 35. High plasticity clays (CH) were observed in the shallow depths of up to 20 ft in bore holes FW-118B, 119B, 129B, 128B and 120B. Based on the soil classifications, the soil types were widely variable which included Lean Clay, Sandy Lean Clay, Lean Clay with Sand (CL), Silt, Sandy Silt, Silt with Sand (ML), Silty Sands (SM) and Fat Clay (CH).

Pinhole tests were performed on four samples in bore holes FW-119B and 115B. A detailed test result is attached for each sample which describes the head applied, turbidity of the effluent and dispersibility classification. Organic content tests were performed on four samples in boreholes FW-129B and 126B and the results are presented in the classification sheets.

One Dimensional Consolidation of Soils:

One Dimensional Consolidation testing was performed on undisturbed samples following ASTM D2435. All samples were saturated at a constant volume state under 100 psf stress for 24 hours prior to start of loading. The consolidation test results are attached for your reference. A summary of the results is presented in Table1.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Sample 20-400 was non-plastic and classified as silty sand (SM) which made sample preparation difficult and the sample prone to disturbance.

Sample 20-572 from borehole FW-118B was expansive so that the stress had increased to 1400 psf under the constant volume 24-hour saturation time. Therefore, two of the loading steps with stresses less than 2000 psf were skipped automatically and loading was continued after saturation from stress level of 2000 psf.

Table.1 Consolidation Tests summary

Sample No.	Bore Hole	Depth (ft)	Compression Ratio	Recompression Ratio	Est. Preconsolidation Stress (psf)	Coefficient of consolidation (ft^2/s)	
						Stress (psf)	
						2000	4000
20-400	FW-104B	24.0-26.0	0.1732	0.0091	7359	1.139E-05	4.389E-06
20-450	FW-103B	17.0-19.0	0.1480	0.0111	3270	9.737E-06	7.549E-06
20-459	FW-106B	10.0-12.0	0.1656	0.0123	3856	5.062E-06	5.806E-06
20-461	FW-106B	20.0-21.8	0.1284	0.0106	8112	4.340E-06	6.578E-06
20-498	FW-105B	20.0-22.0	0.1495	0.0090	4719	9.338E-06	8.304E-06
20-527	FW-118B	10.0-11.1	0.1394	0.0802	7052	4.562E-06	5.328E-06

Direct Shear Testing:

Direct Shear tests were performed on three samples. Three soil specimens were collected from each sample. After saturation, the samples were first consolidated and then sheared with a shearing rate calculated using the time required to achieve 50% consolidation (t50) and estimated horizontal displacement at failure of 0.2 inches (ASTM D3080). The samples were sheared to obtain both the peak and residual shear strength of the soil. Confining pressures of 500, 1000 and 2000 psf were used for samples 20-415, 424 and 484 and confining pressures of 1000, 2000 and 4000 psf were used for samples 20-461 and 498. A summary of the results is presented in Table 2.

Preparation of undisturbed specimens from samples 20-476 and 501, classified as poorly graded sand with silt (SP-SM) and Silt with sand (ML) respectively, was not possible. Therefore, the requested direct shear tests on 20-476 and 20-501 were not performed.

Sample 20-484 indicated expansive properties through consolidation under the confining pressure of 500 psf. Therefore, the sample was not suitable for direct shear testing at the specified normal loads which is reflected in the stress-strain and shear envelopes for peak and residual shear strengths.

Table.2 Direct Shear Tests summary

Sample No.	Bore Hole	Depth (ft)	Peak		Residual	
			c' (ksf)	ϕ'	c' (ksf)	ϕ'
20-415	FW-116B	12.5-14.5	0.15	34	0.25	30
20-424	FW-120B	10.0-12.0	0.20	30	0.20	25
20-461	FW-106B	20.0-21.8	0.25	30	0.18	30
20-484	FW-116B	7.5-9.5	0.40	35	0.25	35
20-498	FW-105B	20.0-22.0	0.20	36	0.10	36

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Triaxial Compression Testing:

Triaxial compression testing was requested on samples 20-541 and 20-552. The sample length for 20-552 was insufficient to perform a minimum of two Consolidated Undrained Triaxial tests, therefore an unconfined compressive strength test was performed. The length of 20-541 was enough for only 2 tests which were performed at confining pressures of 1000 and 4000 psf.

After completion of saturation to degrees of more than 95%, the samples were consolidated in three steps and then sheared in an undrained condition. The shearing rate was calculated using the time required for 90% of the consolidation (t_{90}). Results of Consolidated Undrained testing (ASTM D4767) are attached for your reference. A summary of the results is presented in Table 3.

Table.3 Consolidated Undrained Triaxial summary

Sample No.	Bore Hole	Depth (ft)	Drained		Undrained	
			c' (ksf)	ϕ'	c (ksf)	ϕ
20-541	FW-115B	19.0-21.0	0.25	25	0.30	17

Unconfined Compressive Strength Testing

Unconfined compressive strength (UCS) tests were requested on a total of eight samples, however samples 20-400 and 20-501 were unsuitable for UCS testing. Samples were tested with a strain rate of 1% per minute after extrusion from the Shelby tubes. A summary of the results is presented in Table 4.

Table.4 Unconfined Compressive Strength Test summary

Sample No.	Bore Hole	Depth (ft)	Unconfined Compressive Strength (psi)	Strain at Failure (%)
20-450	FW-103B	17.0-19.0	6	1.91
20-459	FW-106B	10.0-12.0	14	1.58
20-461	FW-106B	20.0-21.8	24	6.01
20-498	FW-105B	20.0-22.0	17	3.13
20-527	FW-118B	10.0-12.0	29	7.78
20-552	FW-119B	14.0-16.0	16	4.74
20-572	FW-108B	19.0-21.0	28	5.76

Test results for the above referenced tests are attached for your reference. Unless otherwise directed, all remaining samples will be retained at our laboratory for three years from the date of this summary. Please feel free to contact me at the Bryte Lab (916-653-8600) if you have any questions or need any additional information.

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CLASSIFICATION SUMMARY

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-104B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI		%	pcf	%		
20-395	104B	S01-5.0-6.5	5.0-6.5										100	87				36	14		18.6			CL	Lean Clay
20-396	104B	S02-8.5-10.0	8.5-10	100	100	100	100	100	100	100	100	100	86	73				29	11		18.6			CL	Lean Clay with sand
20-397	104B	S02-10-10.5	10.0-10.5										100	93											
20-398	104B	S04-18.5-20.0	18.5-20.0	100	100	100	100	100	100	100	100	100	100	97				39	16		22.4			CL	Lean Clay
20-399	104B	D04-21.0-21.5	21.0-21.5								100	95	81	72											
20-400	104B	T01-24.0-26.0	24.0-26.0	100	100	100	100	100	100	100	98	78	51	45					NP		27.3	93.9		SM	Silty sand
20-401	104B	D06-31.5-32.0	31.5-32.0				100	99	99	98	97	85	38	13											
20-402	104B	S07-38.5-40.0	38.5-40.0	100	100	100	100	99	96	90	74	44	20	6							23.2				
20-403	104B	S11-57.5-59.0	57.5-59.0			100	98	91	79	72	68	35	15	7											
20-404	104B	S22-84.0-85.5	84.0-85.5	100	100	100	100	100	100	100	100	100	100	93				46	25		30.5			CL	Lean Clay
20-405	104B	S03-104.0-105.5	104.0-105.5							100	97	48	15	9							27.1				
20-406	104B	S34-114.0-115.5	114.0-115.5	100	100	100	100	98	96	93	90	66	24	15							20.5				

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.1

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-113B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI		%	pcf	%		
20-407	113B	C01-7.5-8.0	7.5-8.0										100	97				47	23		23.6			CL	Lean Clay
20-408	113B	C03-17.0-17.5	17.0-17.5	100	100	100	100	100	100	100	100	100	100	94				48	25		20.5			CL	Lean Clay
20-409	113B	C04-22.0-22.5	22.0-22.5										100	82				41	11		26.6			ML	Silt with sand
20-410	113B	S06-30.0-31.50	22.0-22.5	100	100	100	100	100	100	99	99	98	96	62							34.3				
20-411	113B	C07-38.0-38.5	38.0-38.5				100	98	95	94	92	67	41	33							22.8				
20-412	113B	C08-41.5-45.0	41.5-45.0	100	100	100	100	100	100	100	99	58	9	4											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.1

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-116B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI		%	pcf	%		
20-413	116B	C01-6.5-7.5	6.5-7.5										100	88				48	26					CL	Lean Clay
20-414	116B	S02-10.0-11.5	10.0-11.5	100	100	100	100	100	100	100	100	100	100	89				52	31		24.5			CH	Fat Clay
20-415	116B	T02-12.5-14.5	12.5-14.5										100	97				47	22			70.2		CL	Lean Clay
20-416	116B	C04-17.1-19.7	17.1-19.7	100	100	100	100	78	58	43	33	26	21	16											
20-417	116B	S05-25.0-26.5	25.0-26.5							100	99	98	92	81											
20-418	116B	C06-26.5-27.0	26.5-27.0	100	100	100	100	100	100	100	99	97	84	64				29	11					CL	Sandy Lean Clay
20-419	116B	S08-40.0-41.5	40.0-41.5			100	99	87	78	73	67	41	19	10											
20-420	116B	S12-52.5-54.0	52.5-54.0	100	100	100	100	100	100	100	100	100	100	89				48	20		31.8			ML	Silt
20-421	116B	S13-55.0-56.5	55.0-56.5										100	80											
20-422	116B	S15-60.3-61.1	60.3-61.1	100	100	100	100	100	100	100	100	100	100	87				49	24					CL	Lean Clay

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.:

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-120B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS												HYDROMETER									
				GRAVEL					SAND							SILT & CLAY									
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-423	120B	C01-8.5-9.0	8.5-9.0										100	99				67	44		23.3			CH	Fat Clay
20-424	120B	T01-10.0-12.0	10.0-12.0	100	100	100	100	100	100	100	100	100	100	99				50	25		2 .	98.4		CH	Fat Clay
20-425	120B	C02-12.0-15.0	12.0-15.0										100	99				54	33		22.4			CH	Fat Clay
20-426	120B	S02-15.0-16.5	15.0-16.5	100	100	100	100	100	100	100	100	100	100	94						2.1					
20-427	120B	S03-20.0-21.5	20.0-21.5										100	86				37	13					CL	Lean Clay
20-428	120B	S05-32.5-34.0	32.5-34.0	100	100	100	100	100	100	100	99	99	93	69							35.5				
20-429	120B	C11-46.5-47.0	46.5-47.0					100	99	97	87	46	30	22					NP		13.4			SM	Silty sand
20-430	120B	S11-57.5-59.0	57.5-59.0	100	100	100	100	100	100	100	99	69	17	8							25.4				

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.:

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-121B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS												HYDROMETER									
				GRAVEL					SAND							SILT & CLAY									
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-431	121B	G02-3.5-4.0	3.5-4.0										100	91				46	21		17.6			CL	Lean Clay
20-432	121B	C01-6.5-7.0	6.5-7.0	100	100	100	100	100	100	100	100	100	100	98				60	35		20.8			CH	Fat Clay
20-433	121B	C05-26.5-27.0	26.5-27.0							100	99	98	94	83				35	17		19.6			CL	Lean Clay with sand
20-434	121B	C08-41.5-42.0	41.5-42.0	100	100	100	100	100	100	100	100	100	100	85				31	5					ML	Silt
20-435	121B	S10B-50.8-51.3	50.8-51.3						100	99	98	74	49	31											
20-436	121B	C10-51.5-55.0	51.5-55.0	100	100	100	100	100	100	100	99	90	68	43											
20-437	121B	S11-55.0-56.5	55.0-56.5							100	99	54	18	13											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.:

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-103B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-448	103B	S02-7.0-8.5	7.0-8.5							100	99	99	92	79				38	20		13.6			CL	Lean Clay with sand
20-449	103B	S04-14.5-16	14.5-16.0	100	100	100	100	100	100	100	100	99	94	90				36	16		25.3			CL	Lean Clay
20-450	103B	T02-17.0-19.0	17.0-19.0								100	95	76	64				27	11		22.9	96.84		CL	Sandy Lean Clay
20-451	103B	S06-25.0-26.5	25.0-26.5	100	100	100	100	100	100	99	95	92	80	61					IM						
20-452	103B	S10-35.0-36.5	35.0-36.5				100	99	97	93	85	66	54	52											
20-453	103B	S13-42.5-44.0	42.5-44.0	100	100	100	99	89	84	79	72	61	56	54											
20-454	103B	S25-72.5-74.0	72.5-74.0						100	99	97	96	94	92				53	26		31.8			CH	Fat Clay
20-455	103B	S27-75.6-76.5	75.6-76.5	100	100	100	100	99	99	99	99	87	73	68											
20-456	103B	S31-82.5-84.0	82.5-84.0										100	99				43	16		31.1			ML	Silt
20-457	103B	S42-110.0-115.0	110.0-115.0	100	100	100	96	92	91	91	90	89	84	73											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.:

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-106B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-458	106B	S02-7.5-9.0	7.5-9.0						100	99	99	99	94	85				40	21		19.5			CL	Lean Clay with sand
20-459	106B	T01-10.0-12.0	10_12	100	100	100	100	100	100	99	99	99	98	95				39	16		24.5	91.9		CL	Lean Clay
20-460	106B	S03-17.5-19.0	17.5-19.0					100	99	99	98	98	97	95				40	16		27.7			CL	Lean Clay
20-461	106B	T03-20.0-21.8	20.0-21.8	100	100	100	100	100	100	100	100	100	100	98				35	15		21.4	105.3		CL	Lean Clay
20-462	106B	S05-27.5-29.0	27.5-29.0				100	98	98	98	97	95	82	67				23	2					ML	Sandy Silt
20-463	106B	S09-37.5-39.0	37.5-39.0	100	100	100	100	99	99	98	95	86	61	57											
20-464	106B	S22-65.0-66.5	65.0-66.5			100	93	80	76	72	68	60	55	53											
20-465	106B	S23-67.5-69.0	67.5-69.0	100	100	100	100	100	100	99	99	98	97	96				57	28		37.6			CH	Fat Clay
20-466	106B	S25-72.5-73.6	72.5-73.6							100	99	96	90	84											
20-467	106B	S30-82.5-84.0	82.5-84.0	100	100	100	100	100	100	100	99	97	94	93				42	19					CL	Lean Clay
20-468	106B	S34-90.0-91.5	90.0-91.5						100	99	97	83	66	60											
20-469	106B	S38-100.0-101.5	100.0-101.5	100	100	100	100	98	97	93	83	61	55	53											
20-470	106B	S40-107.5-108.6	107.5-108.6				100	99	98	98	98	97	71	56											
20-471	106B	S42-112.5-114.0	112.5-114.0	100	100	100	83	57	54	52	50	47	44	43											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.2

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-111B-106B-116B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER															ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT %	DRY DENSITY pcf	ORGANIC CONTENT %	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER											
				GRAVEL					SAND						SILT & CLAY											
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI						
20-472	111B	S01-5.0-6.5	5.0-6.5																IM						
20-473	111B	S02-10.0-11.5	10.0-11.5	100	100	100	100	100	100	100	100	99	97	91				33	14		25.6			CL	Lean Clay
20-474	111B	T01-12.5-14.5	12.5-14.5				100	99	91	72	58	40	21	12											
20-475	111B	C04-21.5-25.0	21.5-25.0	100	100	100	100	100	100	98	96	93	91	80				33	10		29.6			CL	Lean Clay with sand
20-476	111B	T02-27.5-29.0	27.5-29.0							100	97	47	20	8					NP					SP-SM	Poorly graded sand with silt
20-477	111B	C08-36.5-40.0	36.5-40.0	100	100	100	100	99	97	94	90	63	15	7											
20-478	111B	S10-50.0-51.5	50.0-51.5			100	96	95	93	90	87	25	5	3											
20-479	111B	C11-61.5-63.7	61.5-63.7	100	100	100	100	100	99	99	98	96	95	93				48	22					CL	Lean Clay
20-480	111B	C15-81.5-83.3	81.5-83.3					100	99	99	93	64	34	23											
20-483	106B	T02-15.0-17.0	15.0-17.0																		28.8	93			
20-484	116B	T01-7.5-9.5	7.5-9.5										100	92				44	23		19.6	106.9		CL	Lean Clay

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.2,20-18.1A

REMARKS:
20-472-Insufficient material for both gradation and atterberg tests
20-476-Poorly graded sand with nonunifrom water content along the tube.

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-129B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-485	129B	S1-5.5-6.5	5.5-6.5										100	98							3.2		
20-486	129B	S2-7.9-9.0	7.90-9.0	100	100	100	100	100	100	100	100	100	100	98				55	33		27.6		2.8	CH	Fat Clay
20-487	129B	S6-17.5-19.0	17.5-19.0						100	99	99	98	96	91				58	41		24.4			CH	Fat Clay
20-488	129B	S09-25.0-26.5	25.0-26.5	100	100	100	97	97	96	95	92	90	85	74				32	13					CL	Lean Clay with sand
20-489	129B	S10-27.5-29.0	27.5-29.0					100	98	95	92	88	80	68											
20-490	129B	S11-30.0-31.5	30.0-31.5	100	100	100	100	100	99	97	95	92	82	68				33	12		28.5			CL	Sandy Lean Clay
20-491	129B	S12-32.5-34.0	32.5-34.0								100	99	83	49				27	7					SC-SM	Silty, clayey sand
20-492	129B	S15-40.0-41.5	40.0-41.5	100	100	100	100	100	99	97	95	81	53	28											
20-493	129B	S17-50.5-51.5	50.5-51.5				100	90	69	48	34	17	8	5											
20-494	129B	S18-55.5-56.5	55.5-56.5	100	100	100	100	100	99	97	95	93	91	89				51	20		38.5			MH	Elastic Silt

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.3

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-105B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		CONTENT %	pcf	CONTENT %		
20-495	105B	S01-5.0-6.5	5.0-6.5							100	99	98	93	85											
20-496	105B	S02-7.5-9.0	7.5-9.0	100	100	100	100	100	100	100	99	99	97	91				37	17					CL	Lean Clay
20-497	105B	S03-10.0-11.5	10.0-11.5											100				38	19					CL	Lean Clay
20-498	105B	T01-20.0-22.0	20.0-22.0	100	100	100	100	100	100	100	100	95	79	68				28	12					CL	Sandy Lean Clay
20-499	105B	S07-22.5-24.0	22.5-24.0							100	99	95	83	71				31	14		24.1			CL	Lean Clay with sand
20-500	105B	S08B-23.5-26.5	23.5-26.5	100	100	100	100	100	99	97	94	83	56	44											
20-501	105B	T02-27.5-29.5	27.5-29.5					100	99	98	97	96	93	77					NP					ML	Silt with sand
20-502	105B	S11-32.5-34.0	32.5-34.0	100	100	100	100	100	100	100	99	93	79	58					NP					ML	Sandy Silt
20-503	105B	S16-45.0-46.5	45.0-46.5						100	99	96	54	15	8											
20-504	105B	S22-57.5-59.0	57.5-59.0	100	100	100	92	71	48	34	27	17	11	7											
20-505	105B	S25-65.0-66.5	65.0-66.5			100	86	75	65	56	47	26	11	7											
20-506	105B	S28-72.5-74.0	72.5'-74.0'	100	100	100	100	100	100	100	99	97	96	93				44	17					ML	Silt
20-507	105B	S32-80.0-81.5	80.0'-81.5'										100	98				46	17					ML	Silt
20-508	105B	S39-95.0-96.5	95.0-96.5	100	100	100	90	84	80	75	62	33	17	12											
20-509	105B	S45-110.0-111.5	110.0'-115.5'				100	92	87	83	79	67	56	43											
20-510	105B	S50-1224.5-124	122.5'-124.0'	100	100	100	99	97	95	93	86	61	18	10											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.3

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-118B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT %	DRY DENSITY pcf	ORGANIC CONTENT %	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI						
20-526	118B	S01-7.5-9.0	7.5-9.0										100	98				55	37					CH	Fat Clay
20-527	118B	T01-10.0-12.0	10.0-12.0	100	100	100	100	100	100	100	100	100	100	98				54	34					CH	Fat Clay
20-528	118B	S8-30.0-31.5	30.0-31.5							100	99	98	82	79				32	8					ML	Silt with sand
20-529	118B	S12-40.0-41.5	40.0-41.5	100	100	98	80	60	48	41	34	17	9	7											
20-530	118B	S18-55.0-56.5	55.0-56.5								100	99	92	66											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.4

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-128B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT %	DRY DENSITY pcf	ORGANIC CONTENT %	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS												HYDROMETER									
				GRAVEL					SAND							SILT & CLAY									
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI						
20-531	128B	S01-5.0-6.0	5.0-6.3									100	99	98				43	20					CL	Lean Clay
20-532	128B	S02-7.5-9.0	7.5-9.0															34	16						
20-533	128B	S03-15.0-16.5	15.0-16.5								100	99	99	98				56	36					CH	Fat Clay
20-534	128B	S05-20.0-21.5	20.0-21.5															34	15						
20-535	128B	S7-25.0-26.5	25.0-26.5							100	99	98	95	83				26	4					ML	Silt with sand
20-536	128B	S10-32.5-34.0	32.5-34.0	100	100	100	100	100	100	100	99	90	63	50											
20-537	128B	S13-40.0-41.5	40.0-41.5															39	13						
20-538	128B	S15-50.0-51.3	50.0-51.3	100	100	100	93	75	57	36	18	3													

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.4

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-115B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	ASTM D2487 GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-539	115B	S03-9.0-10.5	9.0-10.5					100	99	99	99	92	70	60											
20-540	115B	S04-11.5-13.0	11.5-13.0															44	26		23.7				
20-541	115B	T01-19-21	19.0-21.0										100	99				43	20					CL	Lean Clay
20-542	115B	S08-24.0-25.5	24.0-25.5	100	100	100	100	100	100	99	99	98	98	97				41	19		26.7			CL	Lean Clay
20-543	115B	S09-26.5-28.0	26.5-28.0																		26.3				
20-544	115B	S13-36.5-38.0	36.5-38.0	100	100	100	100	100	100	100	100	99	92	84				43	26		20.2			CL	Lean Clay with sand
20-545	115B	S15-44.0-45.5	44.0-45.5															28	8		25.				
20-546	115B	S18-51.5-53.0	51.5-53.0															40	17		28				
20-547	115B	S21-59.0-60.5	59.0-60.5							100	99	99	89	57											
20-548	115B	S24-66.5-67.9	66.5-67.9	100	100	100	79	57	42	24	12	3	0	0											
20-549	115B	S33-89.0-90.5	89.0-90.5							100	99	94	74	50											
20-550	115B	S35-94.0-95.5	94.0-95.5															37	16						

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.4

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-119B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75 mm	37.5 mm	19 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.6 mm	0.3 mm	0.15 mm	0.075 mm	0.005 mm	0.002 mm	0.001 mm	LL	PI		%	pcf	%		
20-551	119B	S03-9.0-10.5	9.0-10.5					100	99	98	98	97	95	93				50	31		23			CH	Fat Clay
20-552	119B	T01-14.0-16.0	14.0-16.0	100	100	100	100	100	100	100	100	97	95	94				58	33					CH	Fat Clay
20-553	119B	S07-21.5-23.0	21.5-23.0															53	30		25.5				
20-554	119B	S09-26.5-28.0	26.5-38.0																						
20-555	119B	S11-31.5-33.0	31.5-33.0					100	99	99	98	98	98	97				54	33		21.8			CH	Fat Clay
20-556	119B	S13-36.5-38.0	36.5-38.0																		19.1				
20-557	119B	S14-43.5-45.0	43.5-45.0					100	99	98	95	92	86	74				32	6		26.3			ML	Silt with sand
20-558	119B	S18-53.5-55.0	53.5-55.0	100	100	100	100	100	100	100	100	100	98	86											
20-559	119B	S20-58.5-60.0	58.5-60.0			100	86	60	44	26	12	3													
20-560	119B	S26-73.5-75.0	73.5-75.0															41	14		34.5				
20-561	119B	S32-88.5-90.0	88.5-90.0							100	96	66	13	5											
20-562	119B	S34-93.5-95.0	93.5-95.0															54	26		33.5				

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.4

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-126B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER															ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER											
				GRAVEL					SAND						SILT & CLAY											
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M									
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001									
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%		
20-563	126B	S01-5.5-6.5	5.5-6.5								100	99	97	92				47	21		28.9		5.5	CL	Lean Clay
20-564	126B	S02-8.0-9.0	8.0-9.0																				4.3		
20-565	126B	S03-10.0-11.5	10.0-11.5															36	15		24.8				
20-566	126B	S07-20.0-21.5	20.0-21.5	100	100	100	100	100	100	100	100	99	96	90				40	19		20.8			CL	Lean Clay
20-567	126B	S08-22.5-24.0	22.5-24.0							100	99	98	97	96				39	11		17.8			ML	Silt
20-568	126B	S11-30.0-31.5	30.0-31.5	100	100	100	100	100	100	100	100	99	98	92							40.9				
20-569	126B	S12-32.5-34.0	32.5-34.0								100	99	98	85											

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.4

REMARKS:

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CLASSIFICATION SUMMARY ANALYSIS

DIV. OF ENGINEERING
GEOTECH. SERVICES BRANCH
BRYTE SOILS AND CONCRETE LAB.

PROJECT: Big Notch Project **FEATURE:** FW-108B

Lab No.	Borehole No.	Field Sample No.	Depth (ft)	PERCENT FINER														ATTERBERG LIMITS		SPECIFIC GRAVITY	MOISTURE CONTENT	DRY DENSITY	ORGANIC CONTENT	GROUP SYMBOL	ASTM D2487 CLASSIFICATION GROUP NAME
				MECHANICAL ANALYSIS											HYDROMETER										
				GRAVEL					SAND						SILT & CLAY										
				3"	1-1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	5 M	2 M	1M								
				75	37.5	19	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	0.005	0.002	0.001								
				mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	LL	PI		%	pcf	%	SYMBOL	GROUP NAME
20-570	108B	S03-9.0-10.5	9.0-10.5							100	99	99	97	89				36	15		18.7			CL	Lean Clay
20-571	108B	S5-16.5-18.0	16.5-18.0	100	100	100	100	100	100	100	100	99	96	91				38	19		23.6			CL	Lean Clay
20-572	108B	T02-19.0-21.0	19.0-21.0									100	99	97				45	23					CL	Lean Clay
20-573	108B	S06-21.5-23.0	21.5-23.0															43	19		24.6				
20-574	108B	S10-31.5-33.0	31.5-33.0								100	95	74	61				25	8					CL	Sandy Lean Clay
20-575	108B	S13A-40.0-41.2	40.0-41.2															33	8						
20-576	108B	S15-55.5-57.0	55.5-57.0																						
20-577	108B	S18-63.0-64.5	63.0-64.5	100	100	100	95	81	68	47	25	6	1												
20-578	108B	S21-70.5-72.0	70.5-72.0			100	94	80	60	28	7	1													
20-579	108B	M26-83.0-84.5	83.0-84.5															36	9						

DATE: 3/8/2021
INITIAL: AZ
REQUEST NO.: 20-18.4

REMARKS: 20-576: Missing sample

IM - INSUFFICIENT MATERIAL
NP - NON-PLASTIC
NG - NO GOOD

GRADATION CURVES

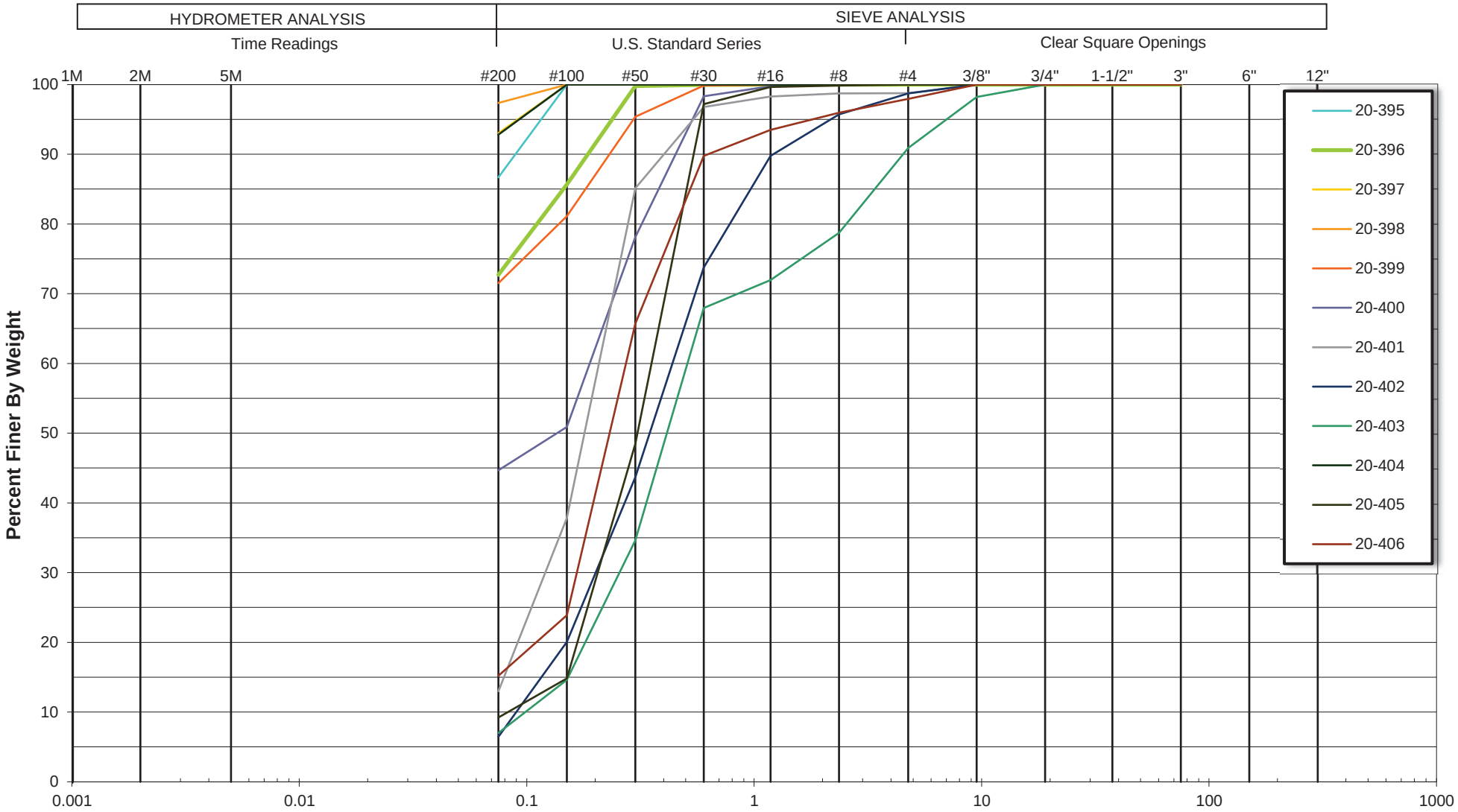
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-104B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

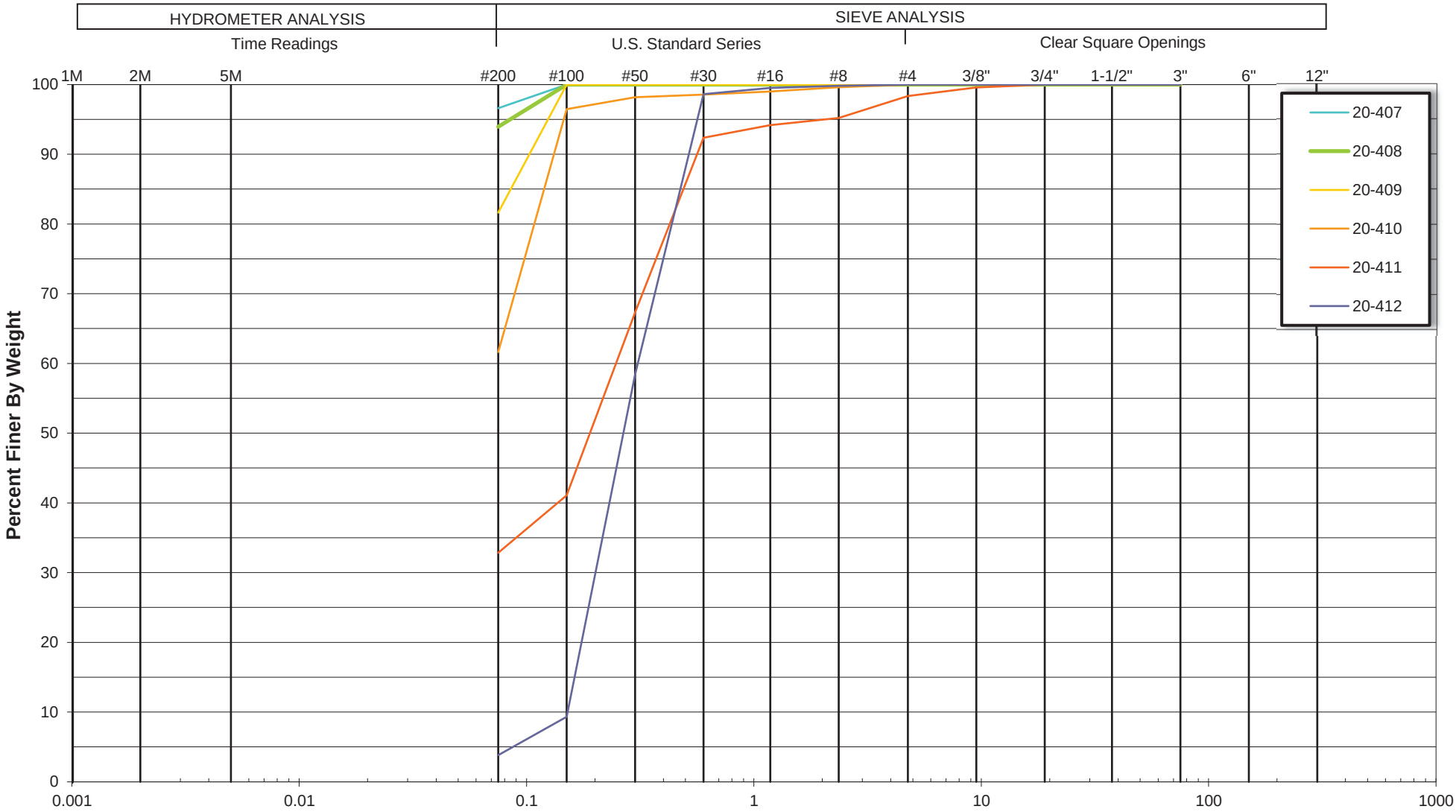
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-113B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

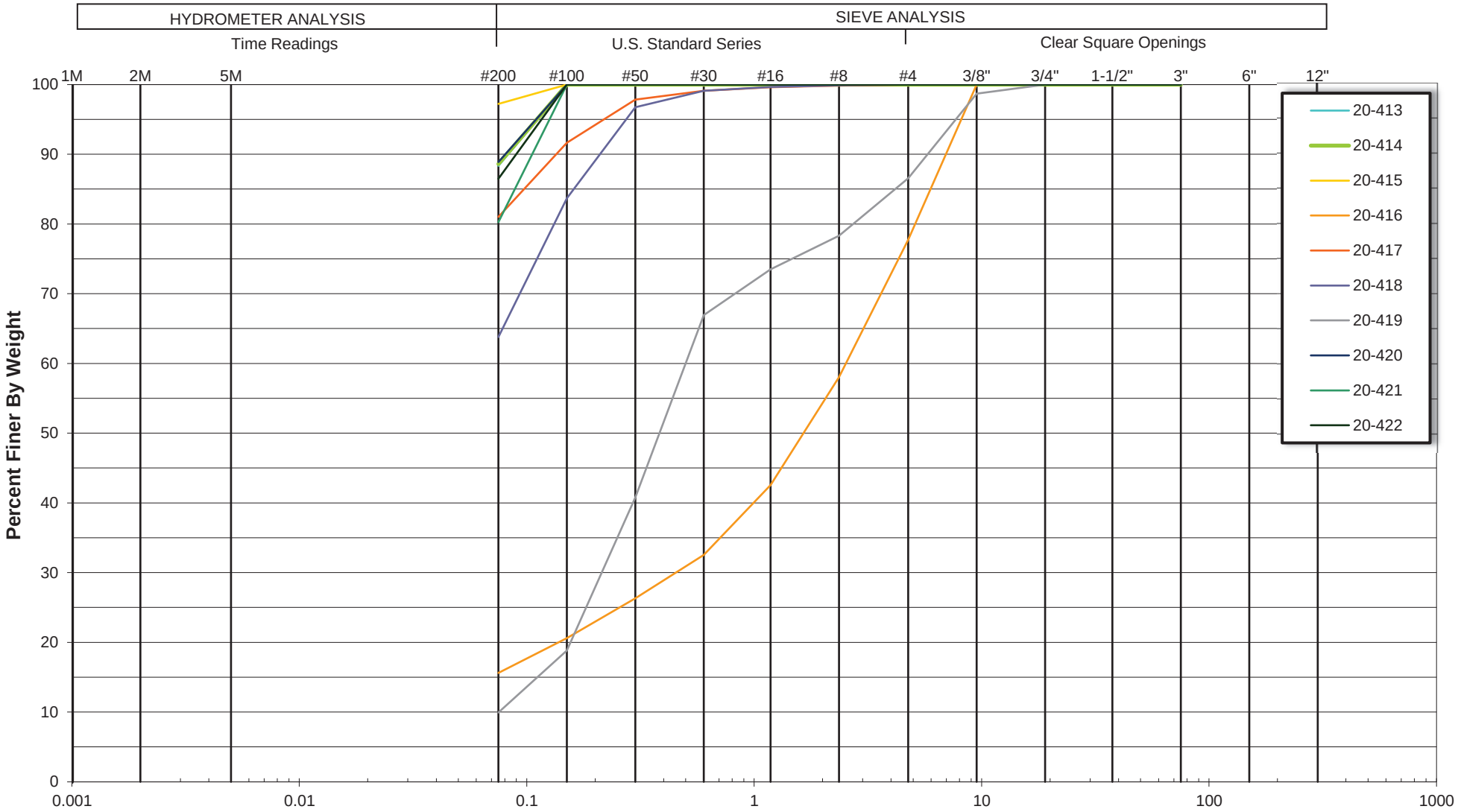
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-116B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

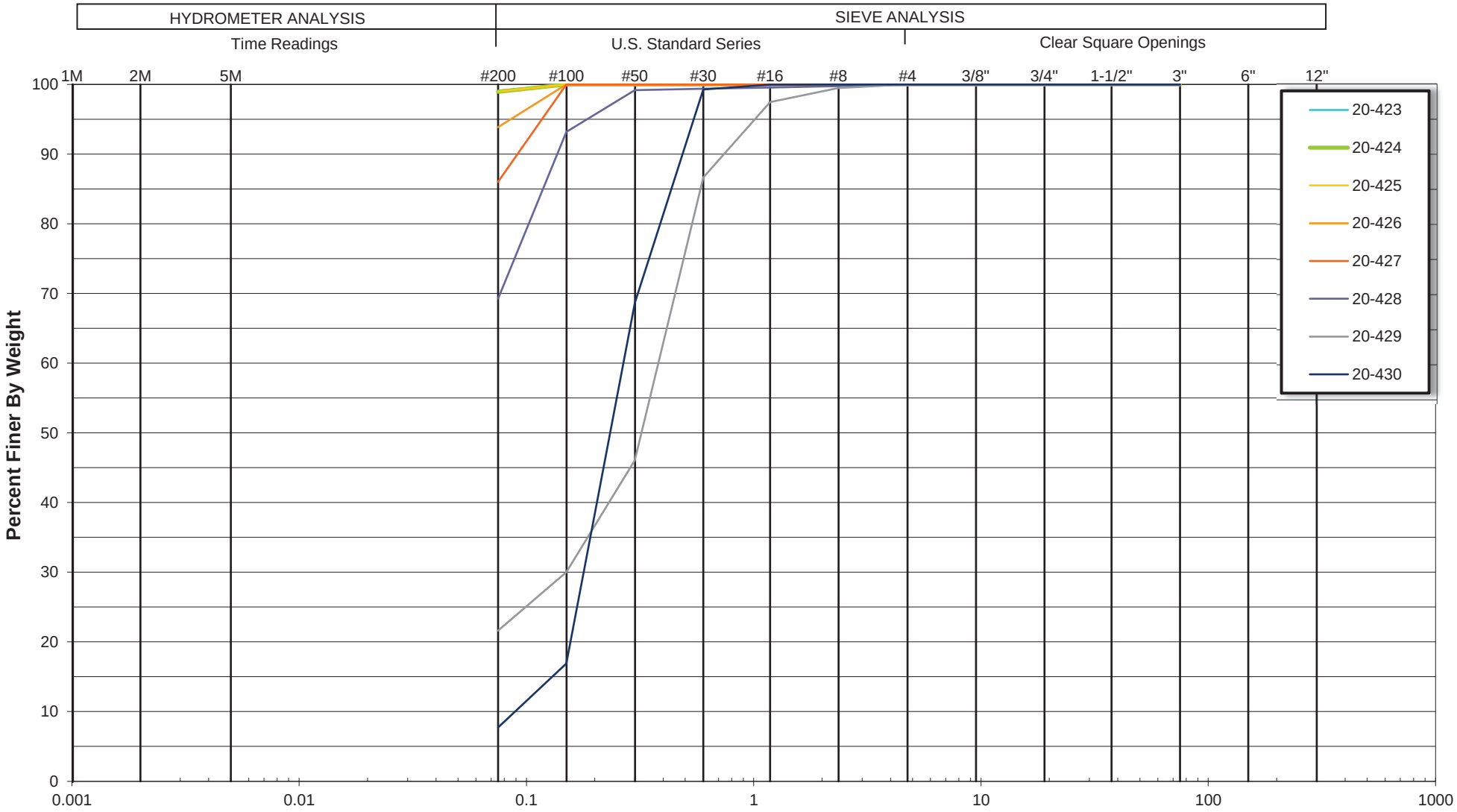
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-120B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

4-120B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

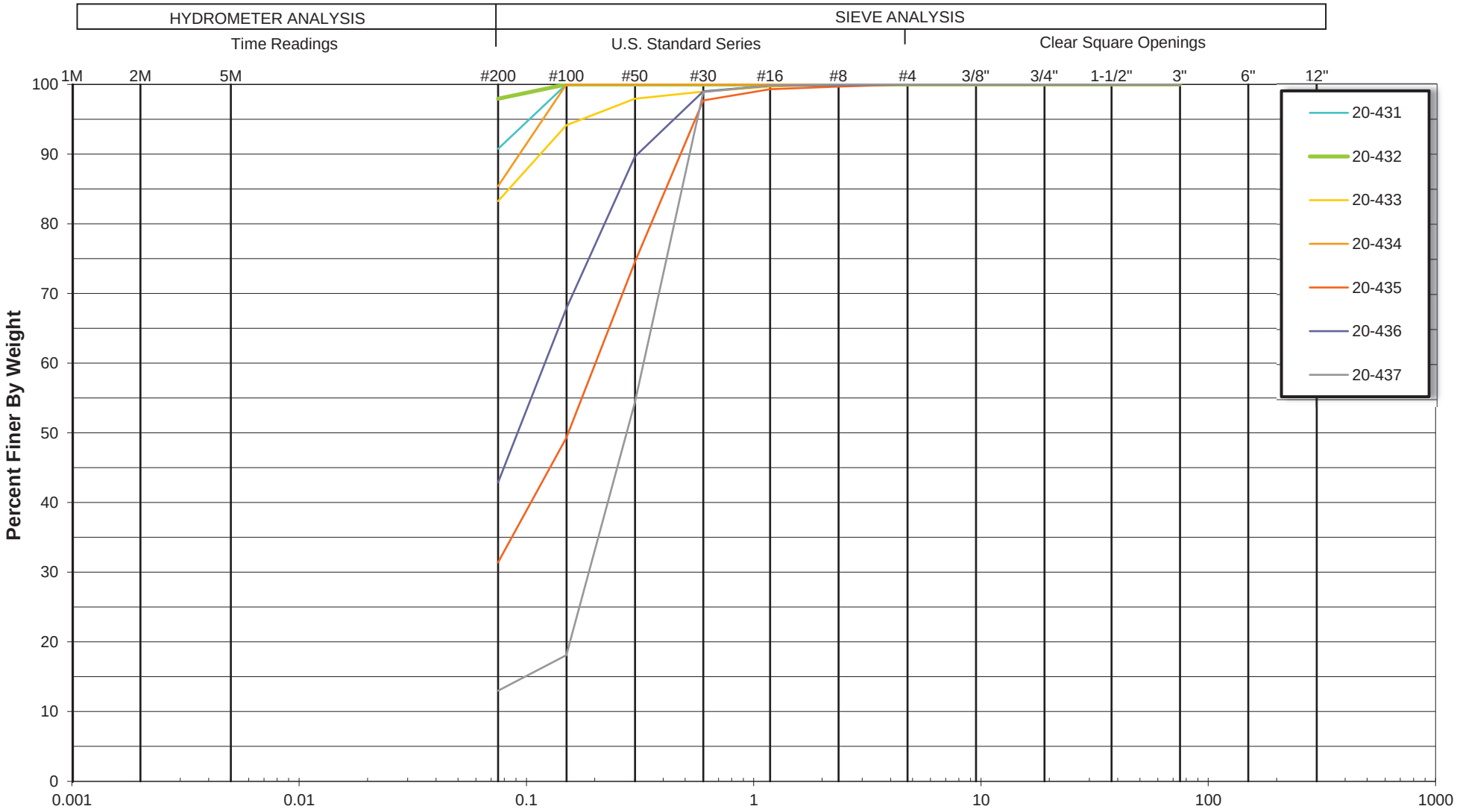
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-121B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

5-121B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

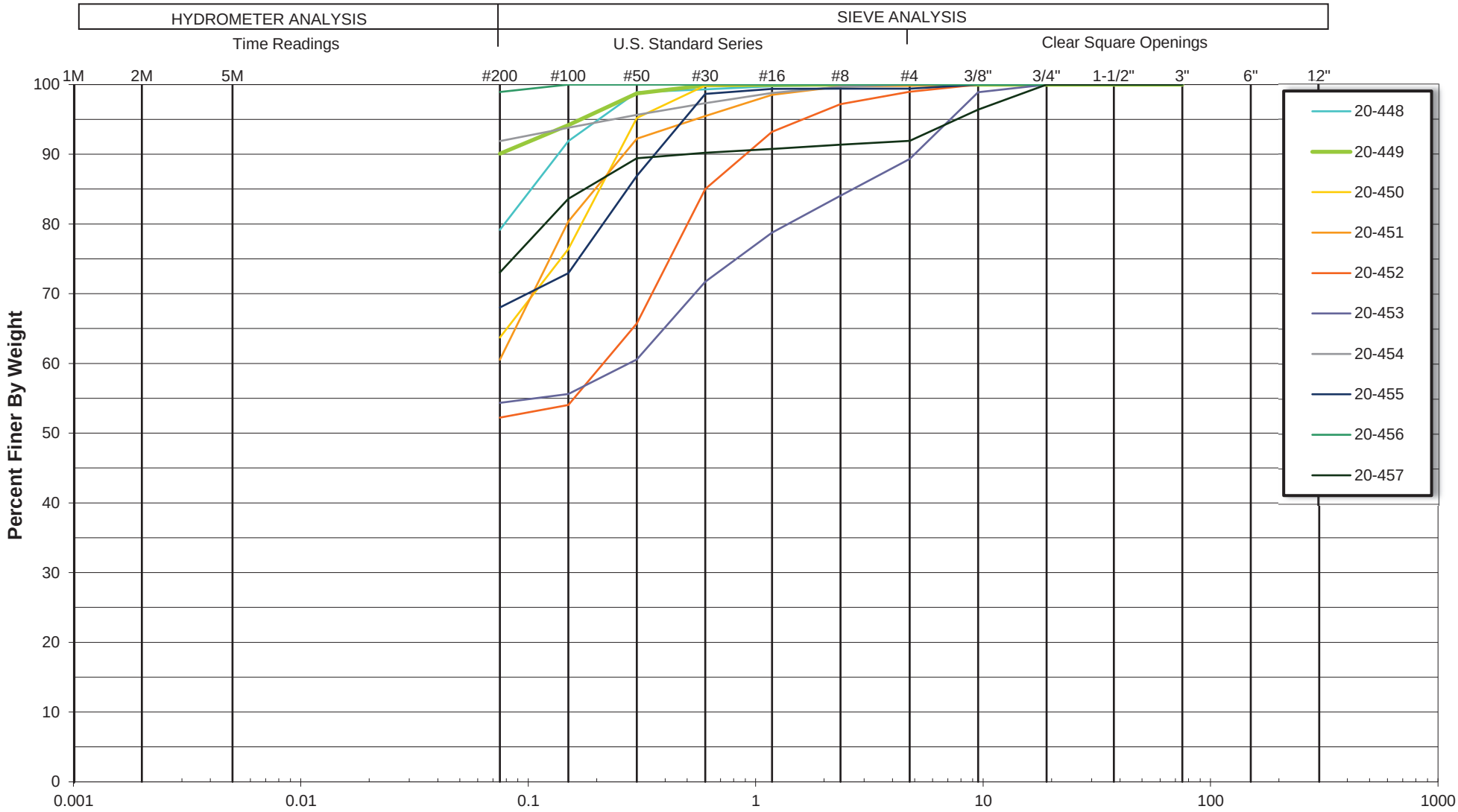
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-103B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

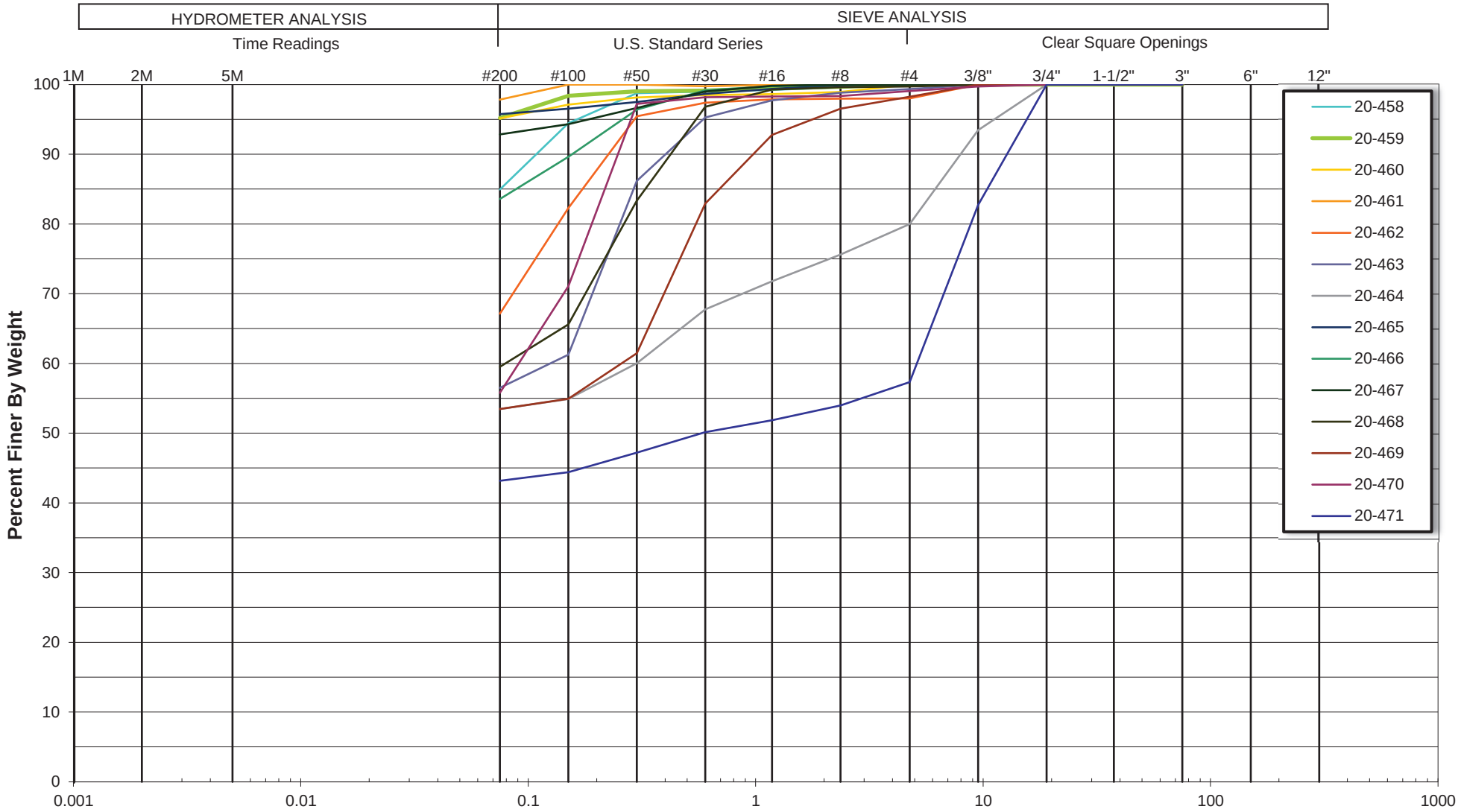
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-106B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

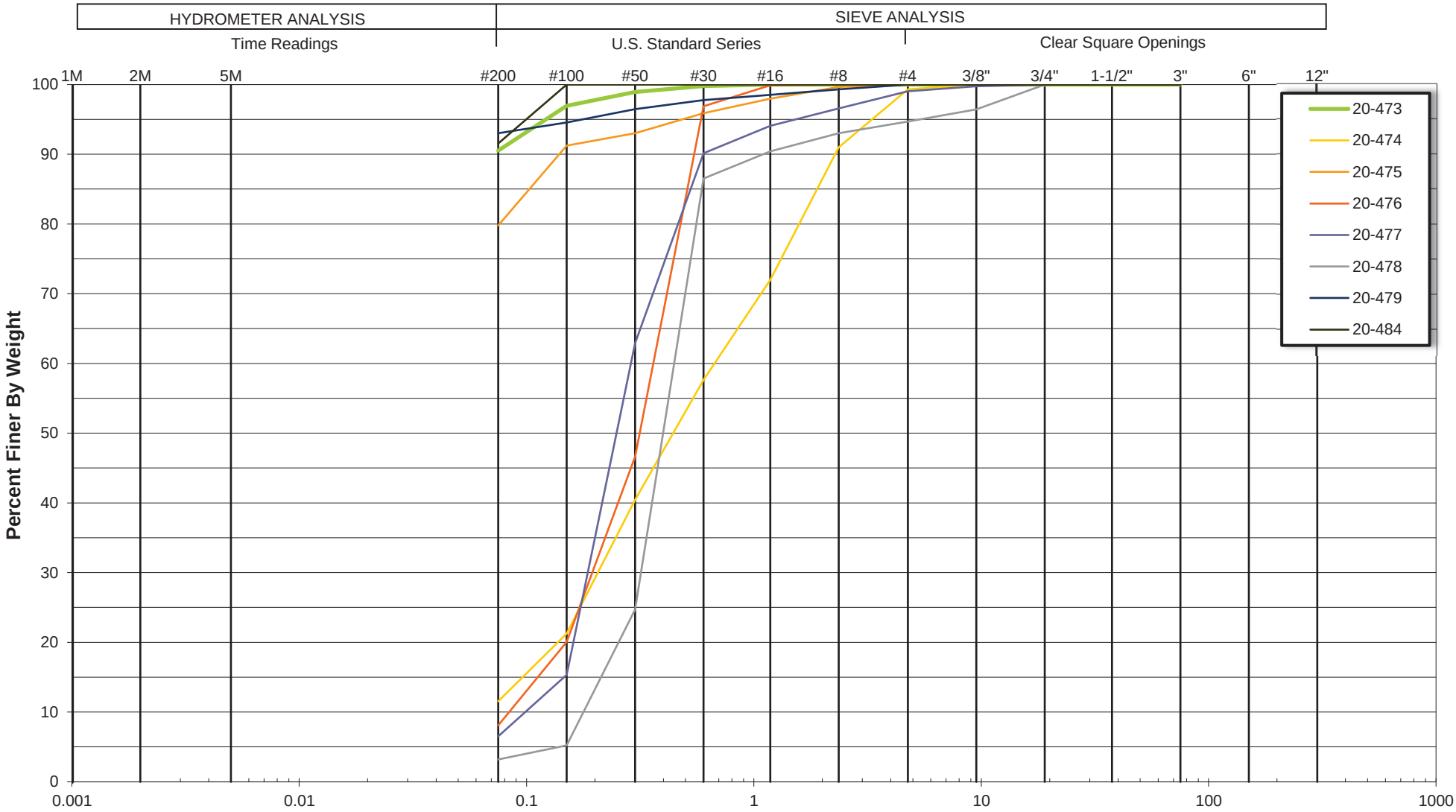
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-111B, 116B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

8-111B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

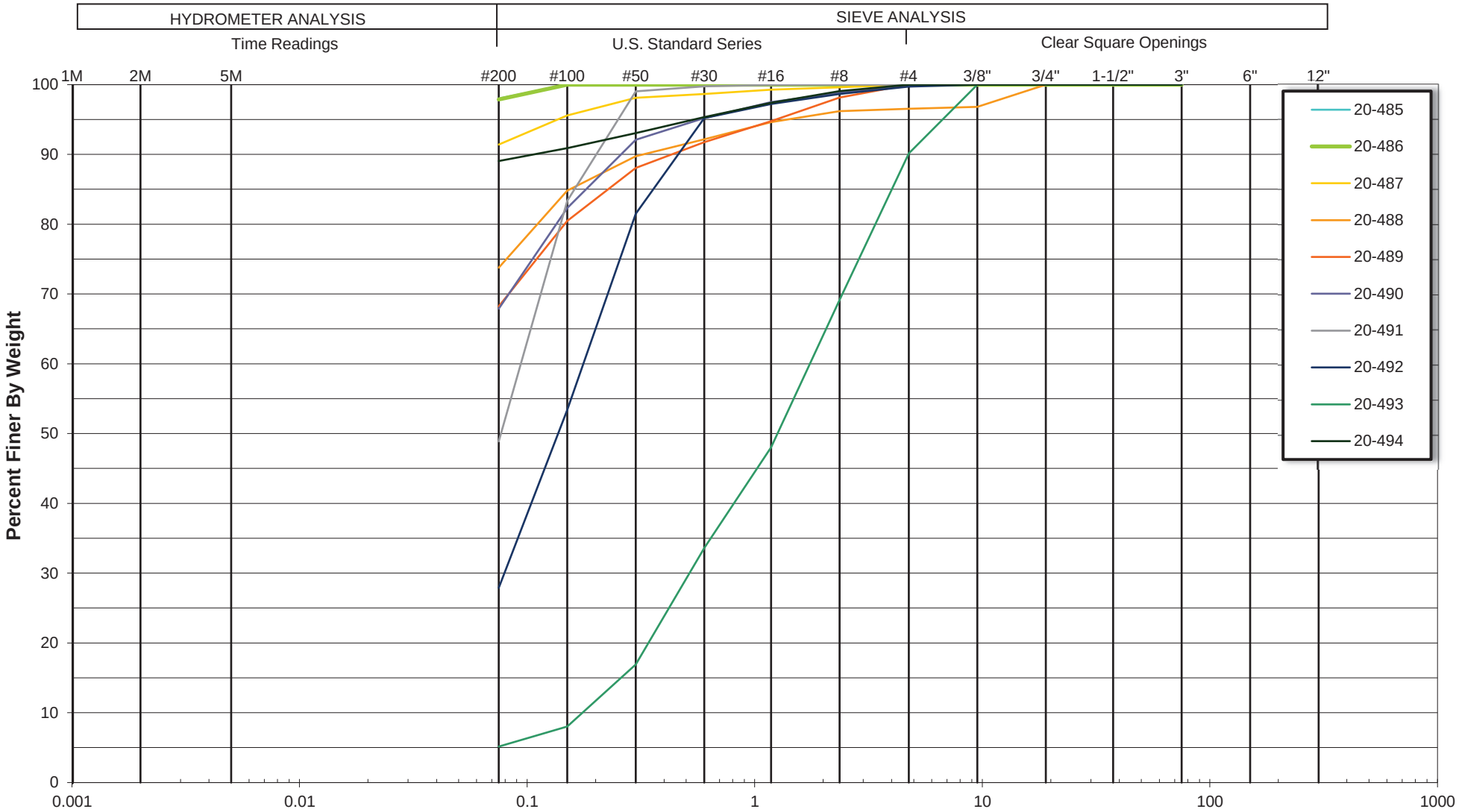
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-129B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

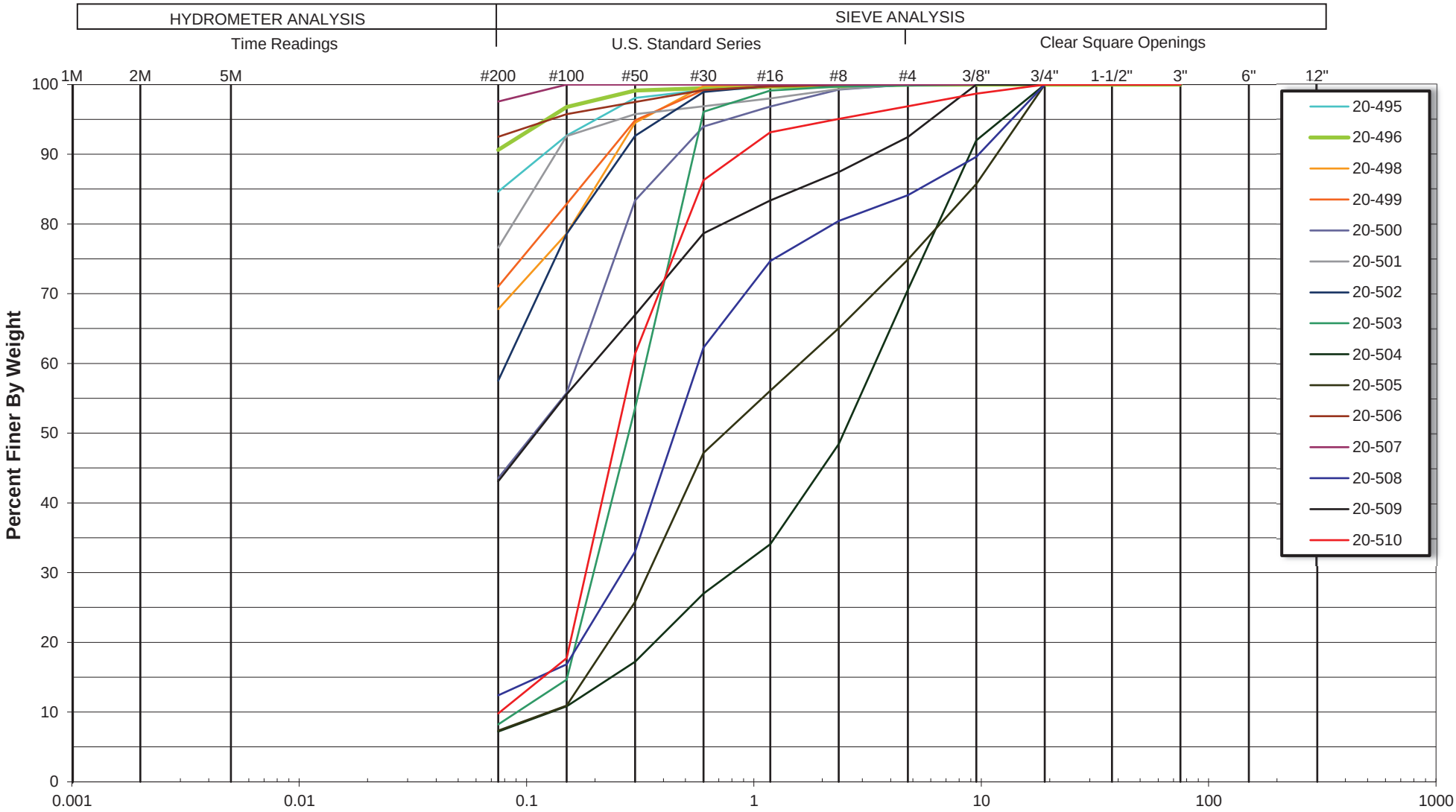
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-105B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

10-105B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

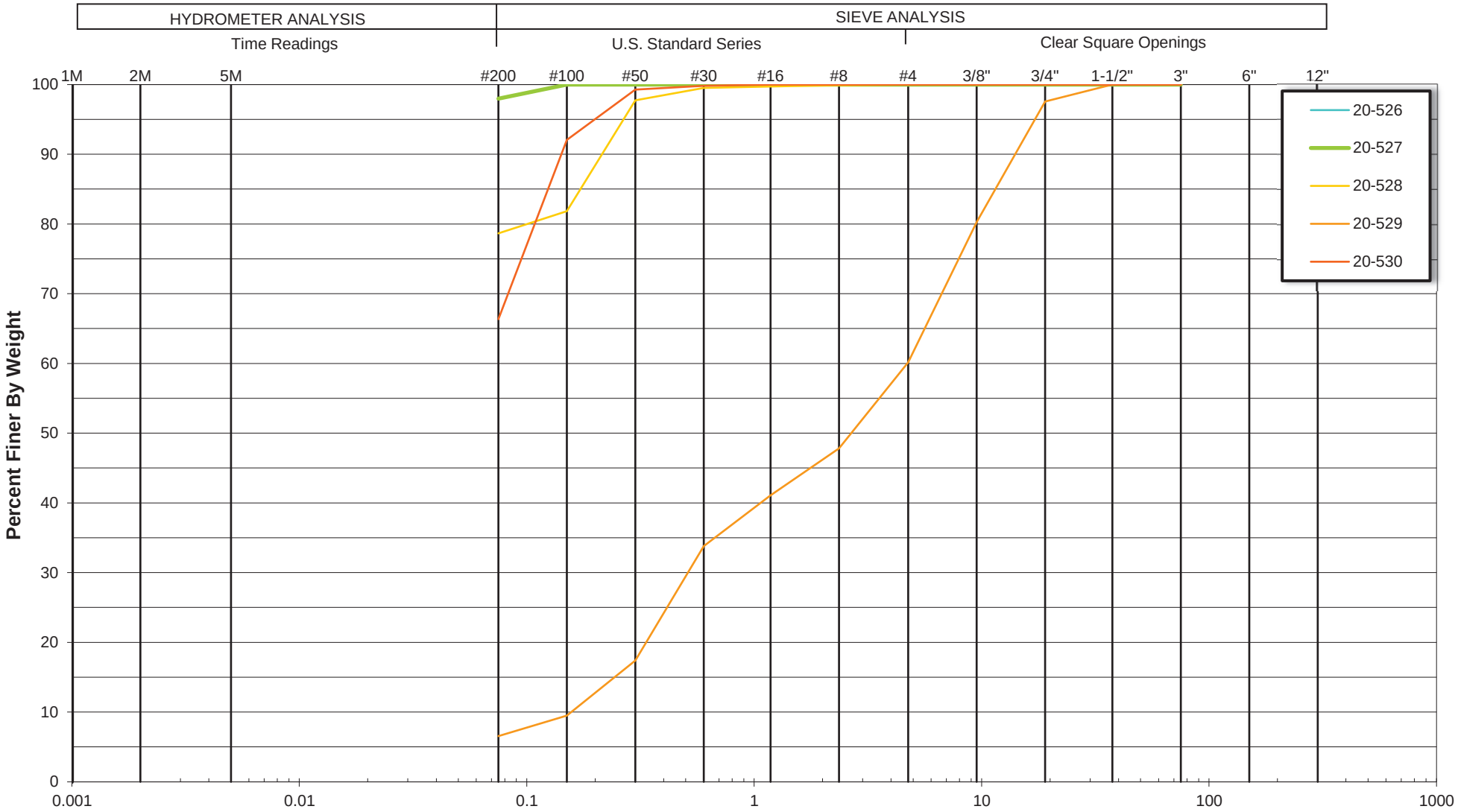
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-118B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

11-118B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

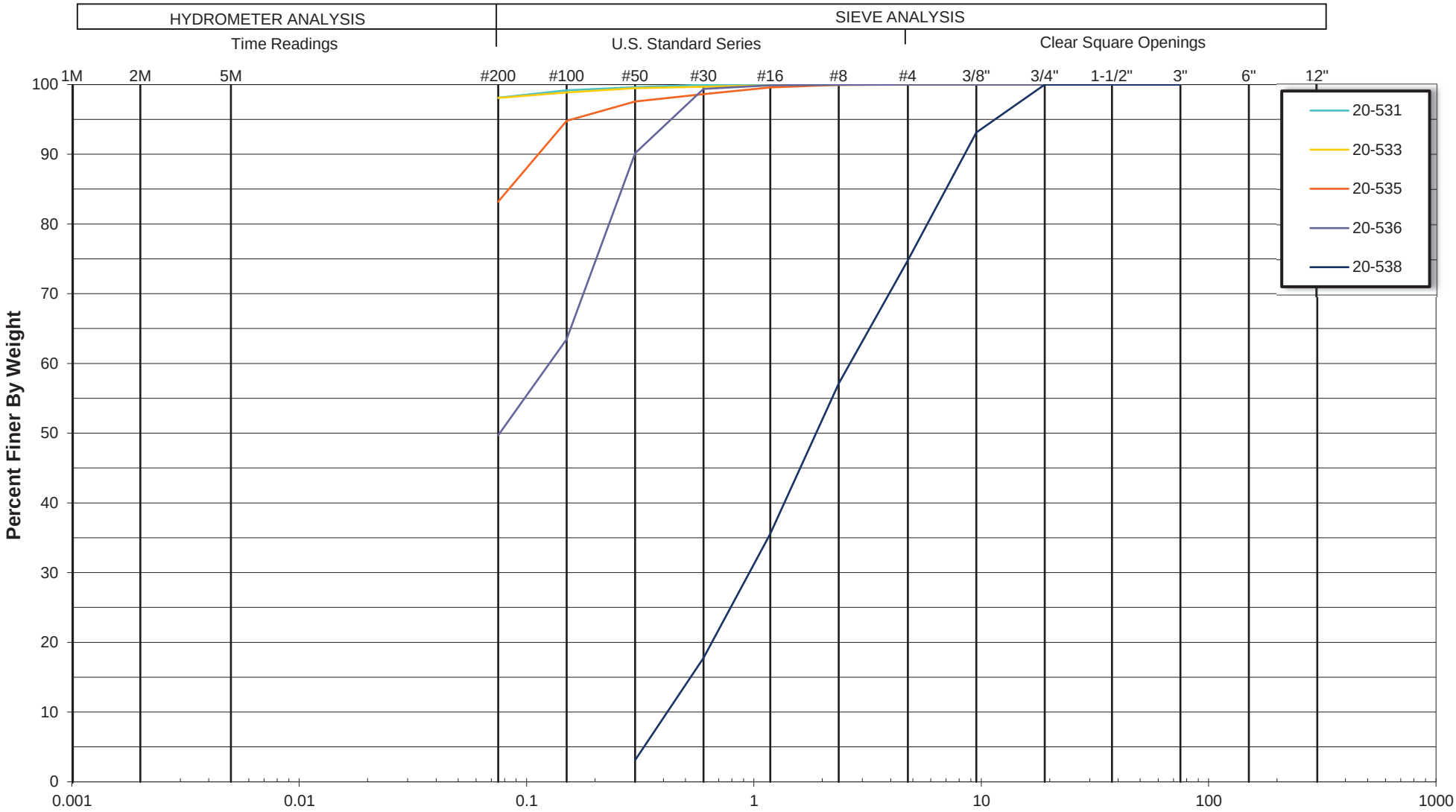
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-128B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

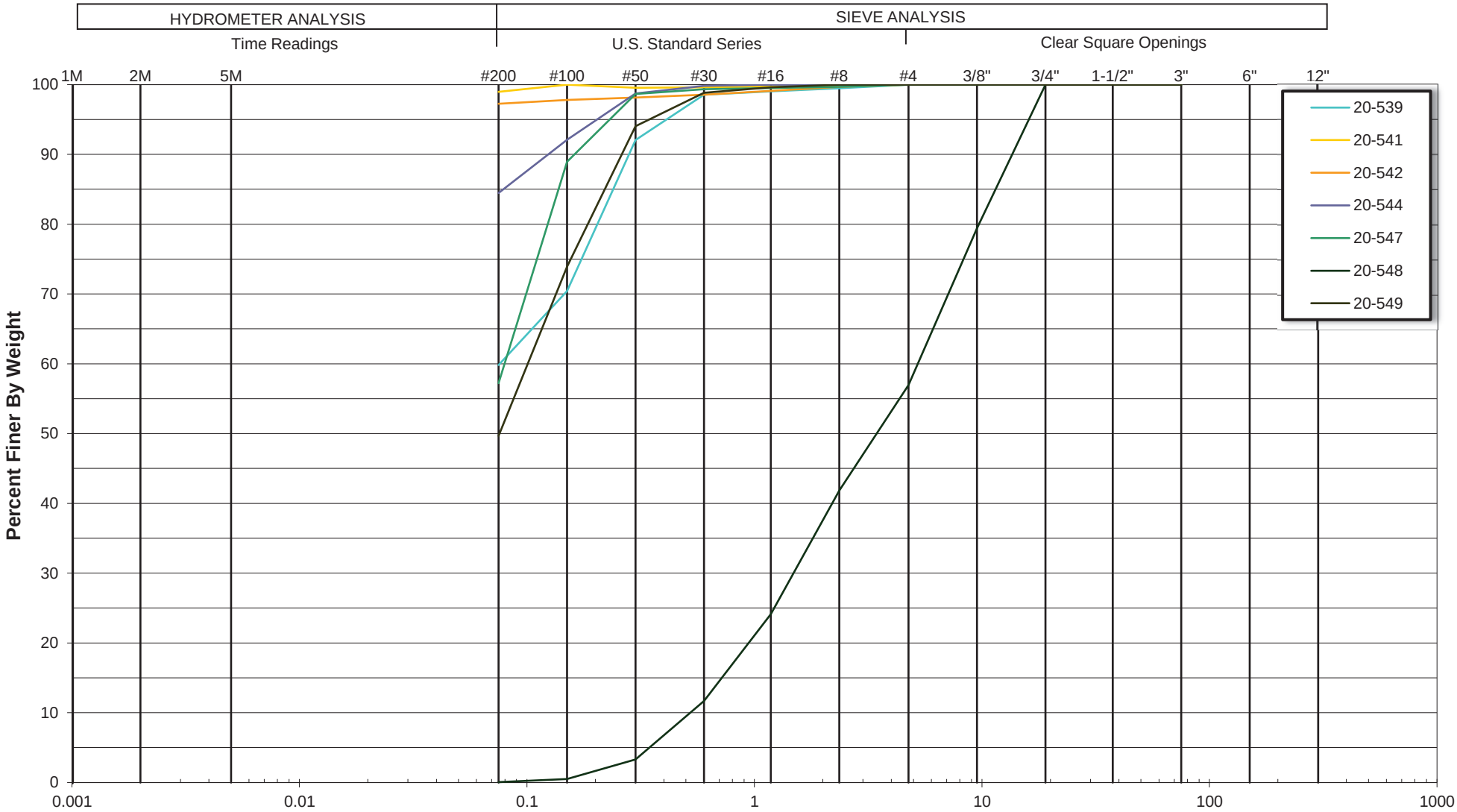
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-115B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

13-115B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

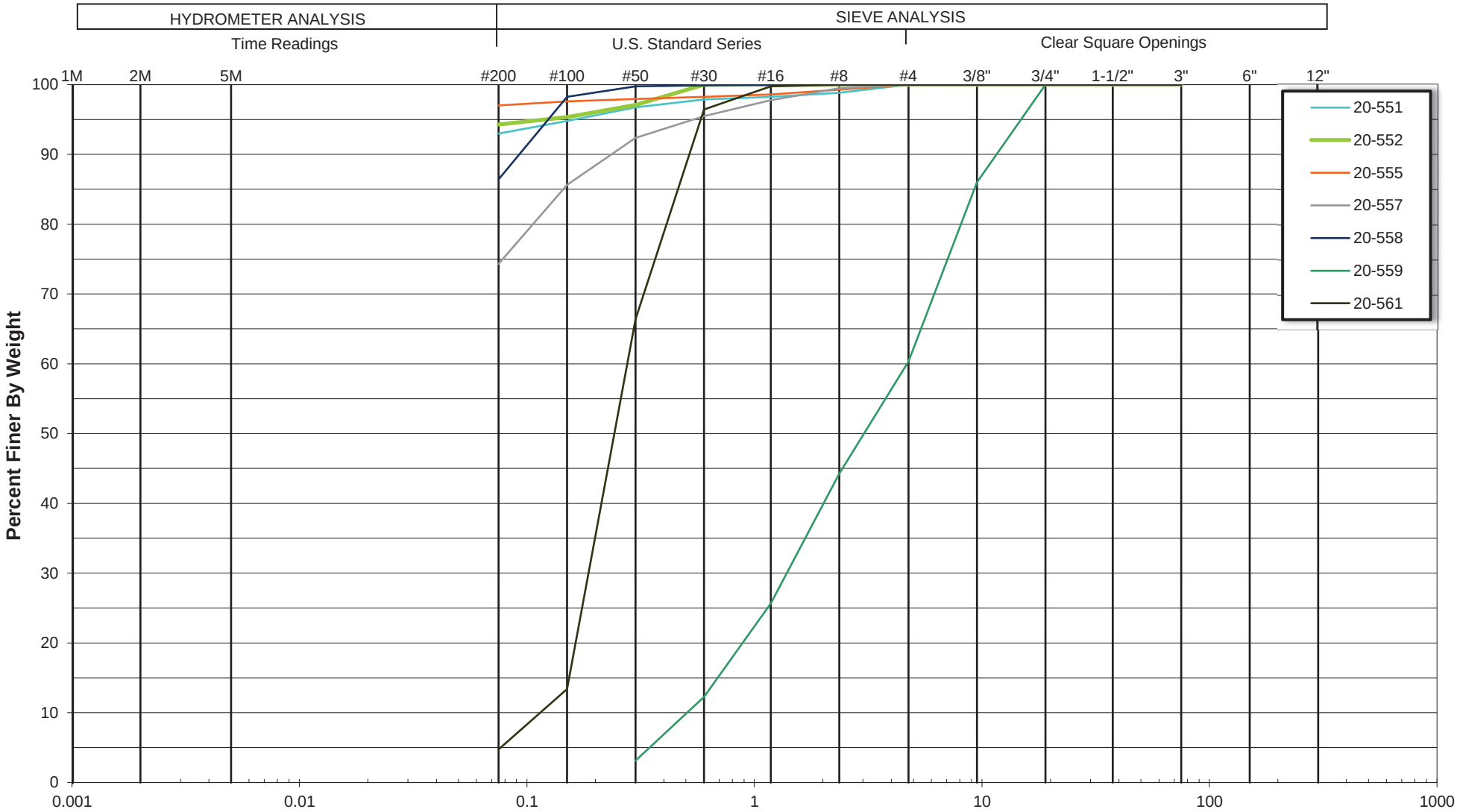
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-119B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

14-119B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

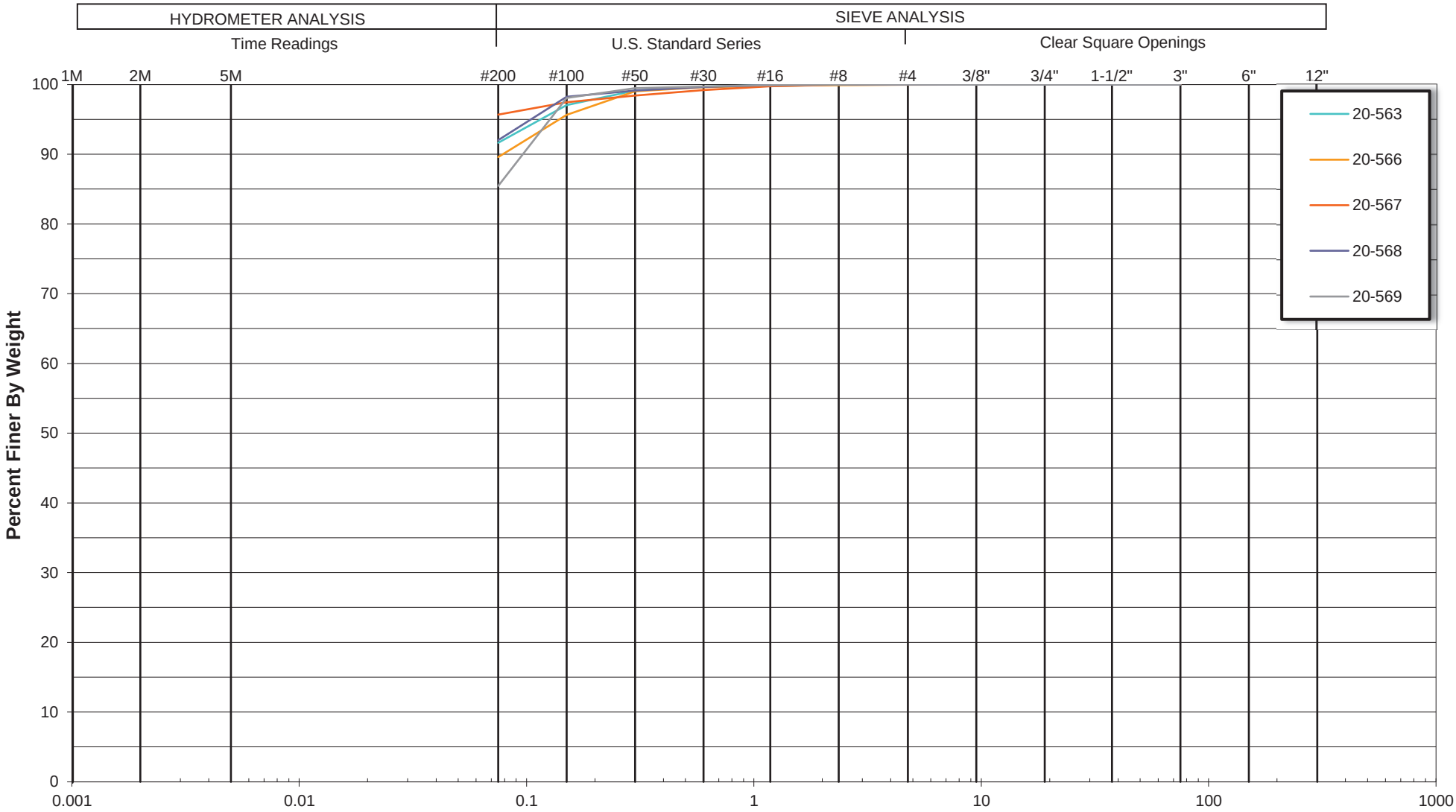
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-126B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

15-126B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

3/10/2021

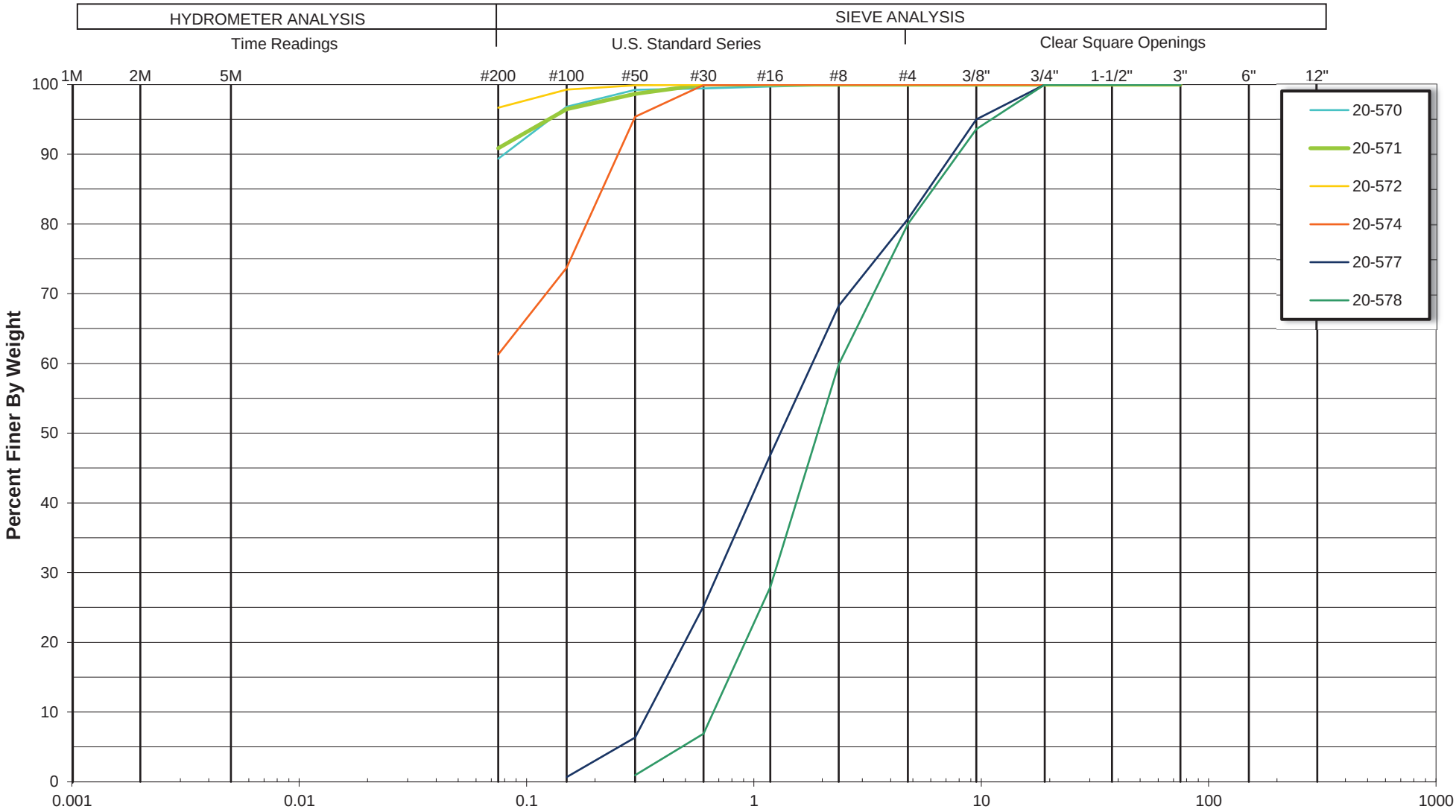
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

State of California
The Natural Resources Agency
Department of Water Resources

Particle Size Analysis Graph

Division of Engineering
Geotech. Services Branch
Dams and Canals Section

FW-108B



Grain Size in Millimeters

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

16-108B-CLASSIFICATION SUMMARY with D2216&D854 two sheet gradation curvexlsm
Gradation Curve

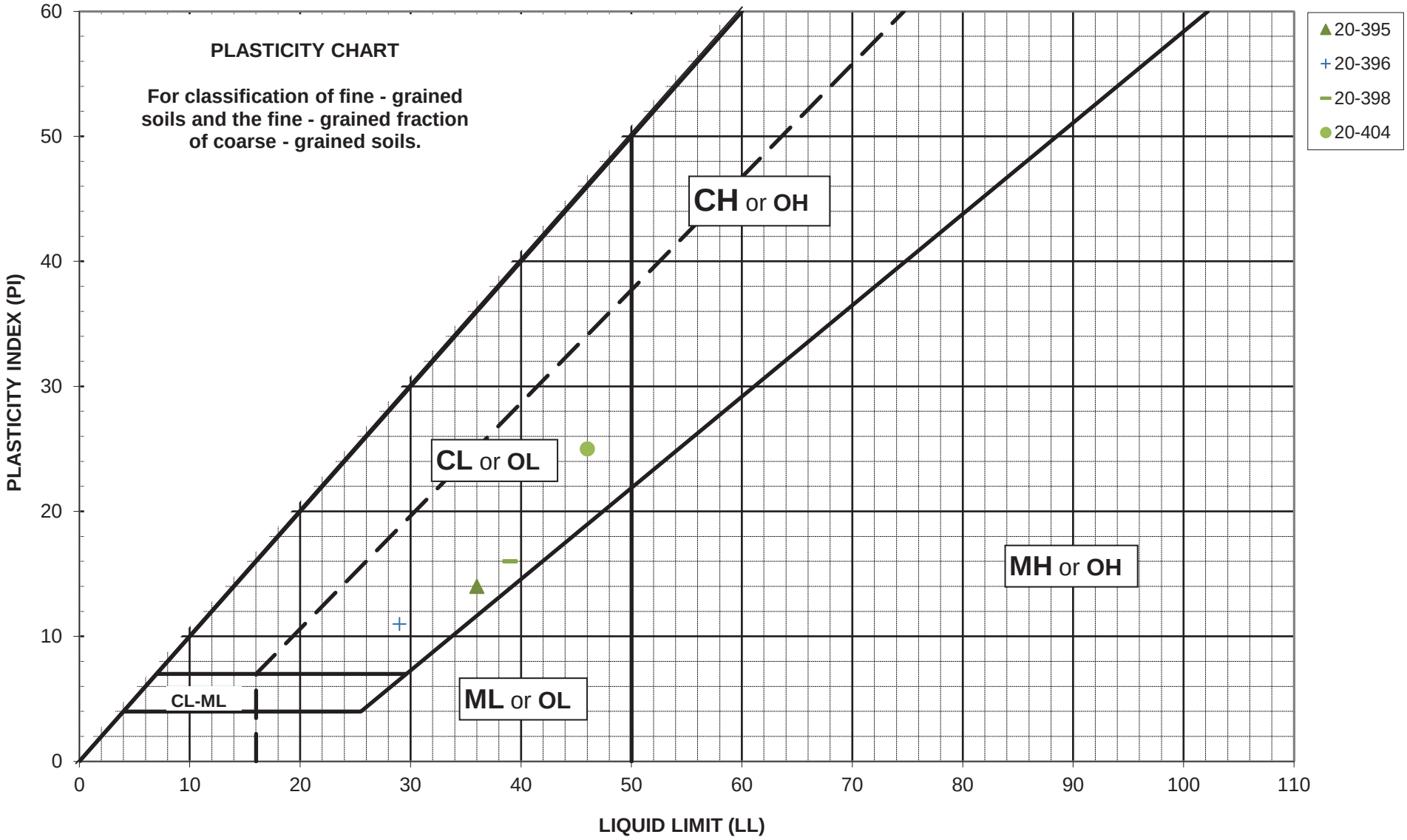
3/10/2021

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

PLASTICITY CHARTS

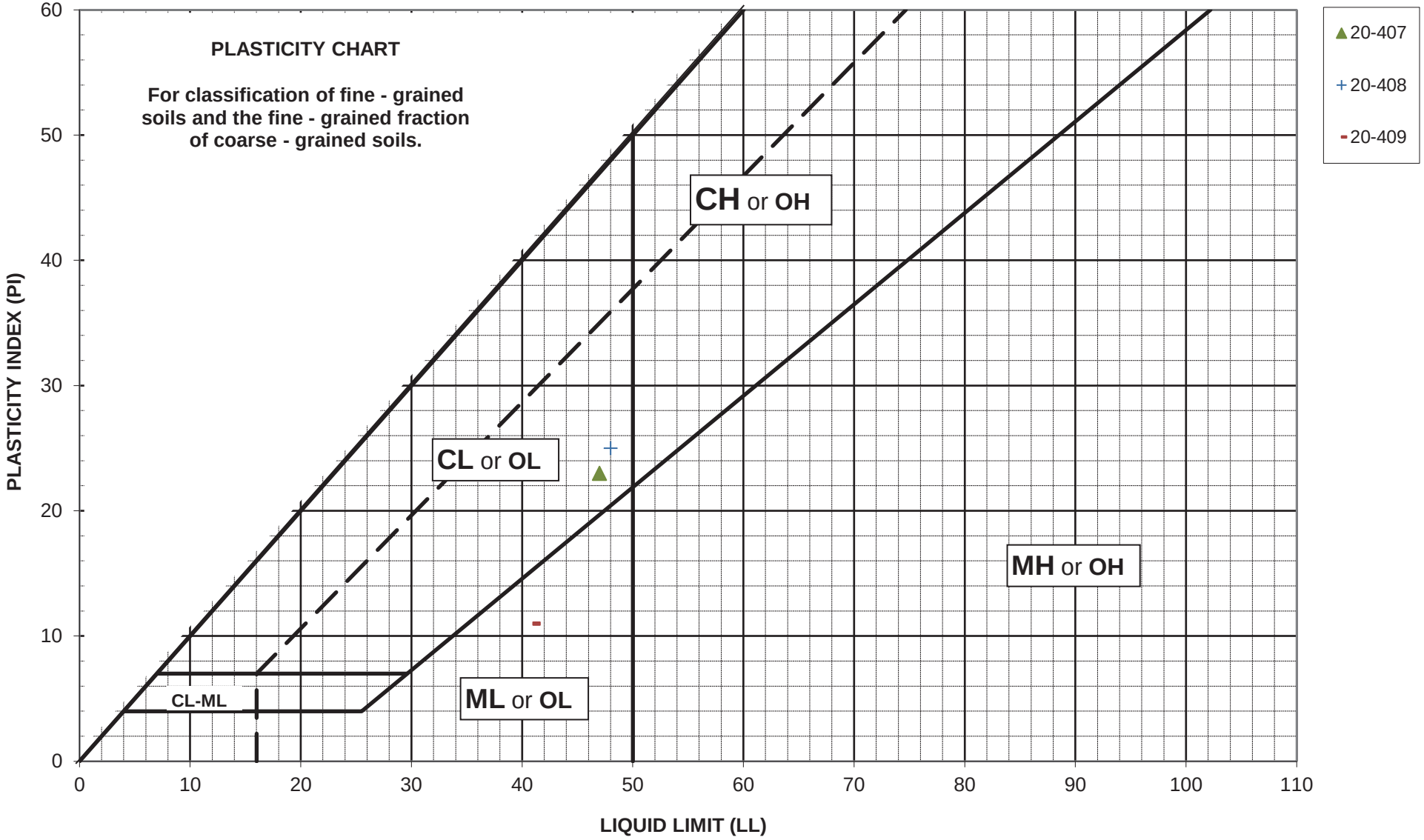
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-104B



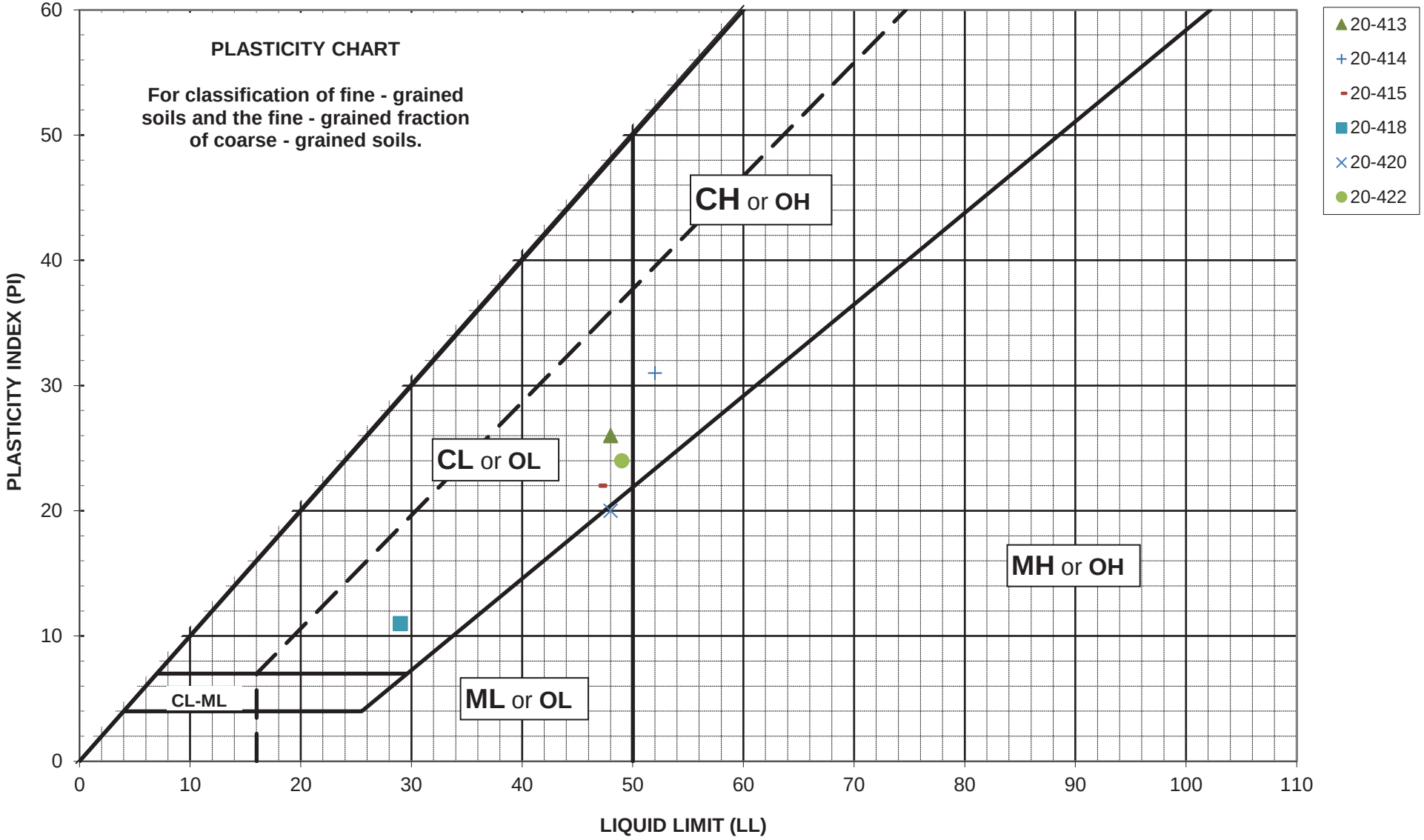
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-113B



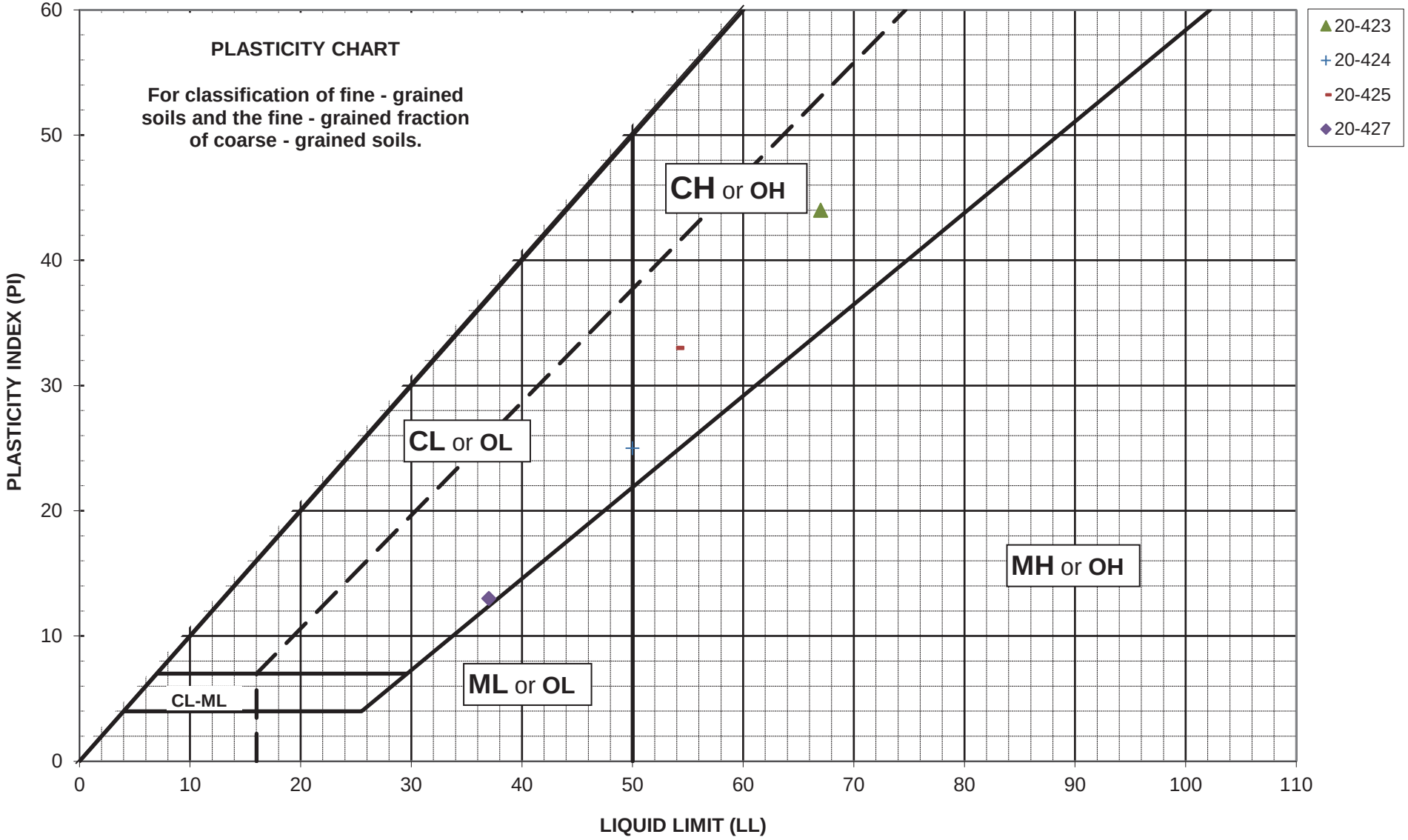
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-116B



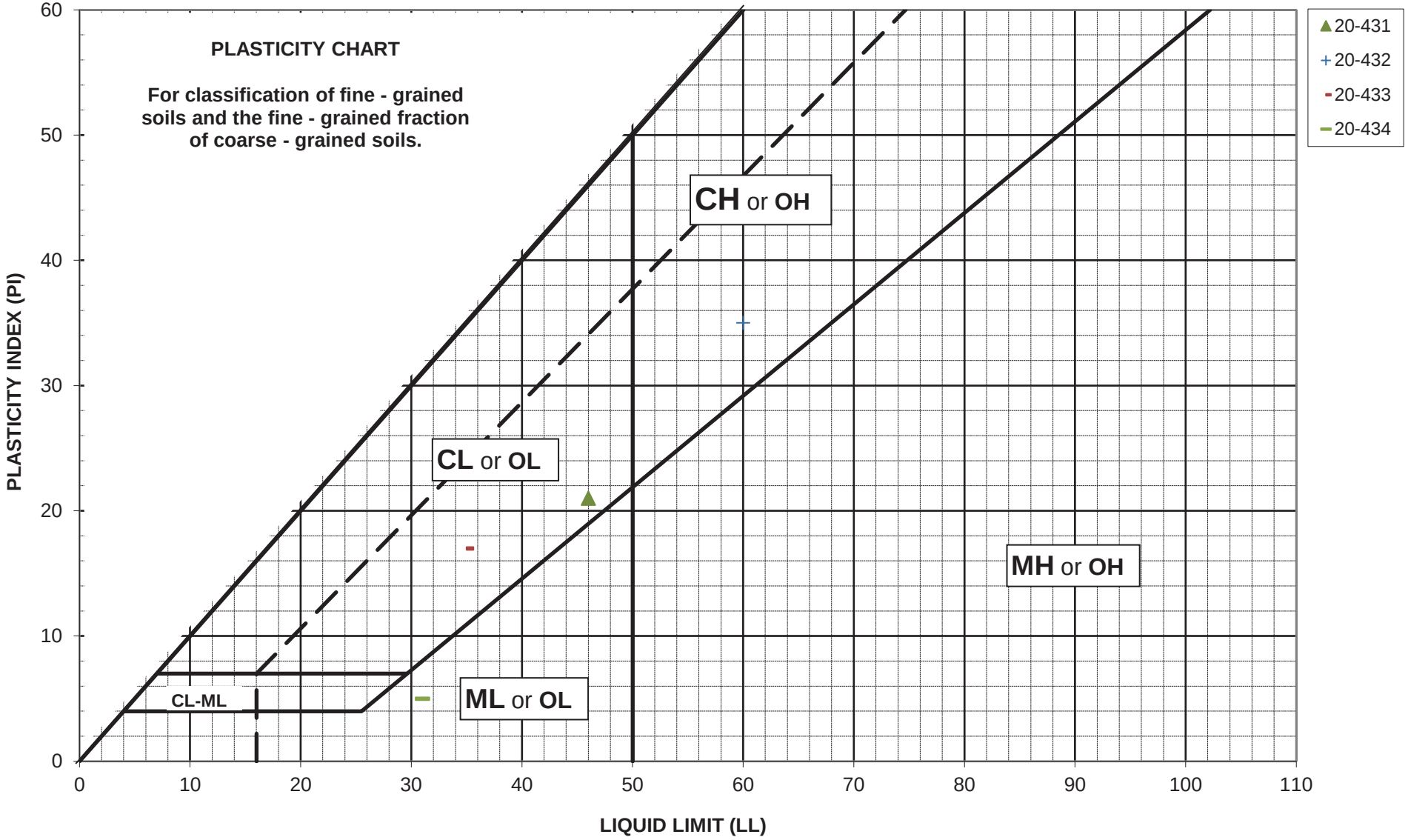
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-120B



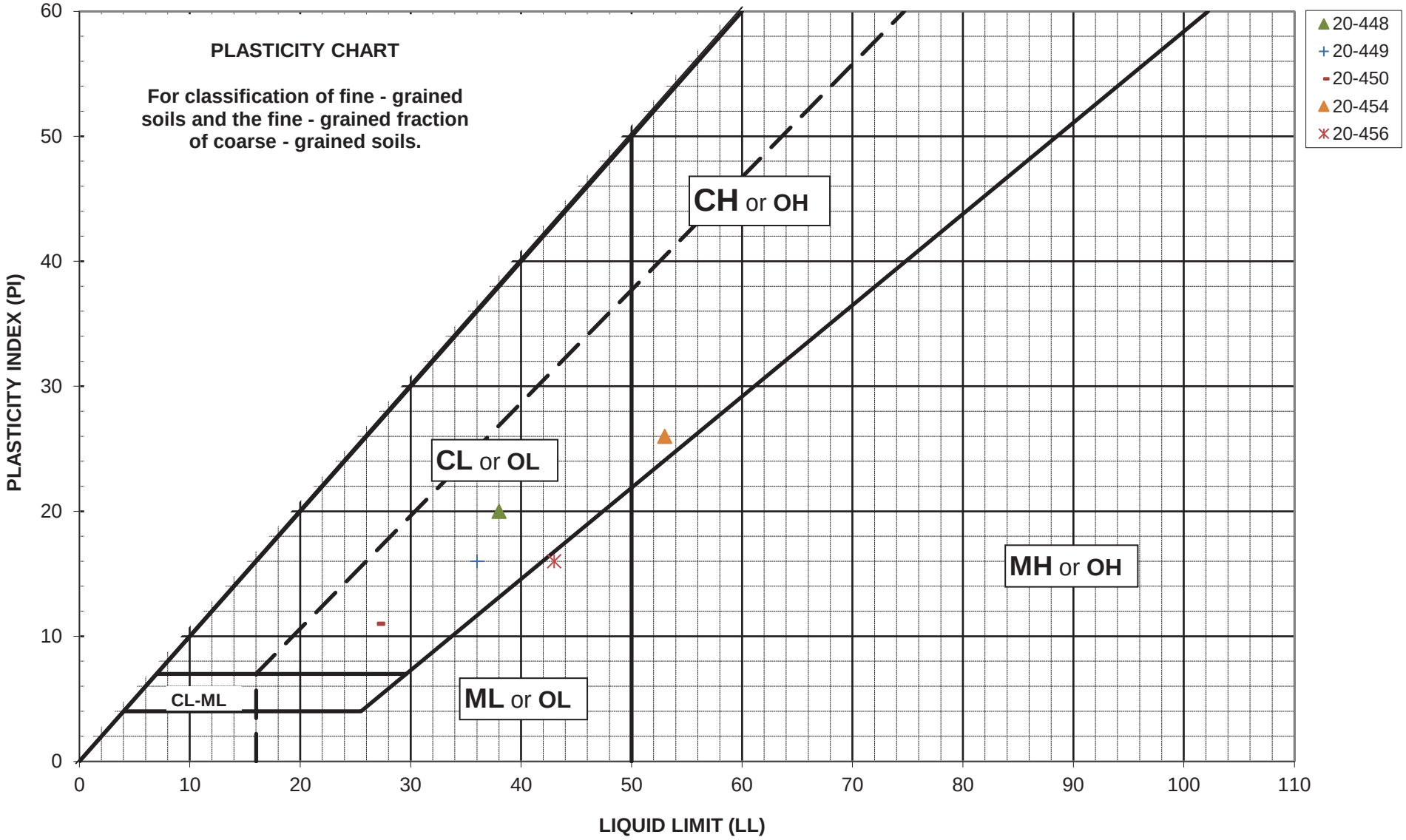
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-121B



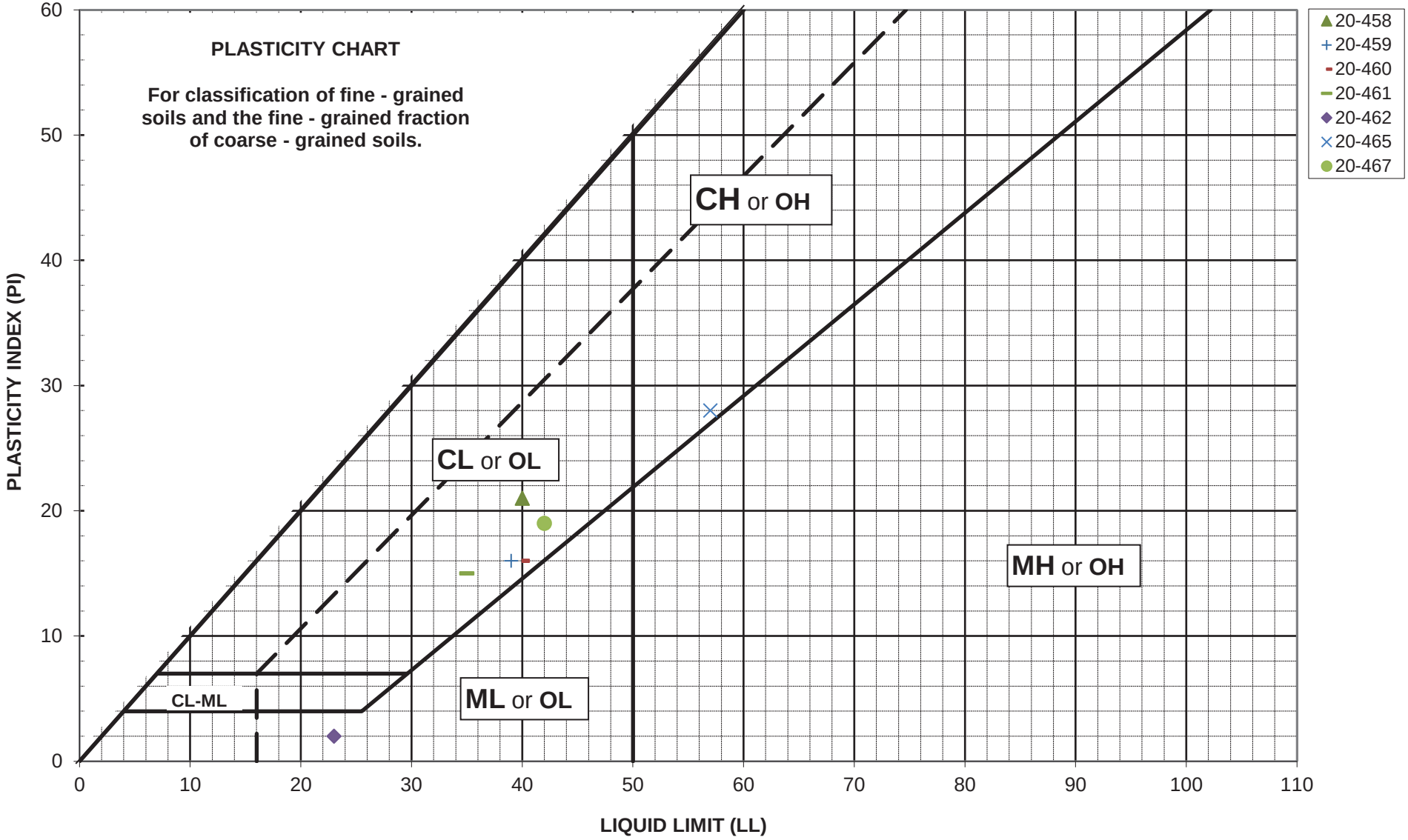
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-103B



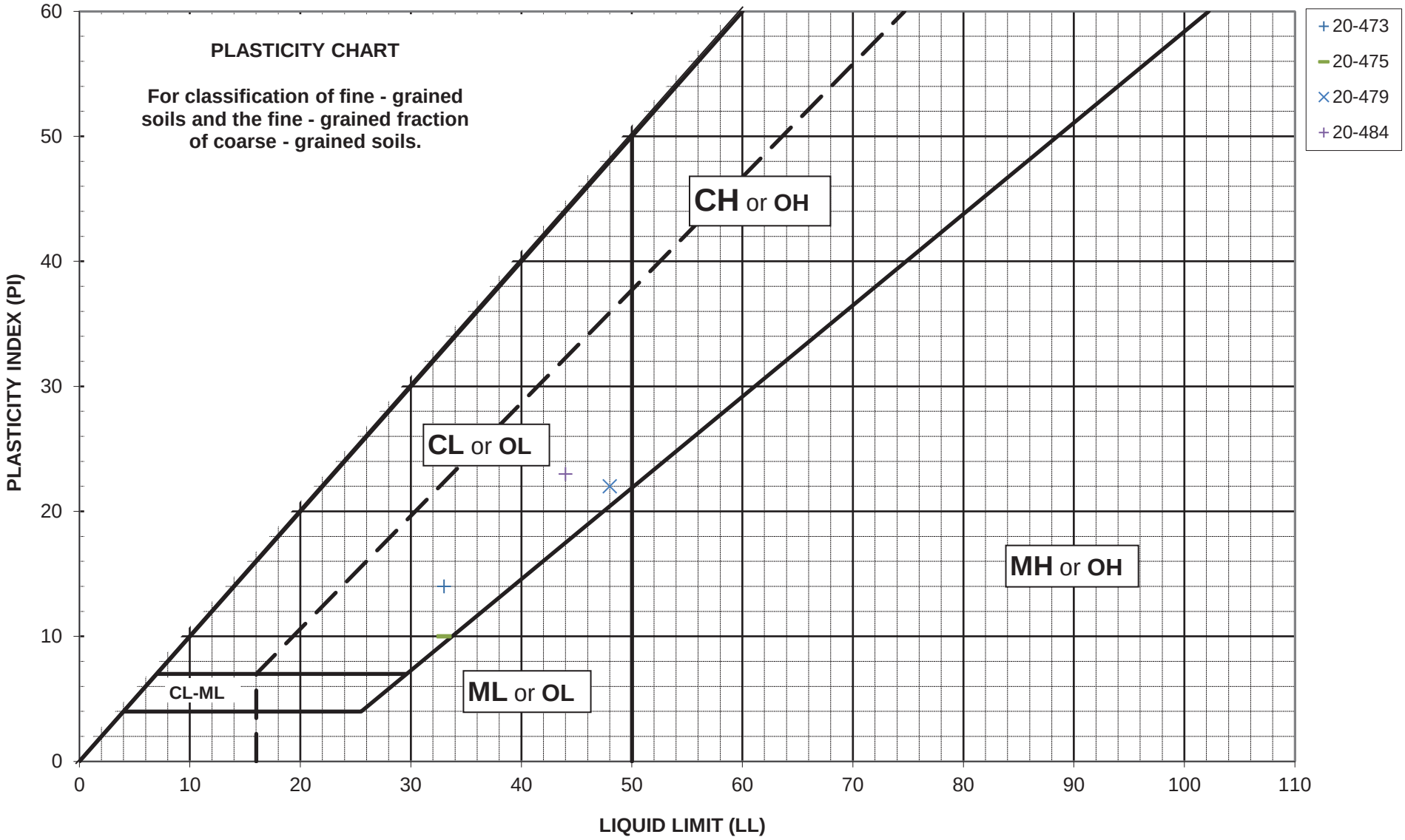
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-106B



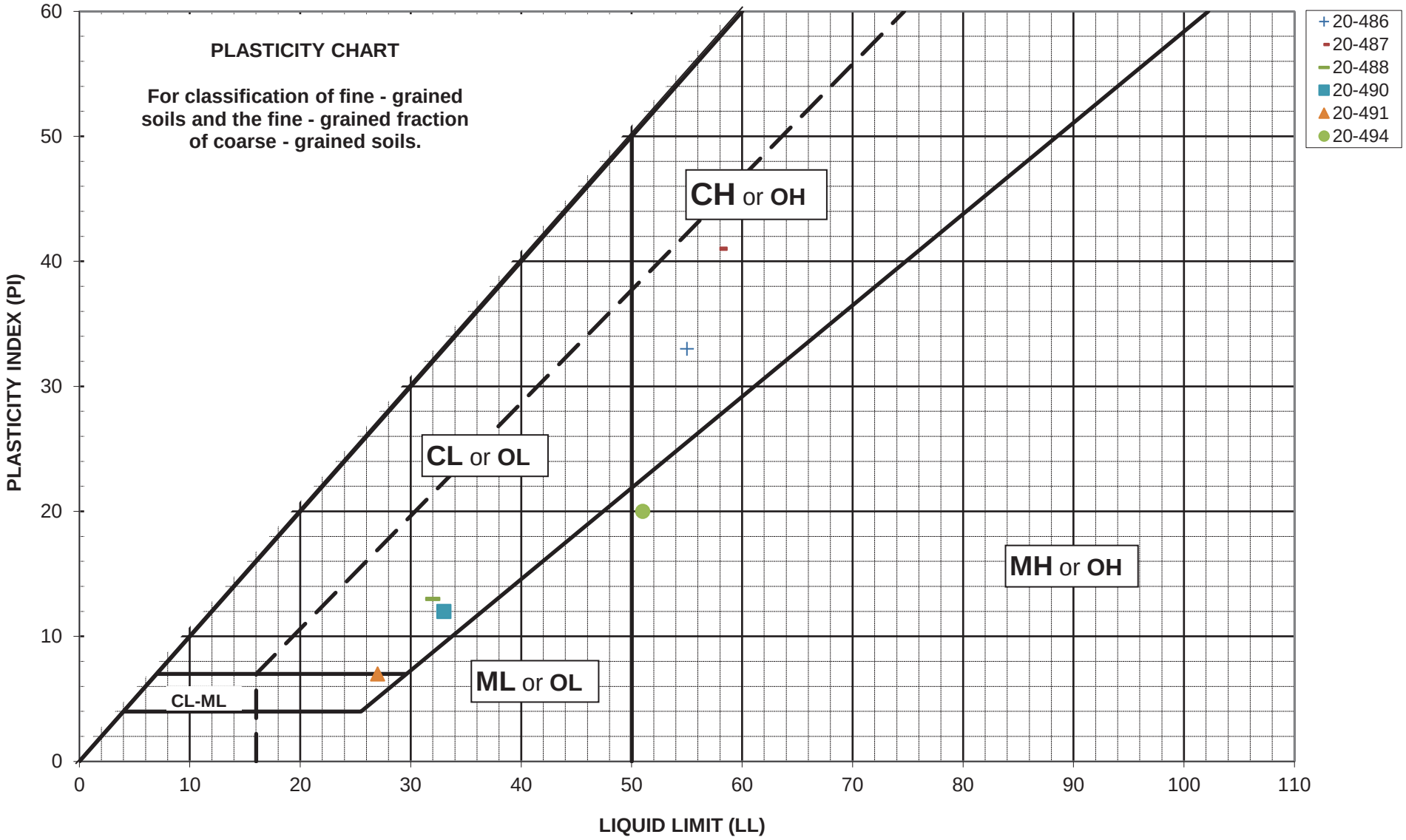
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-111B



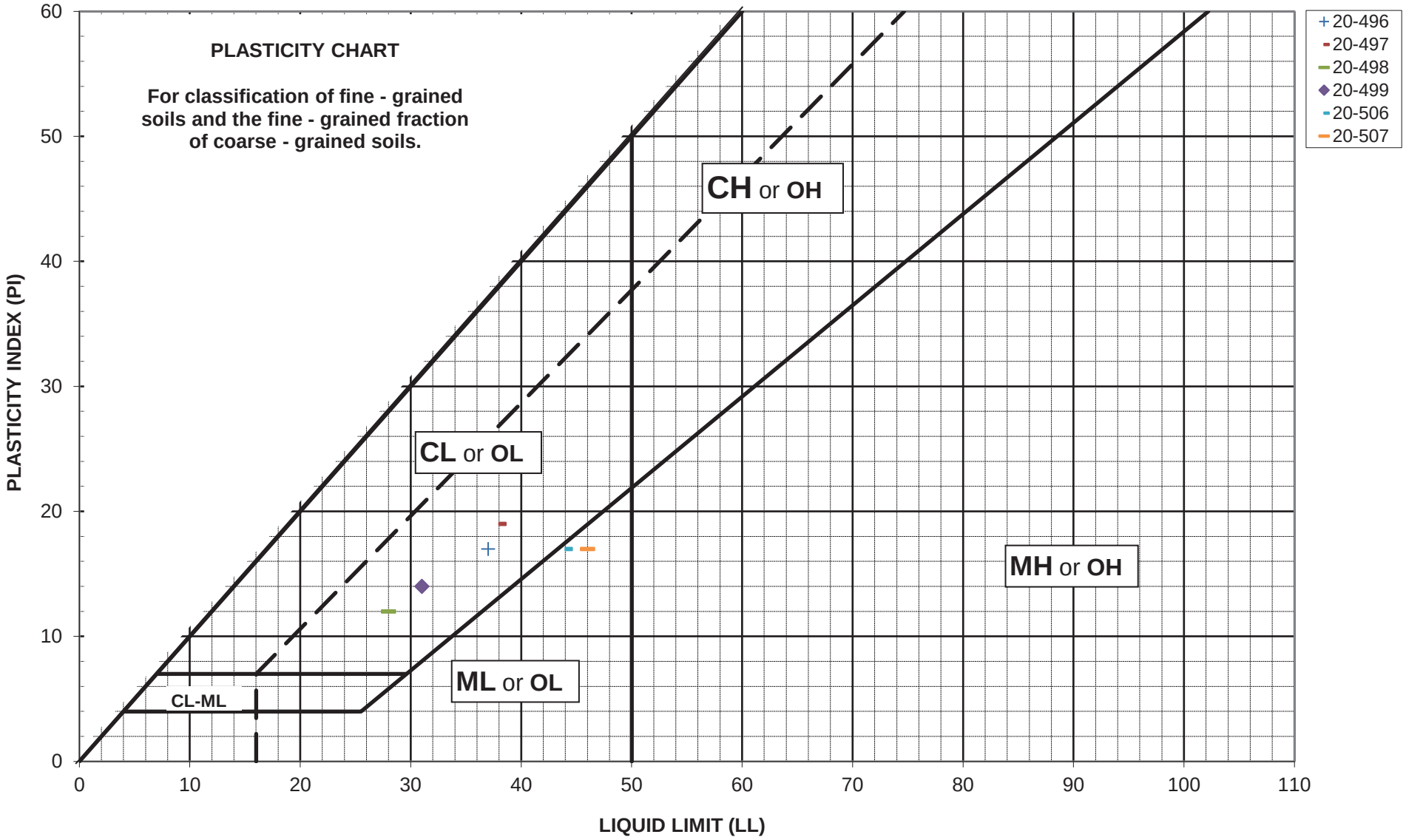
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-129B



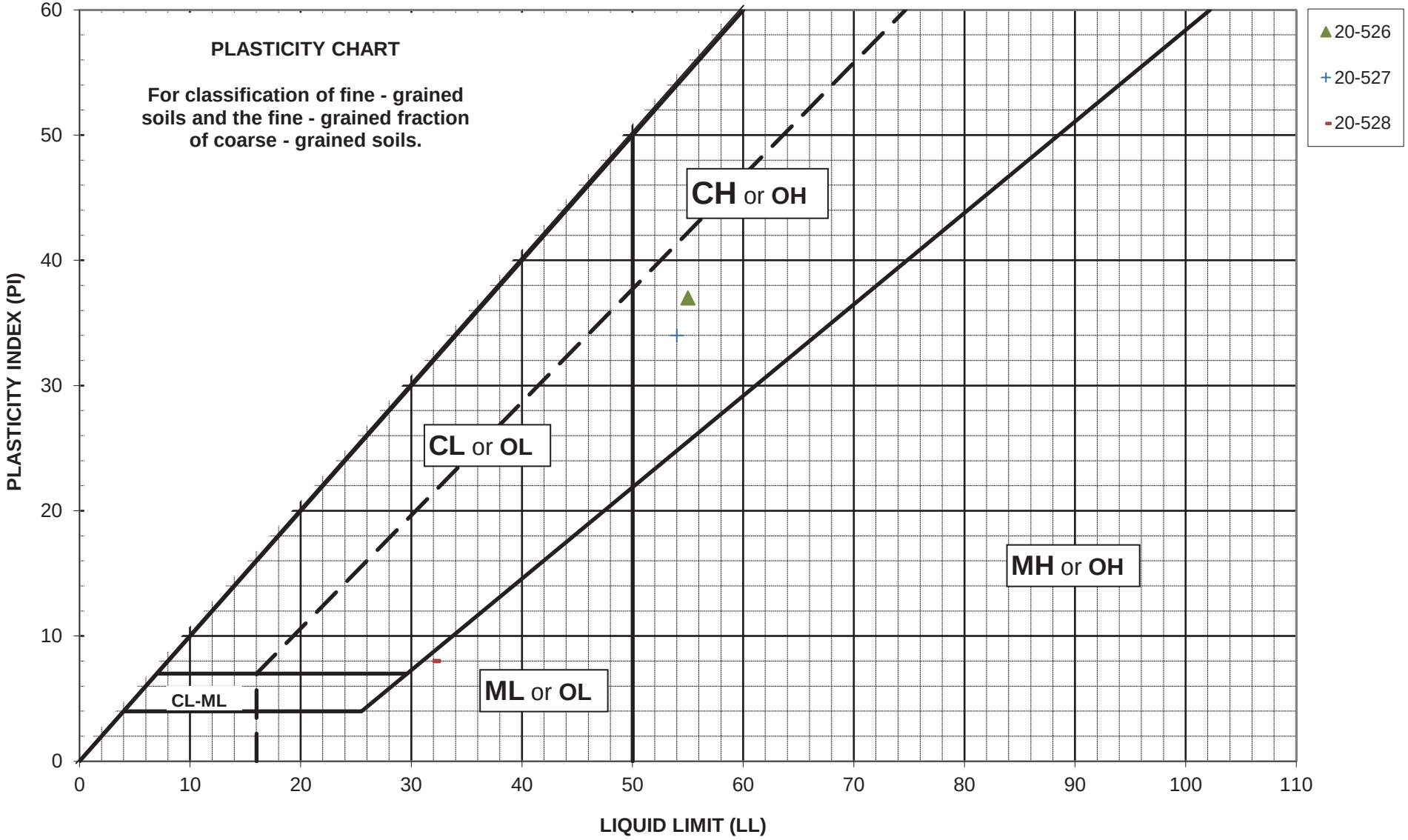
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-105B



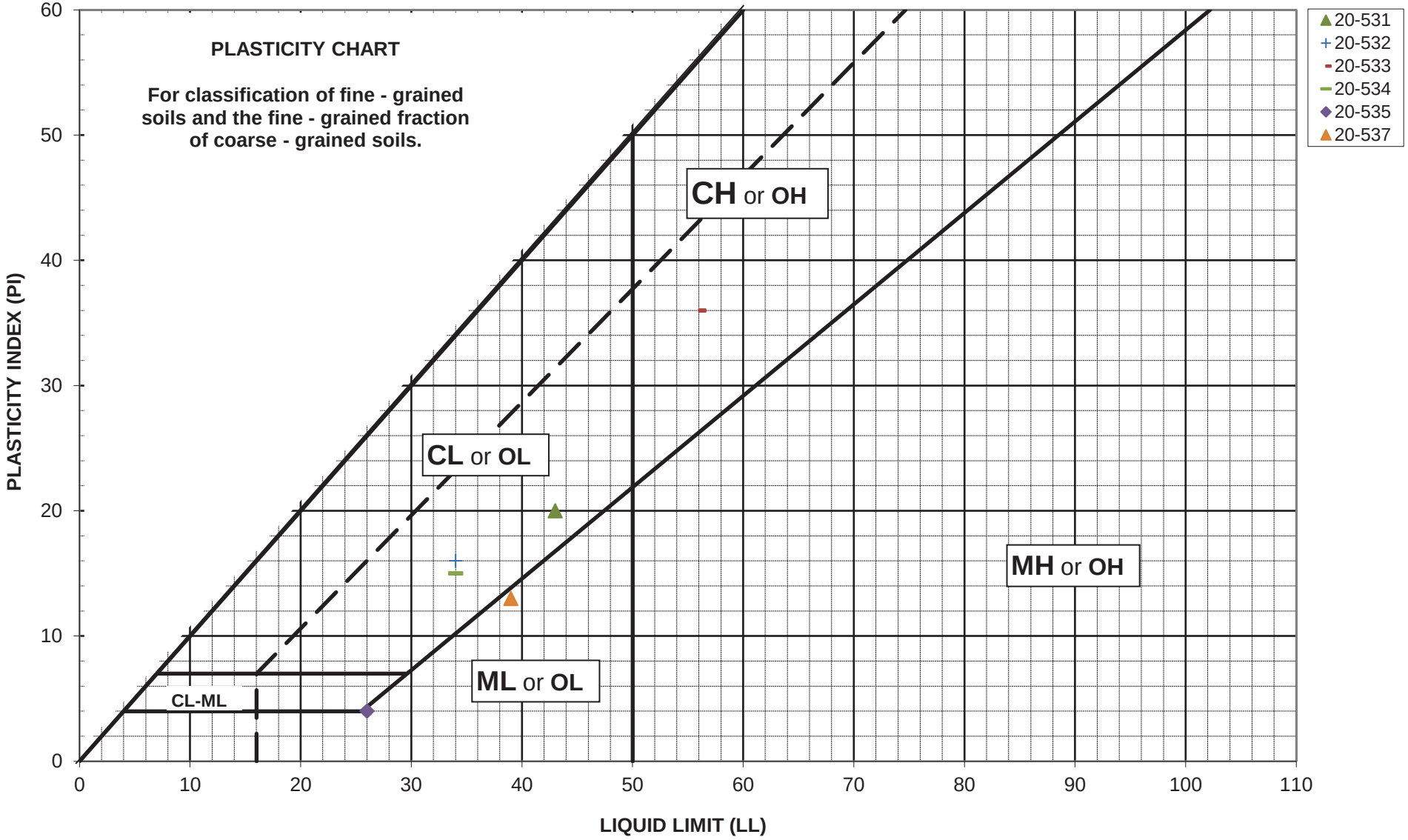
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-118B



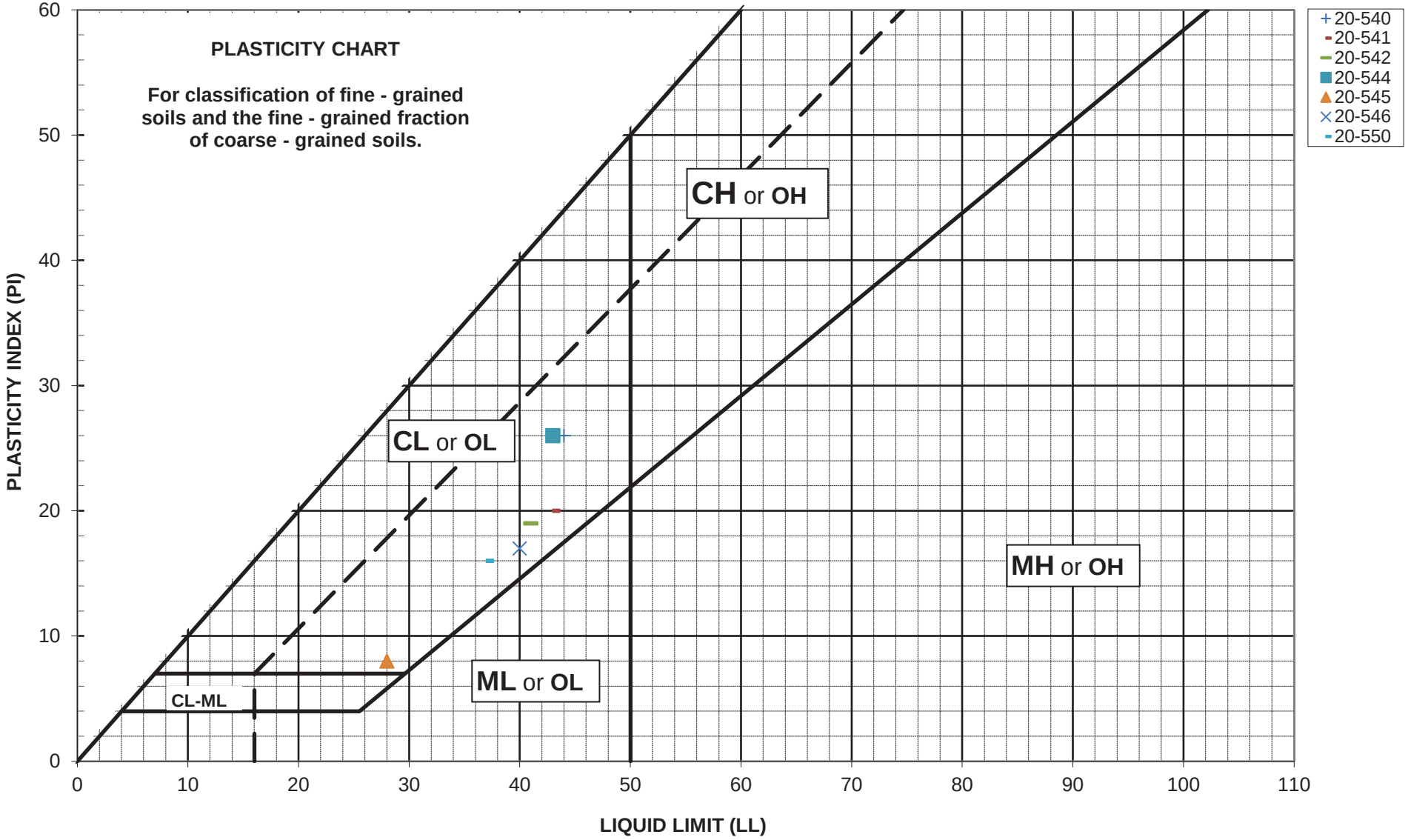
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-128B



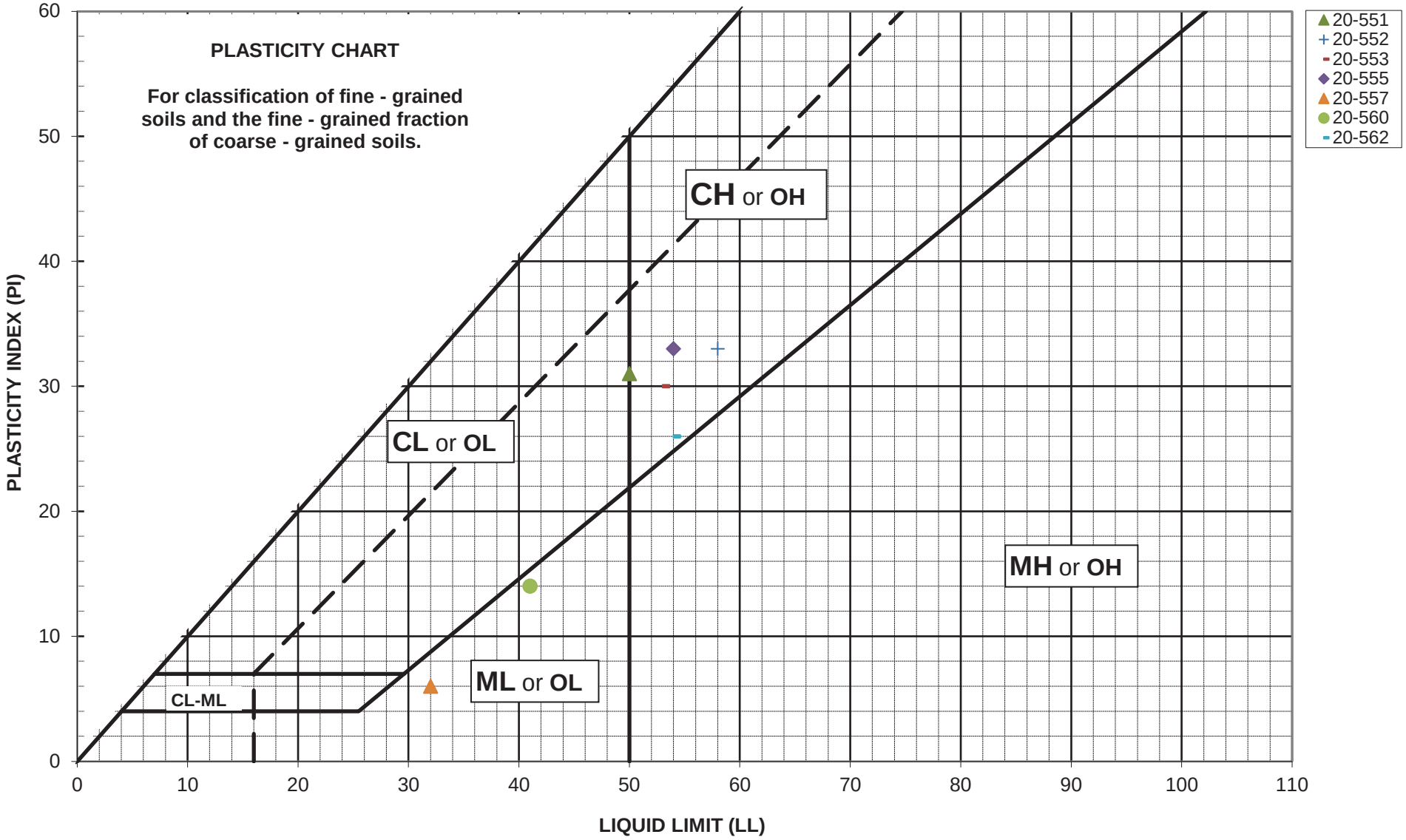
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-115B



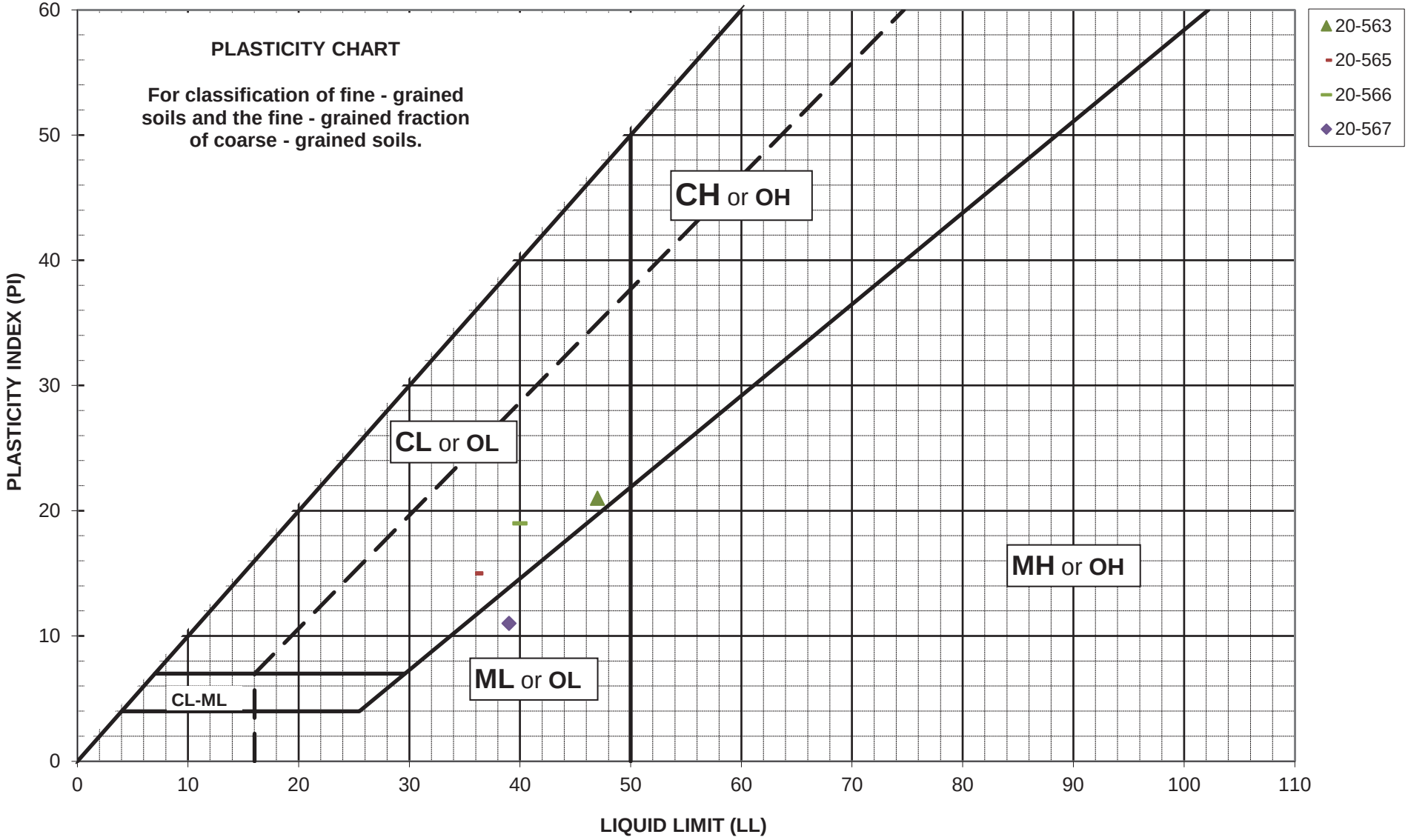
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-119B



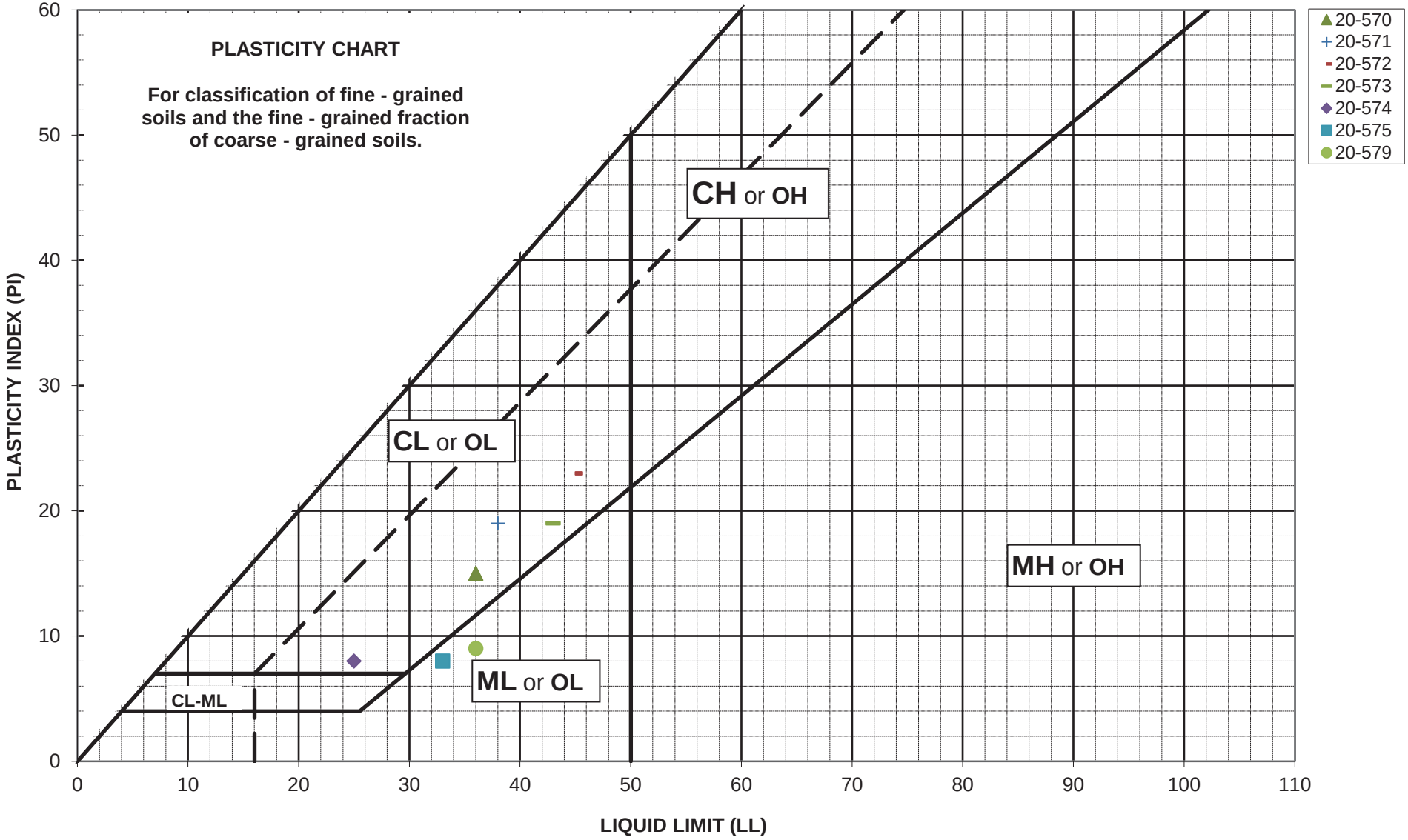
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-126B



DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

FW-108B



DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

PINHOLE TESTS

ASTM D4647
PINHOLE TEST

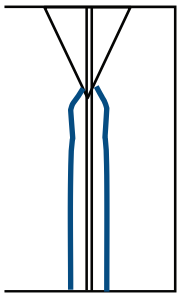
DIVISION of ENGINEERING
GEOTECHNICAL SERVICES BRANCH
BRYTE SOILS and CONRETE LABORATORY

Project: Big Notch
Request No.: 2020-18.4
Sample No.: FW-115B-S09-26.5'-28.0'

Tech.: R. Flores
Date: 1/7/2021
Lab No.: 20-543

ELAPSED TIME (MINUTES)	FLOW				TURBIDITY / EFFLUENT COLOR						PARTICLE FLOW		
	HEAD	mL	sec.	FLOW RATE (mL/sec)	VERY DARK	DARK	MODERATELY DARK	SLIGHTLY DARK	BARELY VISIBLE	COMPLETELY CLEAR	NONE	FEW	HEAVY
1	2"	10	60	0.2			X					X	
2	2"	7	60	0.1			X					X	
3	2"	10	60	0.2			X					X	
4	2"	14	60	0.2			X					X	
5	2"	50	60	0.8				X				X	
6	2"	60	60	1.0				X				X	
7	2"	60	60	1.0				X				X	
8	2"	60	60	1.0				X				X	

NOTES: Used intact specimen
Dispersive, D2



nvelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

ASTM D4647
PINHOLE TEST

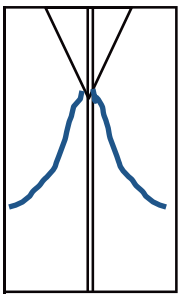
DIVISION of ENGINEERING
GEOTECHNICAL SERVICES BRANCH
BRYTE SOILS and CONRETE LABORATORY

Project: Big Notch
Request No.: 2020-18.4
Sample No.: FW-115B-S15-44'-45.5'

Tech.: R. Flores
Date: 1/12/2021
Lab No.: 20-545

ELAPSED TIME (MINUTES)	FLOW				TURBIDITY / EFFLUENT COLOR						PARTICLE FLOW		
	HEAD	mL	sec.	FLOW RATE (mL/sec)	VERY DARK	DARK	MODERATELY DARK	SLIGHTLY DARK	BARELY VISIBLE	COMPLETELY CLEAR	NONE	FEW	HEAVY
1	2"	17	60	0.3	X							X	
2	2"	18	60	0.3		X						X	
3	2"	18	60	0.3		X						X	
4	2"	35	60	0.6		X						X	
5	2"	49	60	0.8			X					X	
6	2"	50	60	0.8			X					X	
7	2"	52	60	0.9			X					X	
8	2"	55	60	0.9			X					X	
9	2"	57	60	1.0			X					X	
10	2"	59	60	1.0			X					X	

NOTES: Highly Dispersive, D1



nvelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

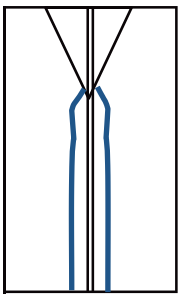
ASTM D4647
PINHOLE TEST

DIVISION of ENGINEERING
GEOTECHNICAL SERVICES BRANCH
BRYTE SOILS and CONRETE LABORATORY

Project: Big Notch
Request No.: 2020-18.4
Sample No.: FW-119B-S09-26.5'-28.0'

Tech.: R. Flores
Date: 1/7/2021
Lab No.: 20-554

ELAPSED TIME (MINUTES)	FLOW				TURBIDITY / EFFLUENT COLOR						PARTICLE FLOW		
	HEAD	mL	sec.	FLOW RATE (mL/sec)	VERY DARK	DARK	MODERATELY DARK	SLIGHTLY DARK	BARELY VISIBLE	COMPLETELY CLEAR	NONE	FEW	HEAVY
1	2"	19	60	0.3				X				X	
2	2"	30	60	0.5				X				X	
3	2"	50	60	0.8				X				X	
4	2"	47	60	0.8				X				X	
5	2"	57	60	1.0				X				X	



nvelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

ASTM D4647
PINHOLE TEST

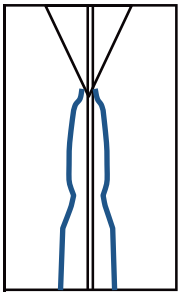
DIVISION of ENGINEERING
GEOTECHNICAL SERVICES BRANCH
BRYTE SOILS and CONRETE LABORATORY

Project: Big Notch
Request No.: 2020-18.4
Sample No.: FW-119B-S13-36.5'-38.0'

Tech.: R. Flores
Date: 1/12/2021
Lab No.: 20-556

ELAPSED TIME (MINUTES)	FLOW				TURBIDITY / EFFLUENT COLOR						PARTICLE FLOW		
	HEAD	mL	sec.	FLOW RATE (mL/sec)	VERY DARK	DARK	MODERATELY DARK	SLIGHTLY DARK	BARELY VISIBLE	COMPLETELY CLEAR	NONE	FEW	HEAVY
1	2"	21	60	0.4			X					X	
2	2"	21	60	0.4			X					X	
3	2"	24	60	0.4			X					X	
4	2"	34	60	0.6				X				X	
5	2"	38	60	0.6				X				X	
6	2"	43	60	0.7				X				X	
7	2"	46	60	0.8					X		X		
8	2"	47	60	0.8					X		X		
9	2"	47	60	0.8					X		X		
10	2"	48	60	0.8					X		X		
11	7"	90	60	1.5					X			X	
12	7"	78	60	1.3					X			X	
13	7"	75	60	1.3					X			X	
14	7"	62	60	1.0					X		X		
15	7"	52	60	0.9					X		X		
16	15"	95	60	1.6					X			X	
17	15"	178	60	3.0					X			X	

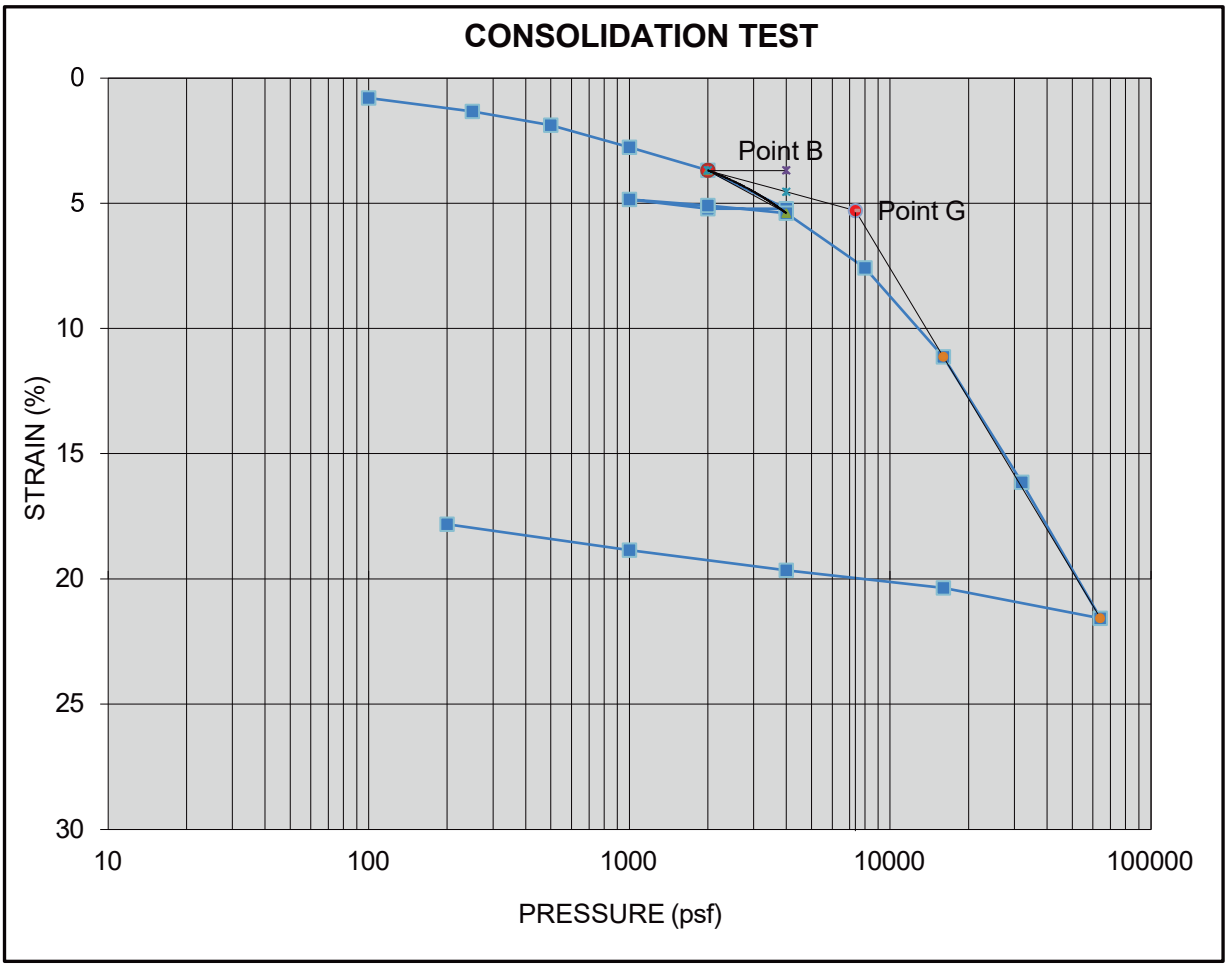
NOTES: Slightly Dispersive, ND3



DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TESTS

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.78	0.80
250	0.77	1.34
500	0.76	1.89
1000	0.74	2.77
2000	0.73	3.69
4000	0.70	5.22
2000	0.70	5.22
1000	0.71	4.85
2000	0.70	5.09
4000	0.70	5.40
8000	0.66	7.59
16000	0.59	11.14
32000	0.50	16.14
64000	0.41	21.57
16000	0.43	20.36
4000	0.44	19.66
1000	0.46	18.85
200	0.47	17.82

Compression Ratio	0.1732
Recompression Ratio	0.0091
Est. Preconsolidation Stress (psf)	7359
Initial Dry density (pcf)	93.9
Initial Moisture (%)	27.3
Final Dry density (pcf)	114.3
Final Moisture (%)	18.6

Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	1.139E-05
4000.00	4.389E-06

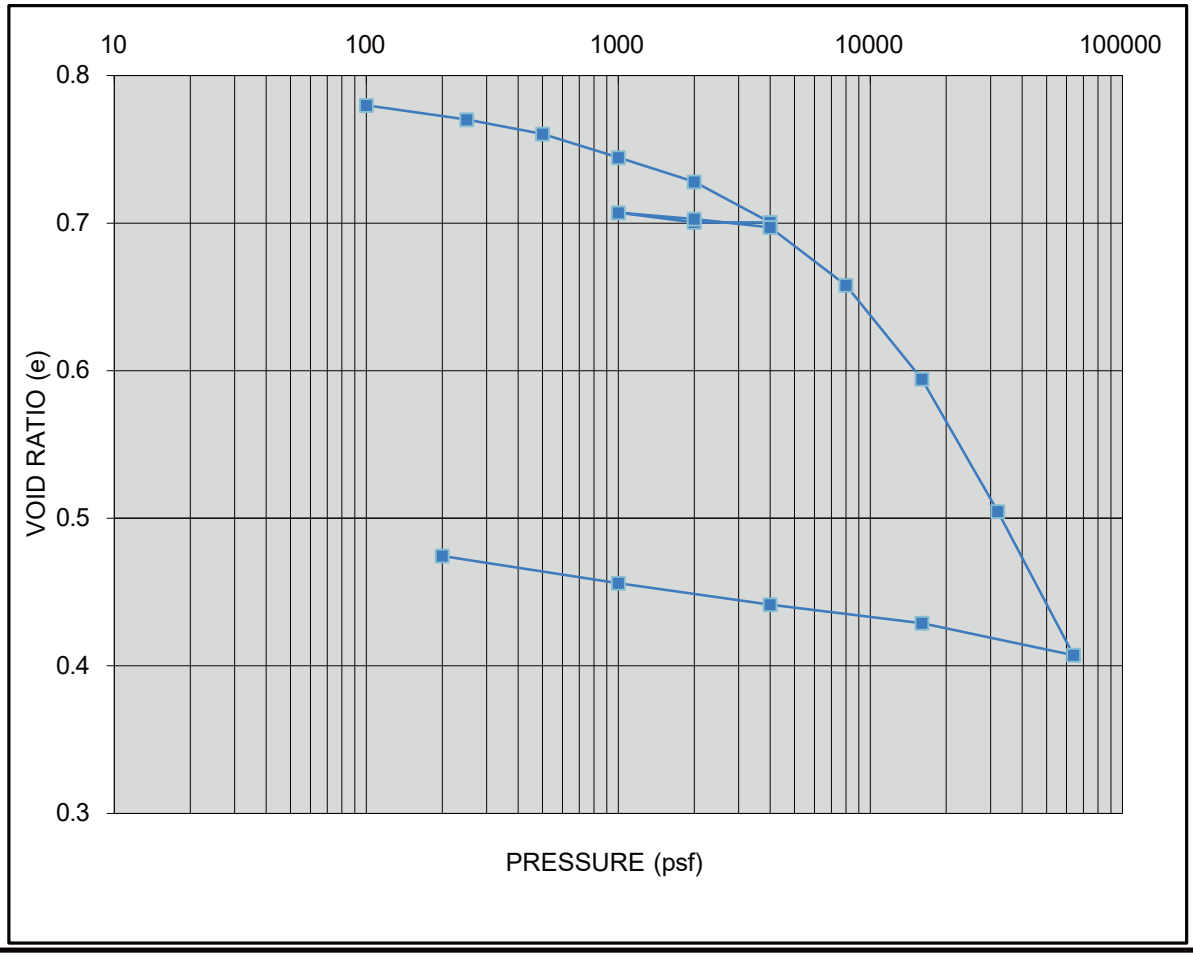
Note: Soil classified as silty sand and experinced disturbance while sampling

Project Name:	Big Notch Project
Hole No.	FW-104B
Field Sample No.	T01, 24.0'-26.0'
Sample No:	20-400
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	11/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TEST



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.79	0.80
250	0.78	1.34
500	0.77	1.89
1000	0.76	2.77
2000	0.74	3.69
4000	0.73	5.22
2000	0.70	5.22
1000	0.70	4.85
2000	0.71	5.09
4000	0.70	5.40
8000	0.70	7.59
16000	0.66	11.14
32000	0.59	16.14
64000	0.50	21.57
16000	0.41	20.36
4000	0.43	19.66
1000	0.44	18.85
200	0.46	17.82

Compression Ratio	0.1732
Recompression Ratio	0.0091
Est. Preconsolidation Stress (psf)	7359
Initial Dry density (pcf)	93.9
Initial Moisture (%)	27.3
Final Dry density (pcf)	114.3
Final Moisture (%)	18.6

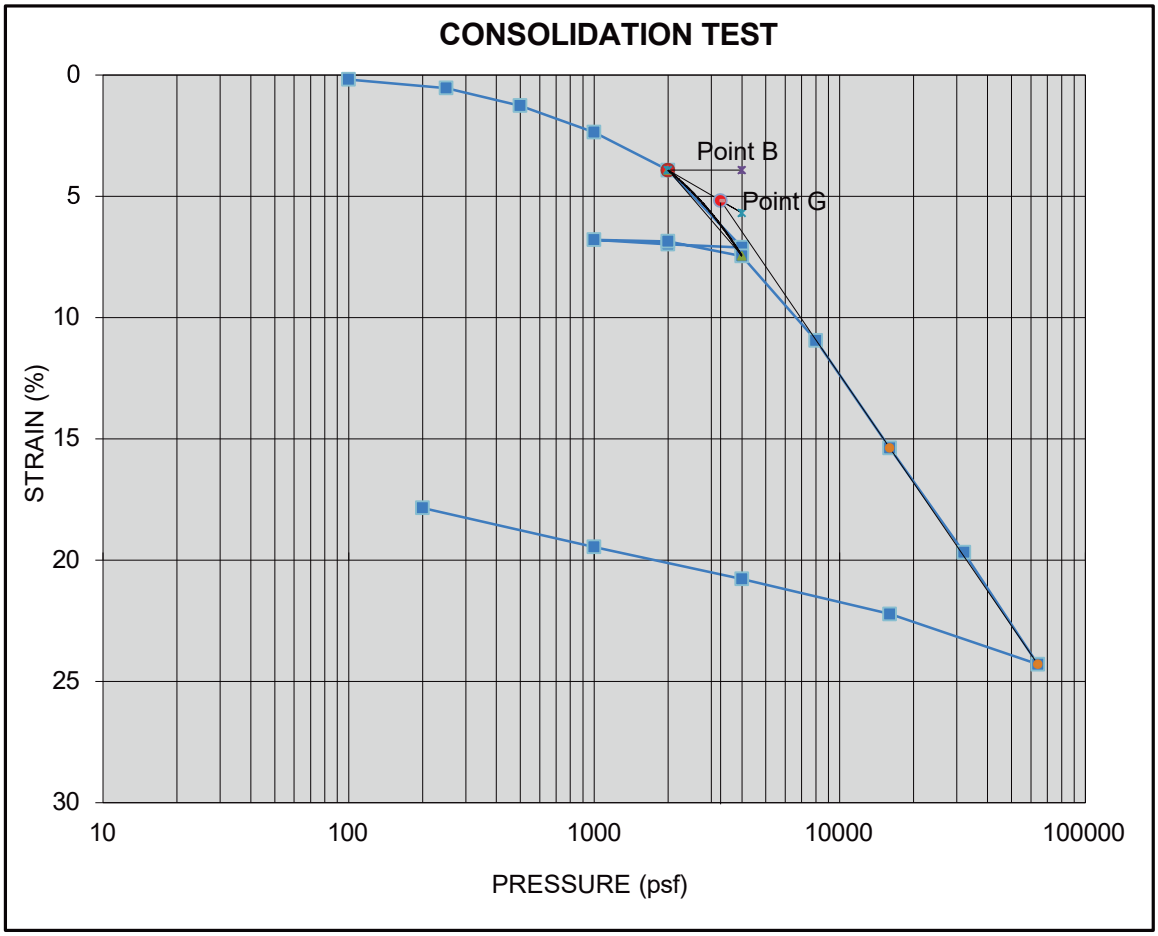
Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	1.139E-05
4000.00	4.389E-06

Project Name:	Big Notch Project
Hole No.	FW-104B
Field Sample No.	T01, 24.0'-26.0'
Sample No:	20-400
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	11/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.74	0.18
250	0.73	0.54
500	0.72	1.26
1000	0.70	2.36
2000	0.67	3.92
4000	0.62	7.11
2000	0.62	6.98
1000	0.62	6.79
2000	0.62	6.86
4000	0.61	7.46
8000	0.55	10.94
16000	0.47	15.38
32000	0.40	19.68
64000	0.32	24.29
16000	0.35	22.22
4000	0.38	20.78
1000	0.40	19.46
200	0.43	17.85

Compression Ratio	0.1480
Recompression Ratio	0.0111
Est. Preconsolidation Stress (psf)	3270
Initial Dry density (pcf)	96.8
Initial Moisture (%)	22.9
Final Dry density (pcf)	117.8
Final Moisture (%)	16.8

Assumed specific gravity (Gs)	2.70

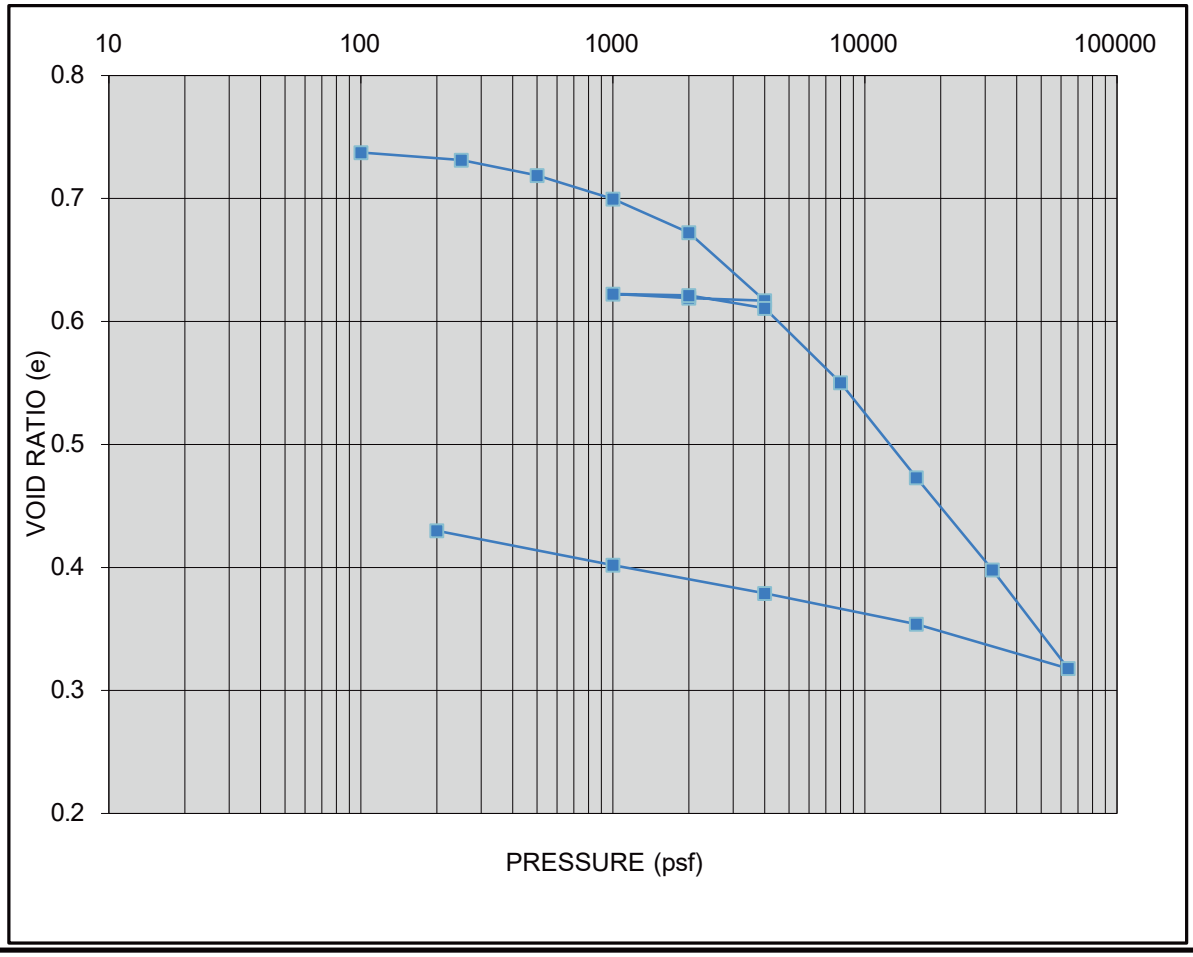
Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	9.737E-06
4000.00	7.549E-06

Project Name:	Big Notch Project
Hole No.	FW-103B
Field Sample No.	T02-17.0-19.0
Sample No:	20-450
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	1/12/2021

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TEST



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.74	0.18
250	0.73	0.54
500	0.72	1.26
1000	0.70	2.36
2000	0.67	3.92
4000	0.62	7.11
2000	0.62	6.98
1000	0.62	6.79
2000	0.62	6.86
4000	0.61	7.46
8000	0.55	10.94
16000	0.47	15.38
32000	0.40	19.68
64000	0.32	24.29
16000	0.35	22.22
4000	0.38	20.78
1000	0.40	19.46
200	0.43	17.85

Compression Ratio	0.1480
Recompression Ratio	0.0111
Est. Preconsolidation Stress (psf)	3270
Initial Dry density (pcf)	96.8
Initial Moisture (%)	22.9
Final Dry density (pcf)	117.8
Final Moisture (%)	16.8

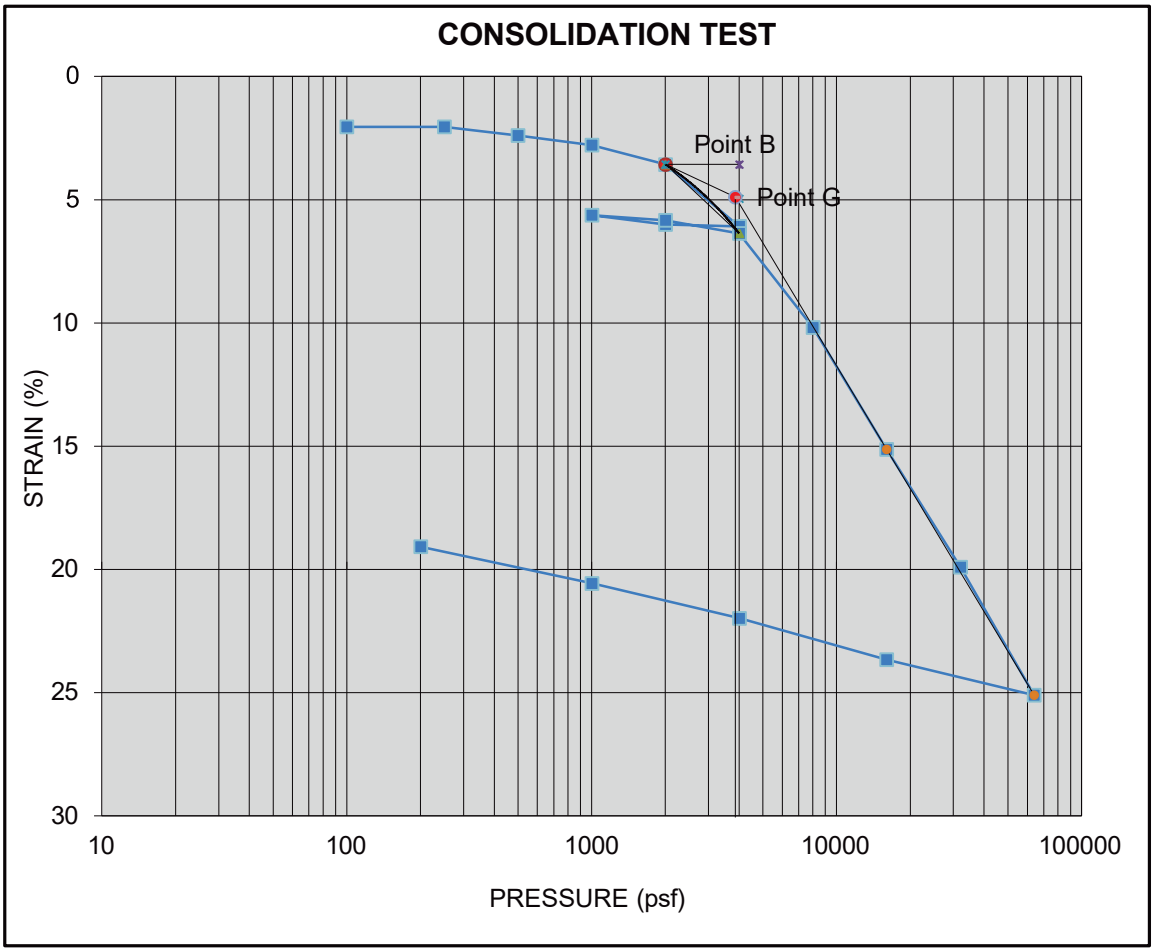
Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	E-06
4000.00	E-06

Project Name:	Big Notch Project
Hole No.	FW-105B
Field Sample No.	T01-17.0-19.0
Sample No:	20-450
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	1/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.80	2.05
250	0.80	2.05
500	0.79	2.39
1000	0.78	2.79
2000	0.77	3.57
4000	0.72	6.08
2000	0.72	6.00
1000	0.73	5.63
2000	0.73	5.84
4000	0.72	6.37
8000	0.65	10.18
16000	0.56	15.13
32000	0.47	19.90
64000	0.37	25.10
16000	0.40	23.66
4000	0.43	21.98
1000	0.46	20.56
200	0.48	19.08

Compression Ratio	0.1656
Recompression Ratio	0.0123
Est. Preconsolidation Stress (psf)	3856
Initial Dry density (pcf)	91.8
Initial Moisture (%)	24.5
Final Dry density (pcf)	113.5
Final Moisture (%)	21.1

Assumed specific gravity (Gs)	2.70

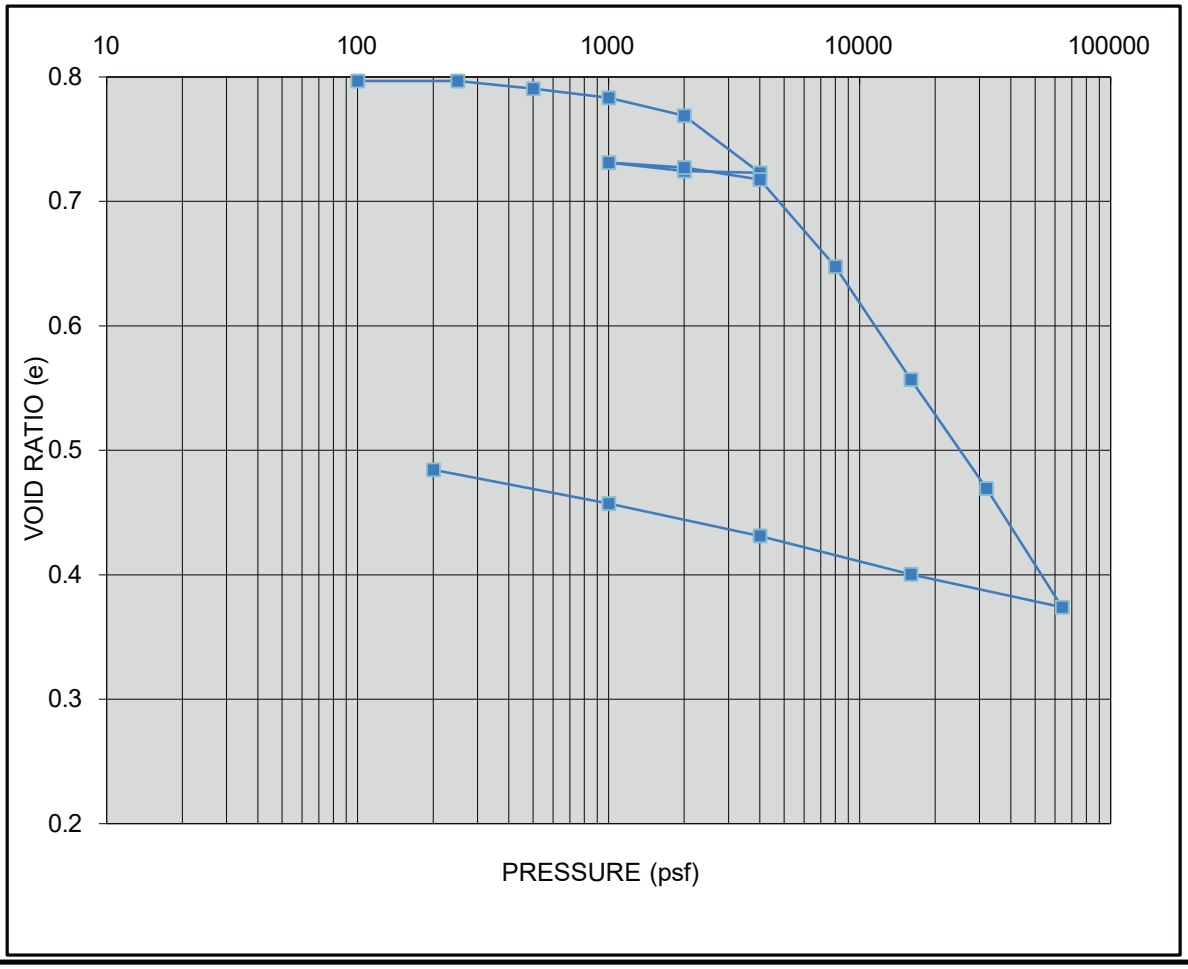
Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	5.062E-06
4000.00	5.806E-06

Project Name:	Big Notch Project
Hole No.	FW-106B
Field Sample No.	T01-10.0-12.0
Sample No:	20-459
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	1/12/2021

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TEST



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.80	2.05
250	0.80	2.05
500	0.79	2.39
1000	0.78	2.79
2000	0.77	3.57
4000	0.72	6.08
2000	0.72	6.00
1000	0.73	5.63
2000	0.73	5.84
4000	0.72	6.37
8000	0.65	10.18
16000	0.56	15.13
32000	0.47	19.90
64000	0.37	25.10
16000	0.40	23.66
4000	0.43	21.98
1000	0.46	20.56
200	0.48	19.08

Compression Ratio	0.1656
Recompression Ratio	0.0123
Est. Preconsolidation Stress (psf)	3856
Initial Dry density (pcf)	91.8
Initial Moisture (%)	24.5
Final Dry density (pcf)	113.5
Final Moisture (%)	21.1

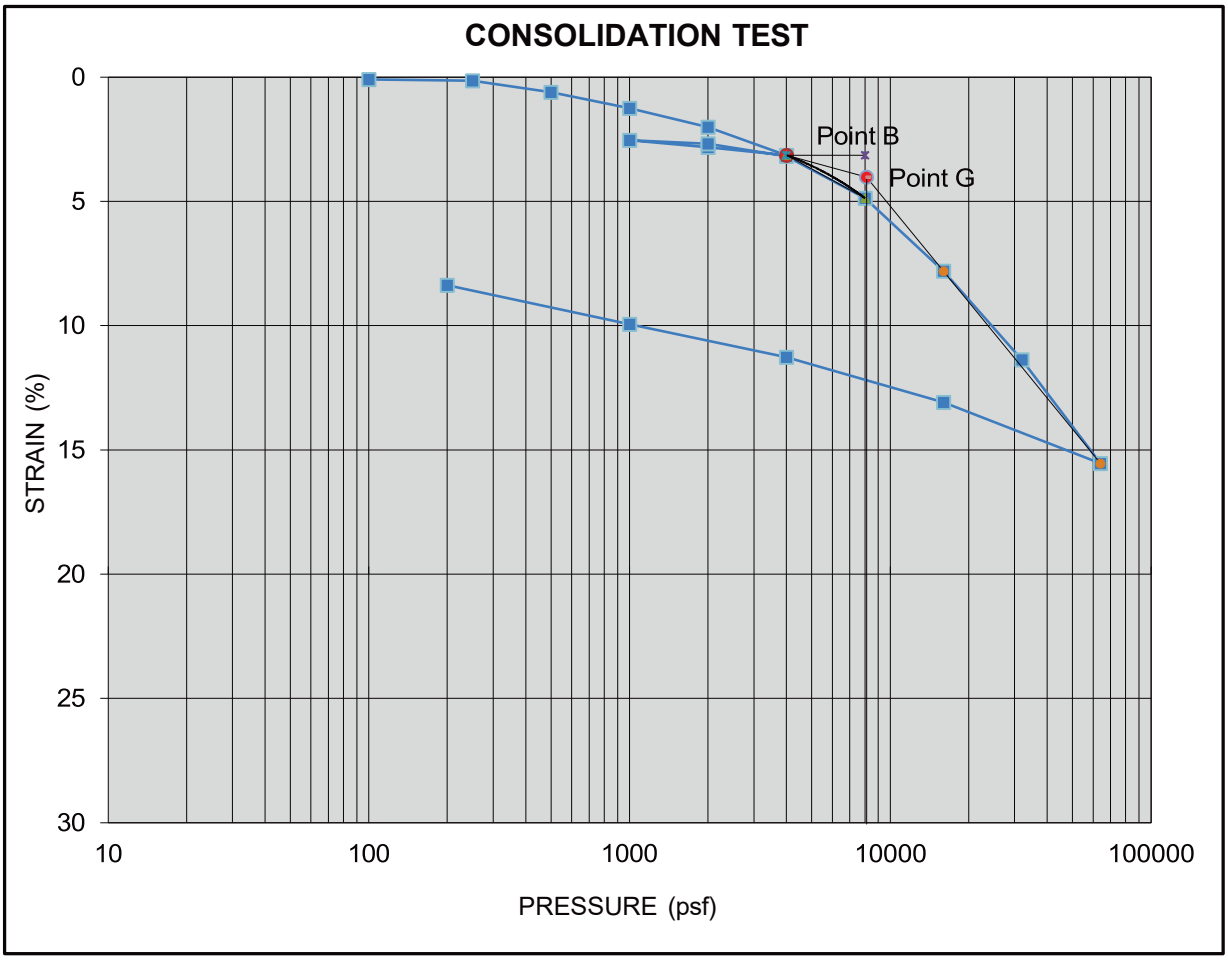
Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	E-06
4000.00	E-06

Project Name:	Big Notch Project
Hole No.	FW-106B
Field Sample No.	T01-10.0-12.0
Sample No:	20-459
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	1/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.60	0.09
250	0.60	0.15
500	0.59	0.61
1000	0.58	1.25
2000	0.57	2.01
4000	0.55	3.14
2000	0.56	2.83
1000	0.56	2.54
2000	0.56	2.68
4000	0.55	3.18
8000	0.52	4.87
16000	0.48	7.81
32000	0.42	11.37
64000	0.35	15.54
16000	0.39	13.09
4000	0.42	11.27
1000	0.44	9.94
200	0.47	8.37

Compression Ratio	0.1284
Recompression Ratio	0.0106
Est. Preconsolidation Stress (psf)	8112
Initial Dry density (pcf)	105.2
Initial Moisture (%)	21.4
Final Dry density (pcf)	114.8
Final Moisture (%)	19.8

Assumed specific gravity (Gs)	2.70

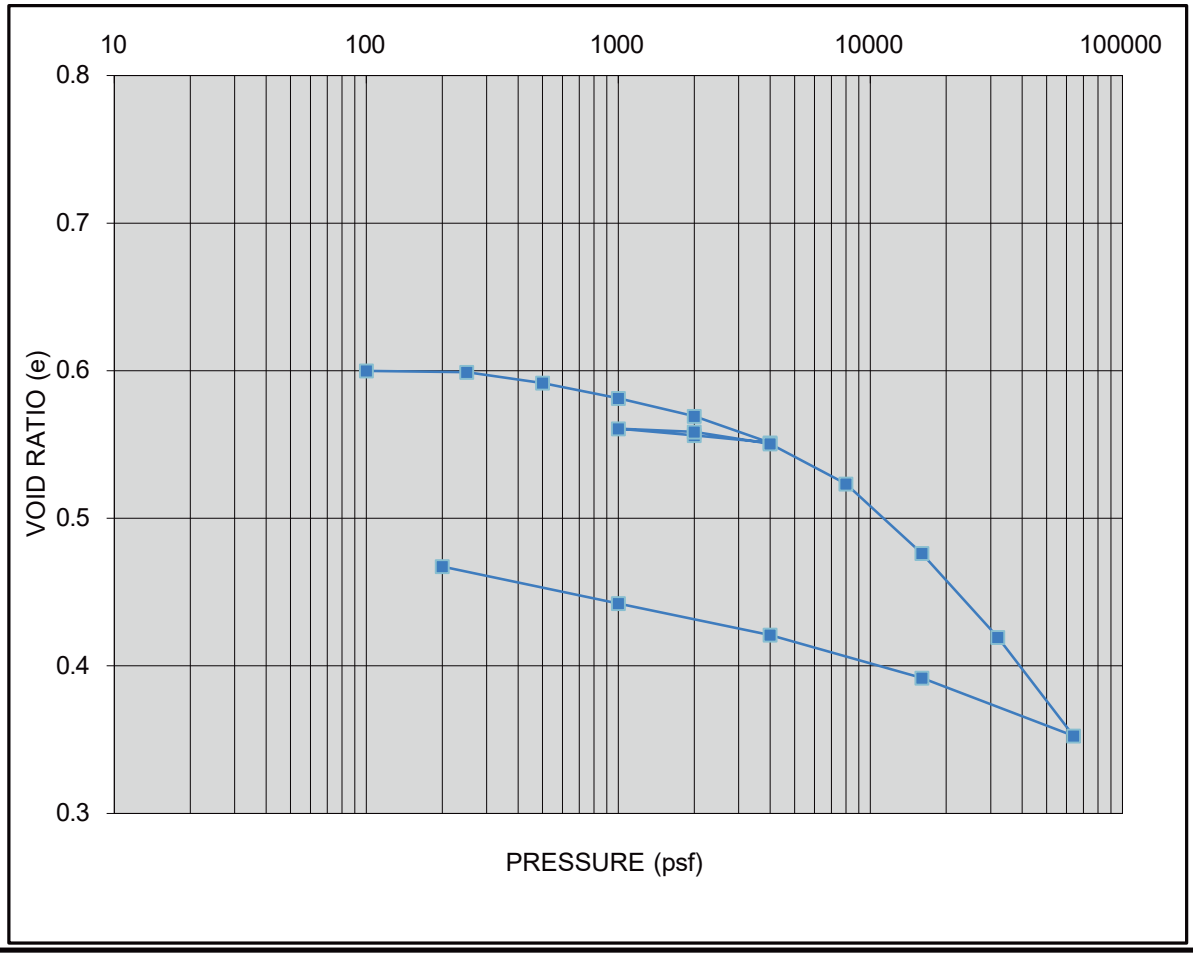
Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	4.340E-06
4000.00	6.578E-06

Project Name:	Big Notch Project
Hole No.	FW-106B
Field Sample No.	T03, 20.0'-21.8'
Sample No:	20-461
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	11/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California
95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TEST



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.60	0.09
250	0.60	0.15
500	0.59	0.61
1000	0.58	1.25
2000	0.57	2.01
4000	0.55	3.14
2000	0.56	2.83
1000	0.56	2.54
2000	0.56	2.68
4000	0.55	3.18
8000	0.52	4.87
16000	0.48	7.81
32000	0.42	11.37
64000	0.35	15.54
16000	0.39	13.09
4000	0.42	11.27
1000	0.44	9.94
200	0.47	8.37

Compression Ratio	0.1284
Recompression Ratio	0.0106
Est. Preconsolidation Stress (psf)	8112
Initial Dry density (pcf)	105.2
Initial Moisture (%)	21.4
Final Dry density (pcf)	114.8
Final Moisture (%)	19.8

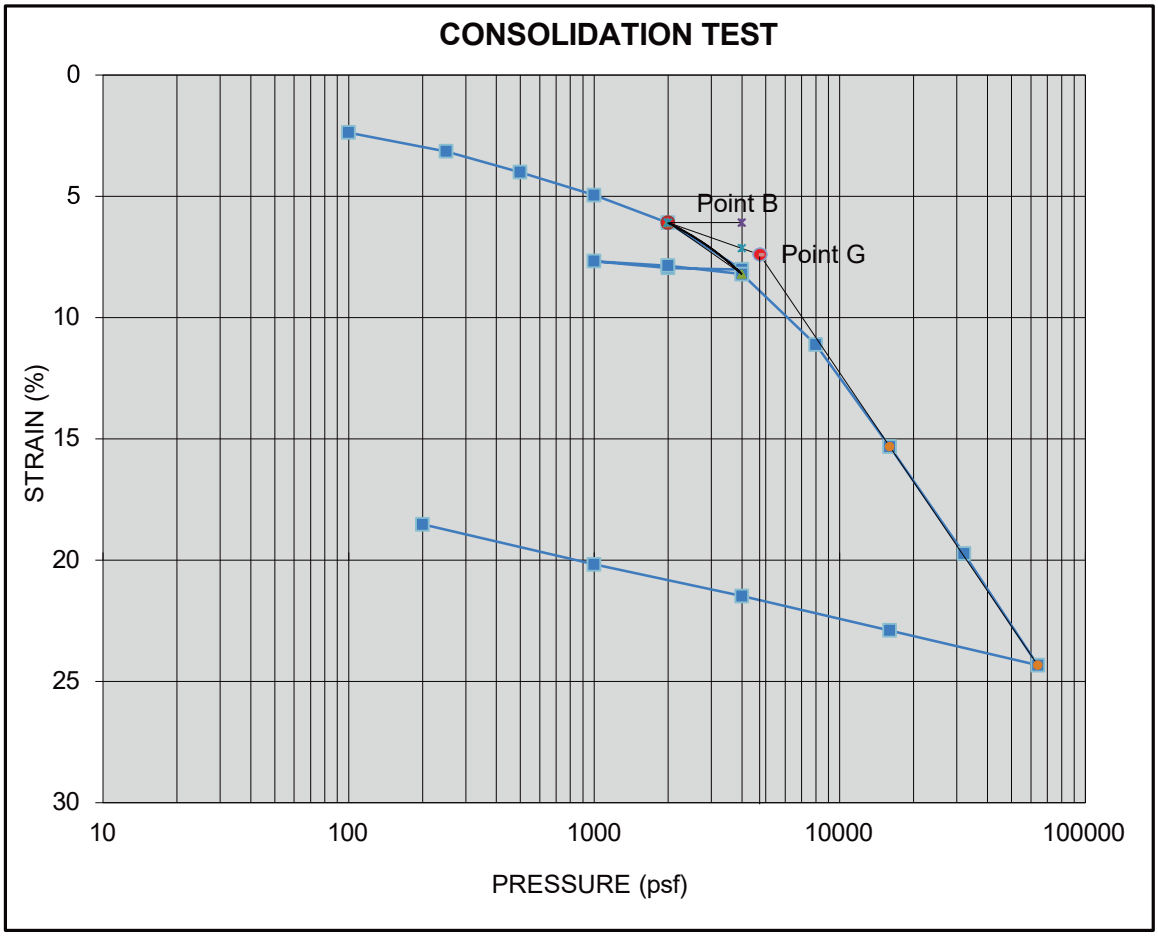
Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	4.340E-06
4000.00	6.578E-06

Project Name:	Big Notch Project
Hole No.	FW-106B
Field Sample No.	T03, 20.0'-21.8'
Sample No:	20-461
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	11/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.64	2.37
250	0.63	3.15
500	0.62	4.01
1000	0.60	4.95
2000	0.58	6.09
4000	0.55	8.02
2000	0.55	7.95
1000	0.55	7.67
2000	0.55	7.86
4000	0.55	8.21
8000	0.50	11.12
16000	0.43	15.33
32000	0.35	19.73
64000	0.27	24.33
16000	0.30	22.90
4000	0.32	21.48
1000	0.34	20.18
200	0.37	18.53

Compression Ratio	0.1495
Recompression Ratio	0.0090
Est. Preconsolidation Stress (psf)	4719
Initial Dry density (pcf)	100.1
Initial Moisture (%)	20.9
Final Dry density (pcf)	122.9
Final Moisture (%)	18.1

Assumed specific gravity (Gs)	2.70

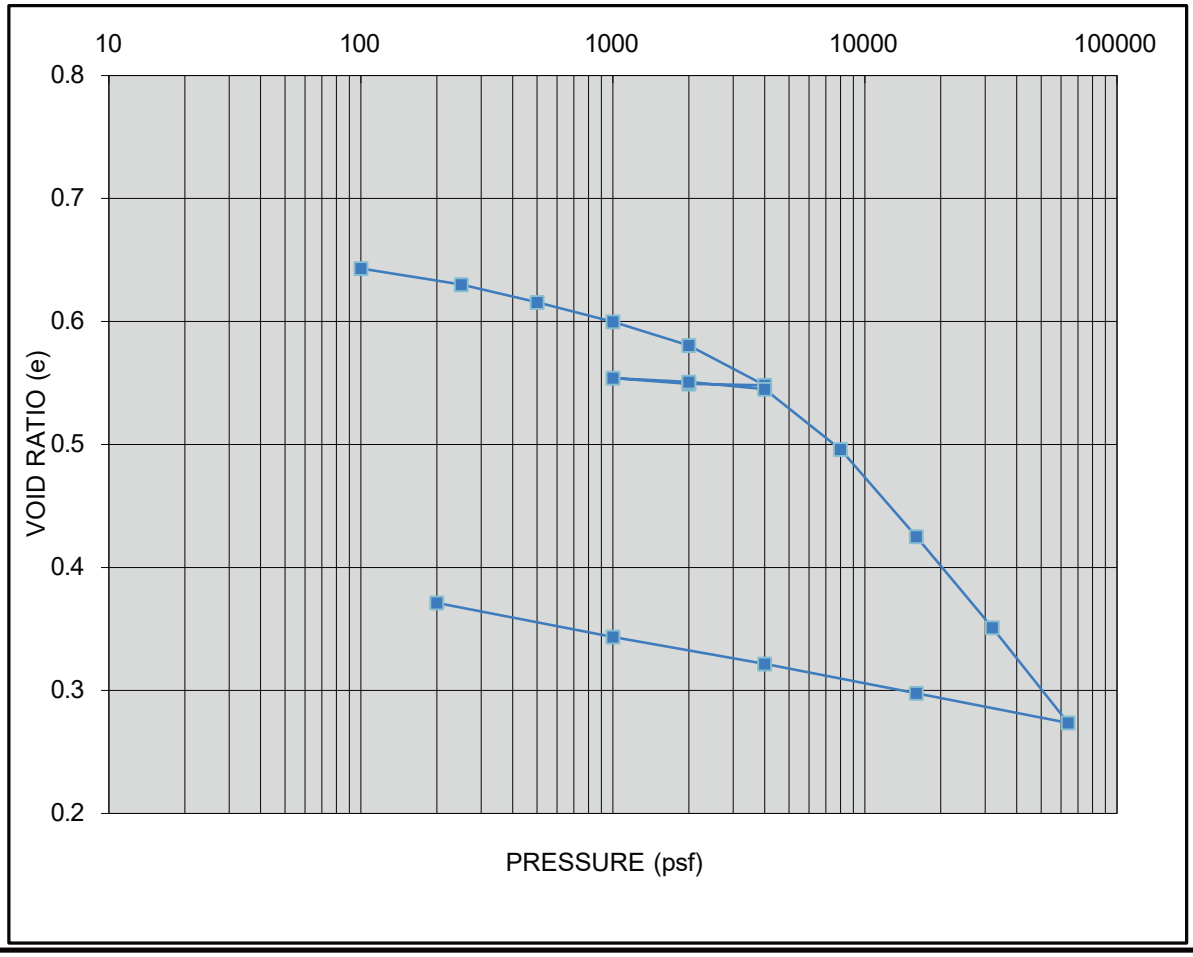
Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	9.338E-06
4000.00	8.304E-06

Project Name:	Big Notch Project
Hole No.	FW-105B
Field Sample No.	T01, 20.0'-22.0'
Sample No:	20-498
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	11/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TEST



Applied Stress (psf)	Void Ratio	Final Strain (%)
100	0.64	2.37
250	0.63	3.15
500	0.62	4.01
1000	0.60	4.95
2000	0.58	6.09
4000	0.55	8.02
2000	0.55	7.95
1000	0.55	7.67
2000	0.55	7.86
4000	0.55	8.21
8000	0.50	11.12
16000	0.43	15.33
32000	0.35	19.73
64000	0.27	24.33
16000	0.30	22.90
4000	0.32	21.48
1000	0.34	20.18
200	0.37	18.53

Compression Ratio	0.1495
Recompression Ratio	0.0090
Est. Preconsolidation Stress (psf)	4719
Initial Dry density (pcf)	100.1
Initial Moisture (%)	20.9
Final Dry density (pcf)	122.9
Final Moisture (%)	18.1

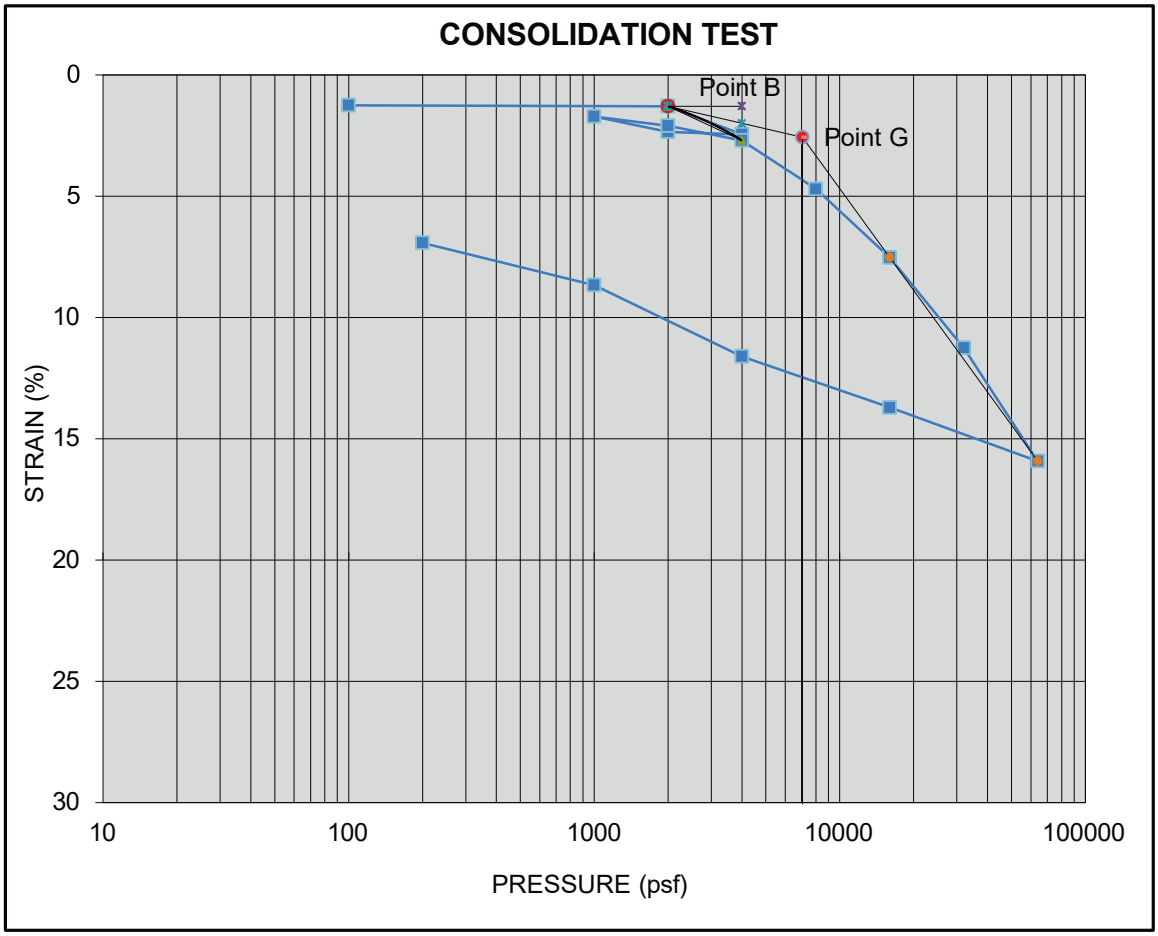
Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	9.338E-06
4000.00	8.304E-06

Project Name:	Big Notch Project
Hole No.	FW-105B
Field Sample No.	T01, 20.0'-22.0'
Sample No:	20-498
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	11/12/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF



Applied Stress (psf)	Void Ratio	Final Strain (%)
0	0.64	0.00
100	0.62	1.25
2000	0.62	1.29
4000	0.60	2.45
2000	0.60	2.34
1000	0.61	1.71
2000	0.60	2.09
4000	0.59	2.70
8000	0.56	4.70
16000	0.51	7.53
32000	0.45	11.25
64000	0.38	15.92
16000	0.41	13.71
4000	0.45	11.61
1000	0.50	8.66
200	0.52	6.92
0	0.64	0.00
0	0.64	0.00

Compression Ratio	0.1394
Recompression Ratio	0.0802
Est. Preconsolidation Stress (psf)	7052
Initial Dry density (pcf)	102.9
Initial Moisture (%)	23.8
Final Dry density (pcf)	110.6
Final Moisture (%)	22.3

Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	4.562E-06
4000.00	5.328E-06

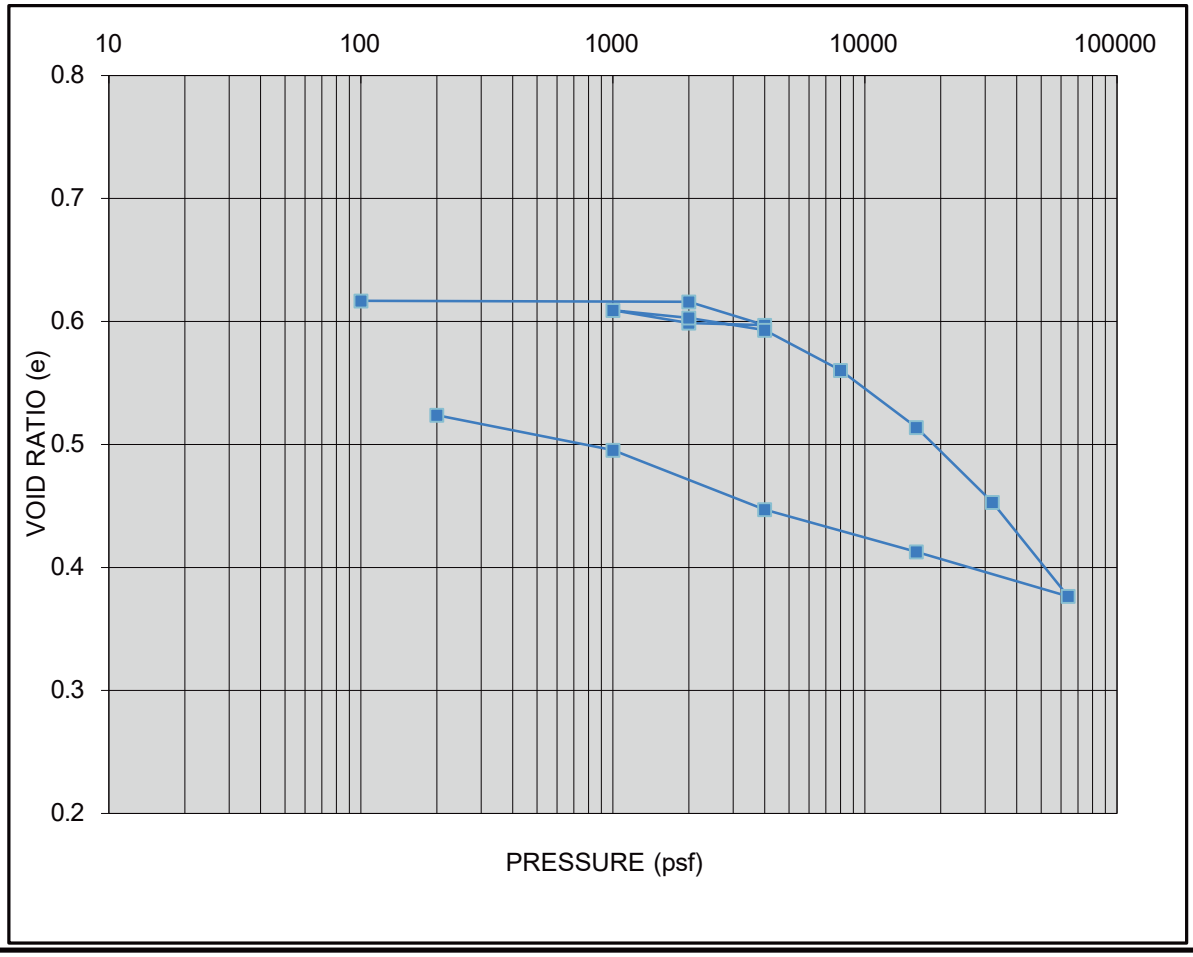
Note: Soil indicated swelling pressures up to 1400 psf under constant volume saturation step

Project Name:	Big Notch Project
Hole No.	FW-118B
Field Sample No.	T01,10.0'-11.1'
Sample No:	20-527
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	2/1/2020

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

CONSOLIDATION TEST



Applied Stress (psf)	Void Ratio	Final Strain (%)
0	0.64	0.00
100	0.62	1.25
2000	0.62	1.29
4000	0.60	2.45
2000	0.60	2.34
1000	0.61	1.71
2000	0.60	2.09
4000	0.59	2.70
8000	0.56	4.70
16000	0.51	7.53
32000	0.45	11.25
64000	0.38	15.92
16000	0.41	13.71
4000	0.45	11.61
1000	0.50	8.66
200	0.52	6.92
0	0.64	0.00
0	0.64	0.00

Compression Ratio	0.1394
Recompression Ratio	0.0802
Est. Preconsolidation Stress (psf)	7052
Initial Dry density (pcf)	102.9
Initial Moisture (%)	23.8
Final Dry density (pcf)	110.6
Final Moisture (%)	22.3

Assumed specific gravity (Gs)	2.70

Stress (psf)	Coefficent of Consolidation (ft^2/s)
2000.00	4.562E-06
4000.00	5.328E-06

Project Name:	Big Notch Project
Hole No.	FW-118B
Field Sample No.	T01-10.0'-11.1'
Sample No:	20-527
Test Req. No:	2020-18
Sample Type:	Shelby
Date:	2/1/2021

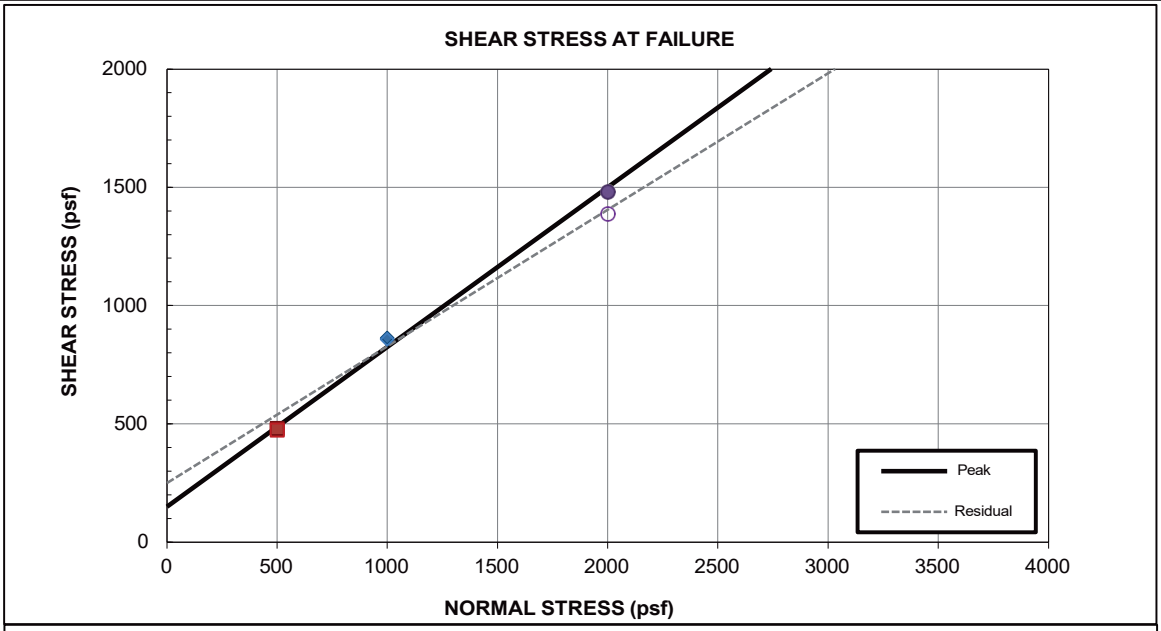
Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

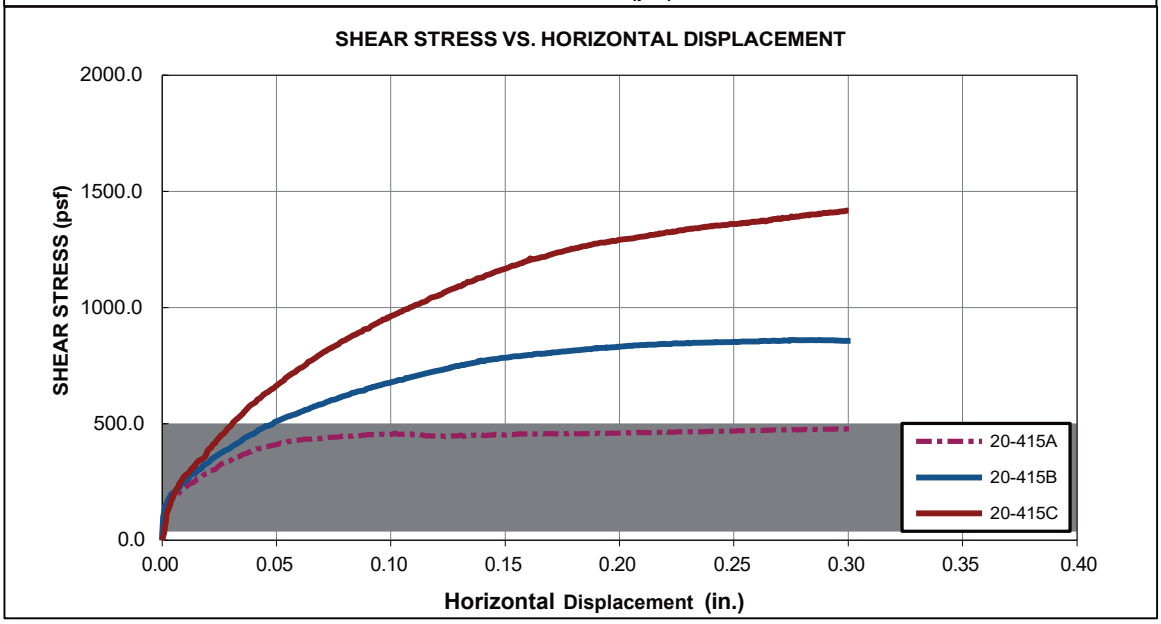
DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

DIRECT SHEAR TESTS

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Direct Shear Test
ASTM D3080





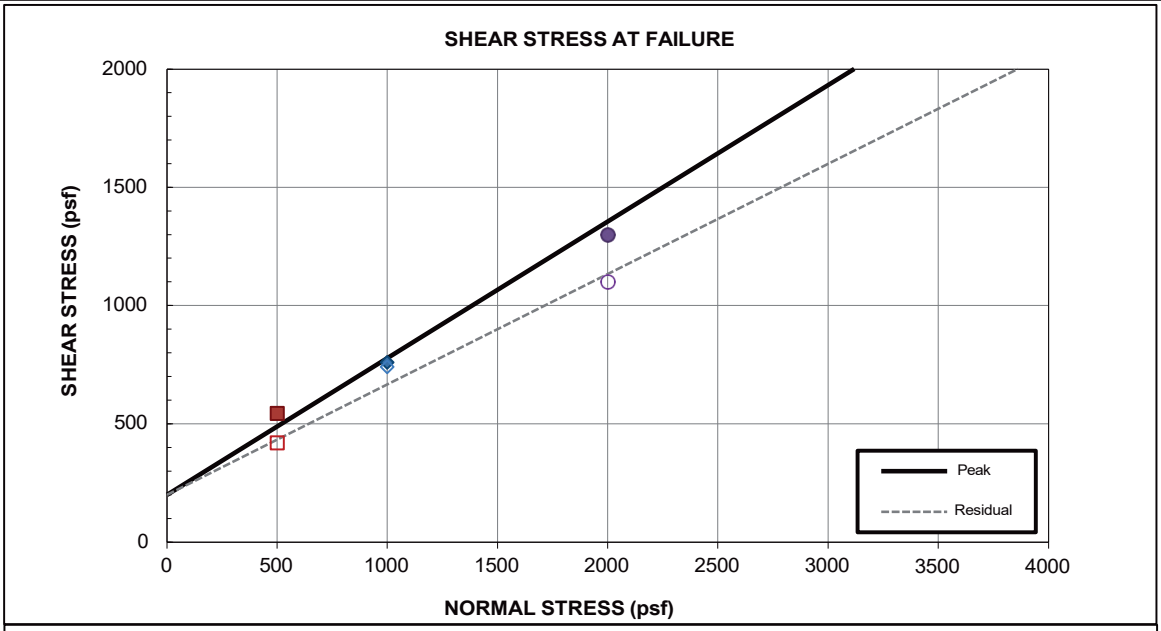
Sample ID:	Applied Normal Stress (psf)	Peak Shear Stress (psf)	Residual Shear Stress (psf)	Initial Moisture Content (%)	Final Moisture Content (%)	Dry Density (pcf)	Plastic Index (per ASTM D4318)	Percent Fines (per ASTM D1140)
20-415A	500	481.1	474.1	31.2	34.5	69.7	22	97
20-415B	1000	862.6	857.2	30.1	31.8	71.7	22	97
20-415C	2000	1478.8	1388.4	29.2	30.6	69.2	22	97

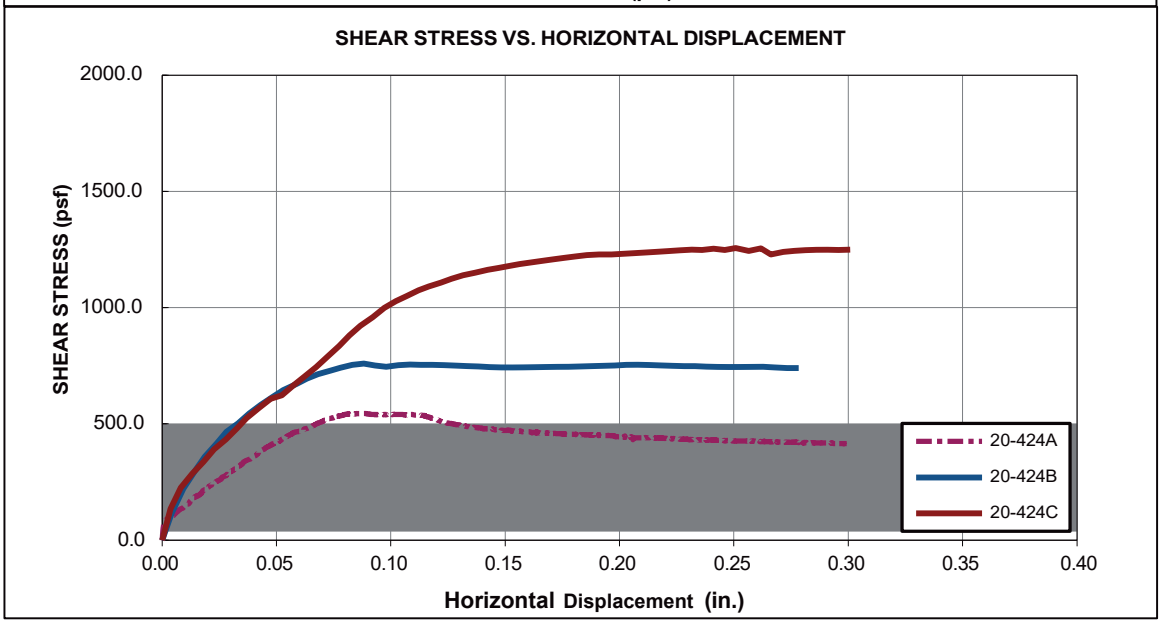
	Peak	Residual
Cohesion (c), psf	150.0	250.0
Coshesion (c), psi	1.0	1.7
Friction angle (phi), deg.	34	30

Sample No:	20-415	Project Name:	Big Notch
Test Req. No:	2020-18	Location:	116B
Sample Type:	Undisturbed	Depth (ft):	12.5-14.5
Shear Rate: (in/min)	5.90E-04	Bryte Soils and Concrete Lab 1450 Riverbank Road Sacramento, CA 95605 (916)375-6012	
Date:	11/21/2020		

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Direct Shear Test
ASTM D3080





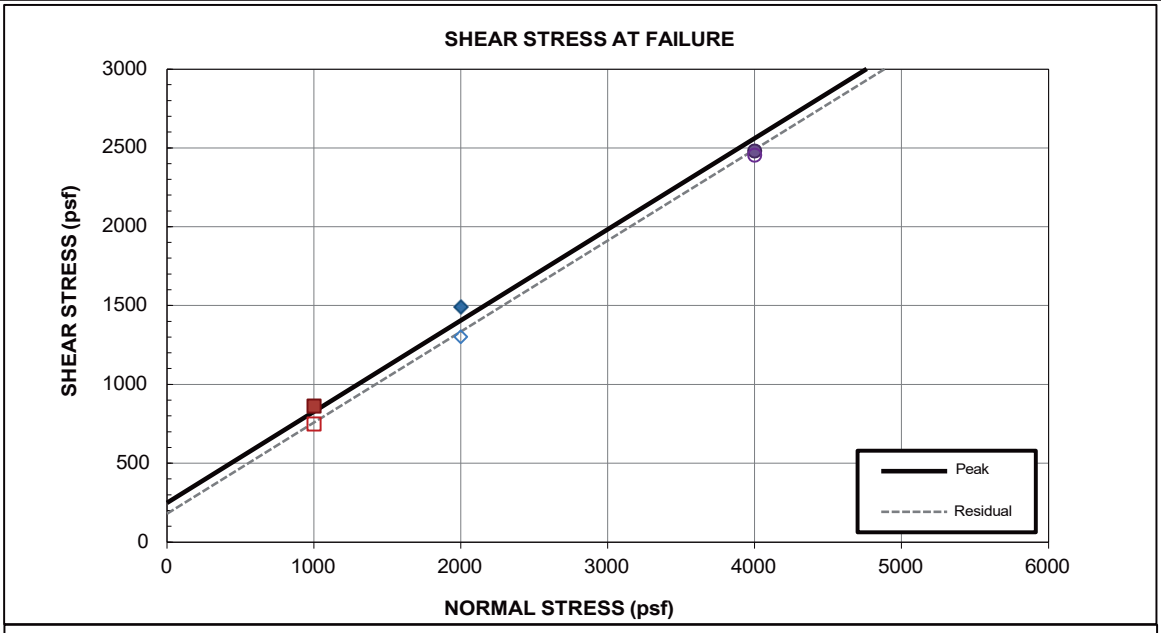
Sample ID:	Applied Normal Stress (psf)	Peak Shear Stress (psf)	Residual Shear Stress (psf)	Initial Moisture Content (%)	Final Moisture Content (%)	Dry Density (pcf)	Plastic Index (per ASTM D4318)	Percent Fines (per ASTM D1140)
20-424A	500	545.0	420.5	25.7	31.7	98.9	25	99
20-424B	1000	759.5	740.3	26.5	28.8	98.1	25	99
20-424C	2000	1298.1	1100.0	26.6	28.2	98.2	25	99

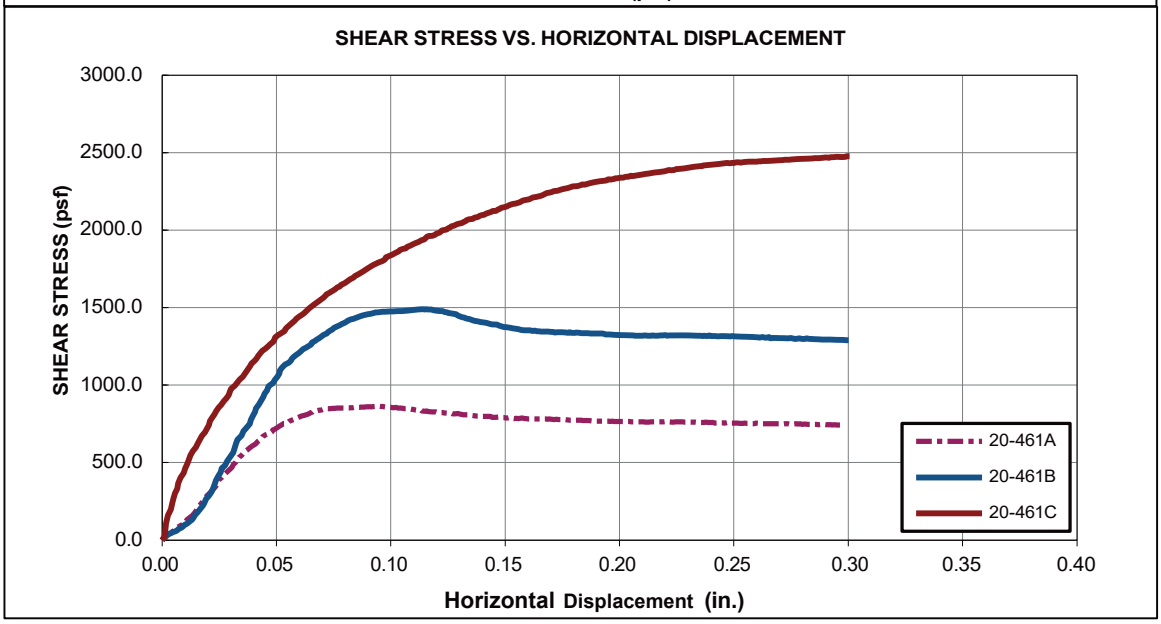
	Peak	Residual
Cohesion (c), psf	200.0	200.0
Coshesion (c), psi	1.4	1.4
Friction angle (phi), deg.	30	25

Sample No:	20-424	Project Name:	Big Notch
Test Req. No:	2020-18	Location:	120B
Sample Type:	Undisturbed	Depth (ft):	10.0-12.0
Shear Rate: (in/min)	5.00E-03	Bryte Soils and Concrete Lab 1450 Riverbank Road Sacramento, CA 95605	
Date:	12/22/2020	(916)375-6012	

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Direct Shear Test
ASTM D3080





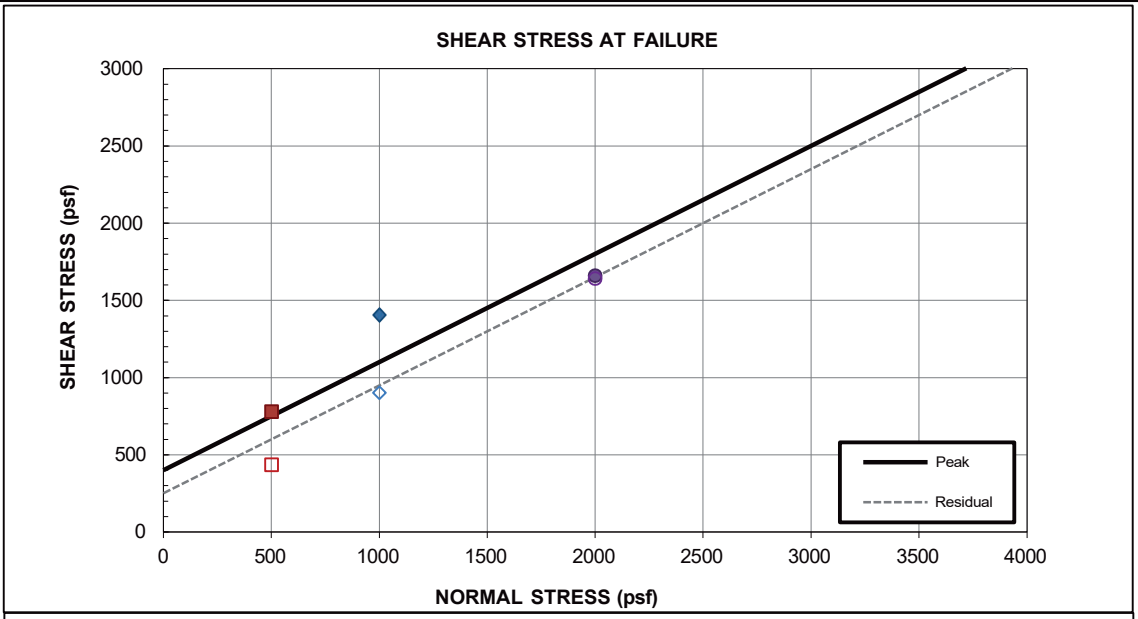
Sample ID:	Applied Normal Stress (psf)	Peak Shear Stress (psf)	Residual Shear Stress (psf)	Initial Moisture Content (%)	Final Moisture Content (%)	Dry Density (pcf)	Plastic Index (per ASTM D4318)	Percent Fines (per ASTM D1140)
20-461A	1000	863.6	749.0	22.1	28.3	98.4	15	98
20-461B	2000	1490.2	1301.5	22.7	25.0	98.2	15	98
20-461C	4000	2480.6	2454.9	24.1	25.2	99.0	15	98

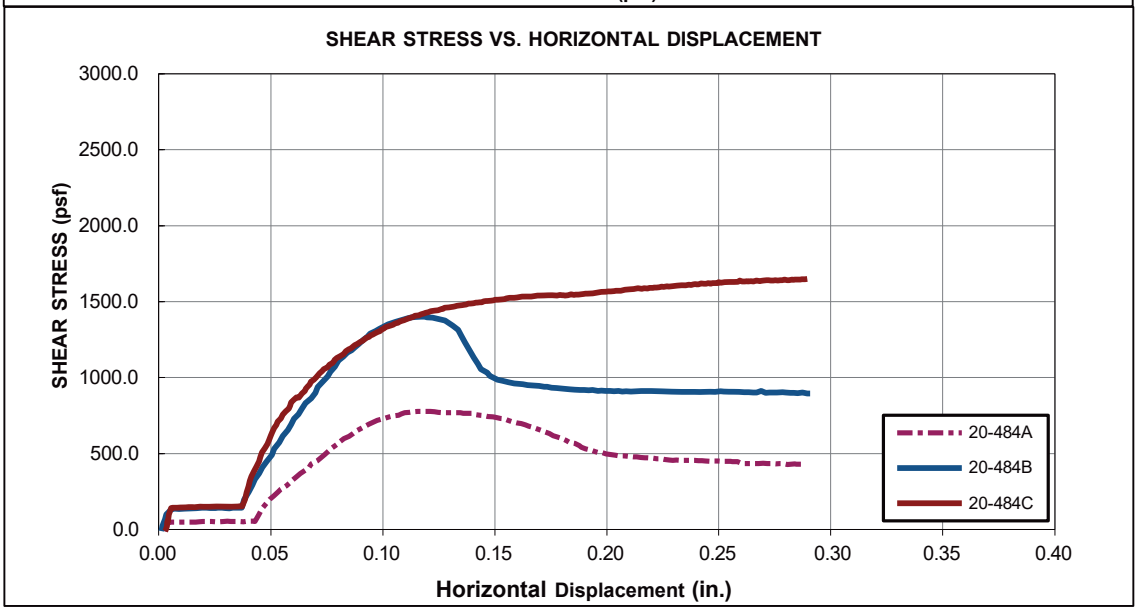
	Peak	Residual
Cohesion (c), psf	250.0	180.0
Coshesion (c), psi	1.7	1.3
Friction angle (phi), deg.	30	30

Sample No:	20-461	Project Name:	Big Notch
Test Req. No:	2020-18	Location:	106B
Sample Type:	Undisturbed	Depth (ft):	20.0-21.8
Shear Rate: (in/min)	1.00E-03	Bryte Soils and Concrete Lab 1450 Riverbank Road Sacramento, CA 95605	
Date:	1/25/2021	(916)375-6012	

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Direct Shear Test
ASTM D3080





Sample ID:	Applied Normal Stress (psf)	Peak Shear Stress (psf)	Residual Shear Stress (psf)	Initial Moisture Content (%)	Final Moisture Content (%)	Dry Density (pcf)	Plastic Index (per ASTM D4318)	Percent Fines (per ASTM D1140)
20-484A	500	777.7	434.6	19.6	22.4	87.8	23	98
20-484B	1000	1401.0	899.8	21.0	20.3	85.5	23	98
20-484C	2000	1658.0	1639.6	24.7	16.1	83.5	23	98

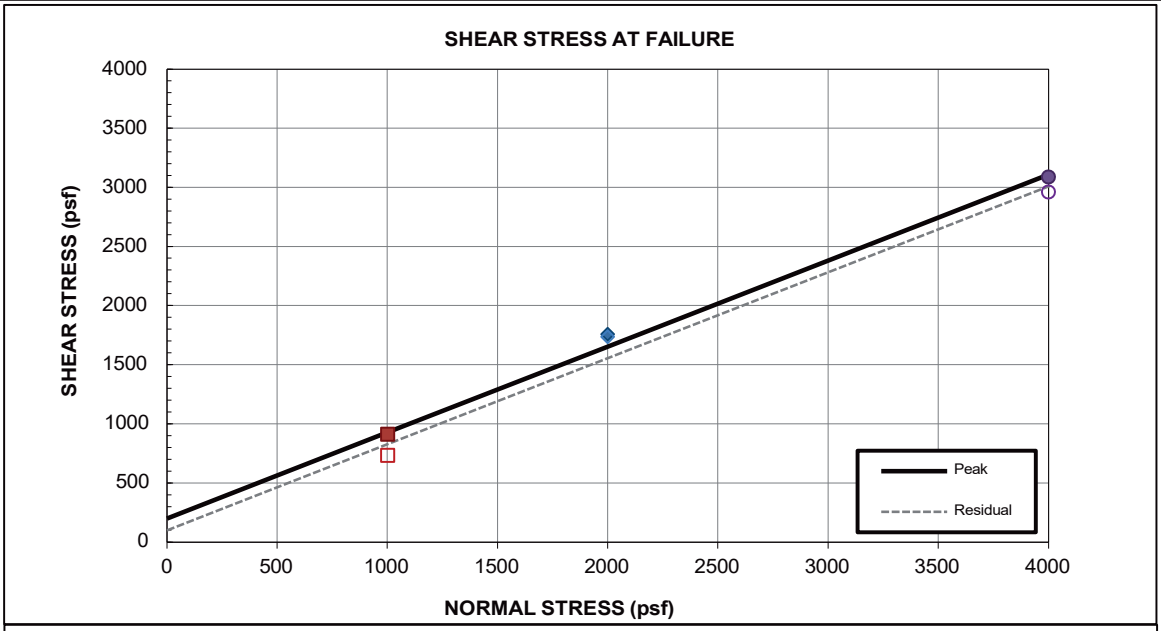
	Peak	Residual
Cohesion (c), psf	400.0	250.0
Coshesion (c), psi	2.8	1.7
Friction angle (phi), deg	35	35

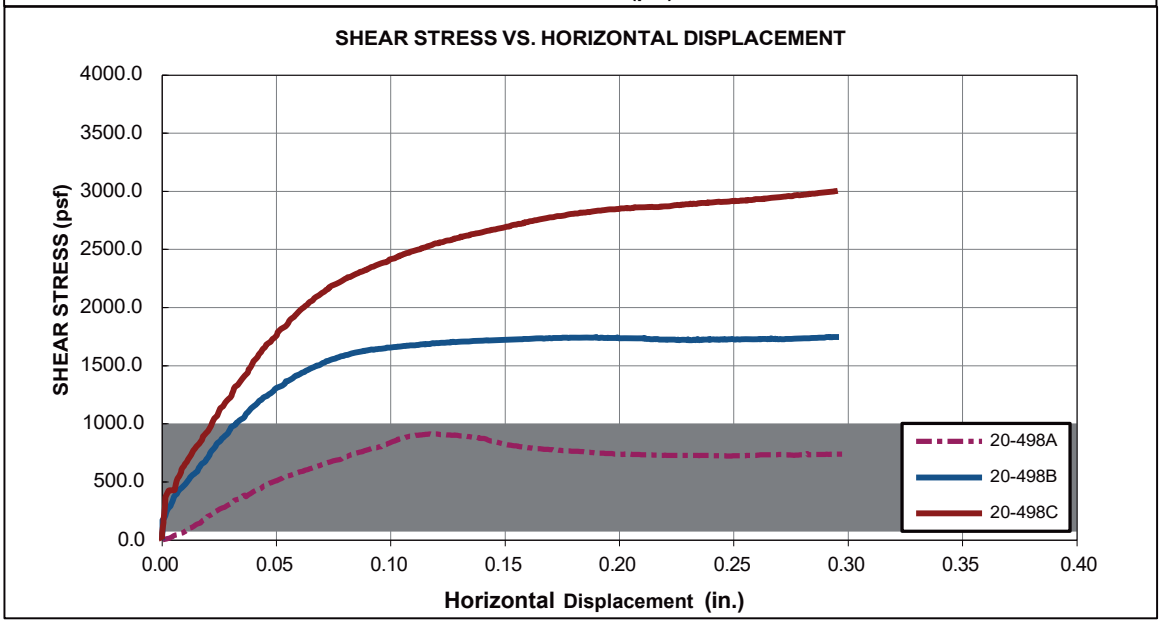
Note: The soil experinced expansion at lower confining stresses which could have affected the shear response.

Sample No:	20-484	Project Name:	Big Notch
Test Req. No:	2020-18	Location:	116B
Sample Type:	Undisturbed	Depth (ft):	7.5-9.5
Shear Rate: (in/min)	1.84E-03	Bryte Soils and Concrete Lab 1450 Riverbank Road Sacramento, CA 95605	
Date:	2/24/2021	(916)375-6012	

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Direct Shear Test
ASTM D3080





Sample ID:	Applied Normal Stress (psf)	Peak Shear Stress (psf)	Residual Shear Stress (psf)	Initial Moisture Content (%)	Final Moisture Content (%)	Dry Density (pcf)	Plastic Index (per ASTM D4318)	Percent Fines (per ASTM D1140)
20-498A	1000	913.1	733.2	19.0	23.5	82.7	12	98
20-498B	2000	1756.4	1734.7	18.6	22.6	83.6	12	98
20-498C	4000	3088.4	2960.6	19.3	20.4	82.7	12	98

	Peak	Residual
Cohesion (c), psf	200.0	100.0
Coshesion (c), psi	1.4	0.7
Friction angle (phi), deg.	36	36

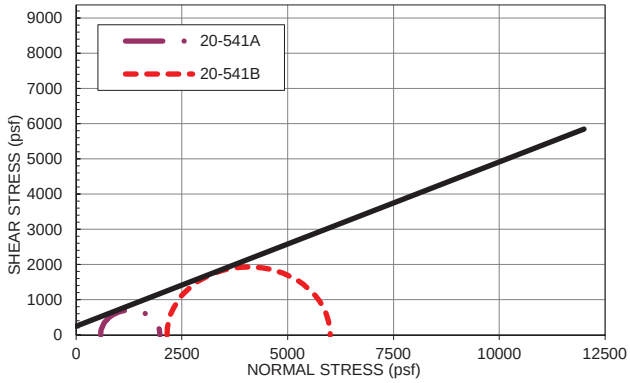
Sample No:	20-498	Project Name:	Big Notch
Test Req. No:	2020-18	Location:	105B
Sample Type:	Undisturbed	Depth (ft):	20-22
Shear Rate: (in/min)	5.33E-04	Bryte Soils and Concrete Lab 1450 Riverbank Road Sacramento, CA 95605	
Date:	2/26/2021	(916)375-6012	

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

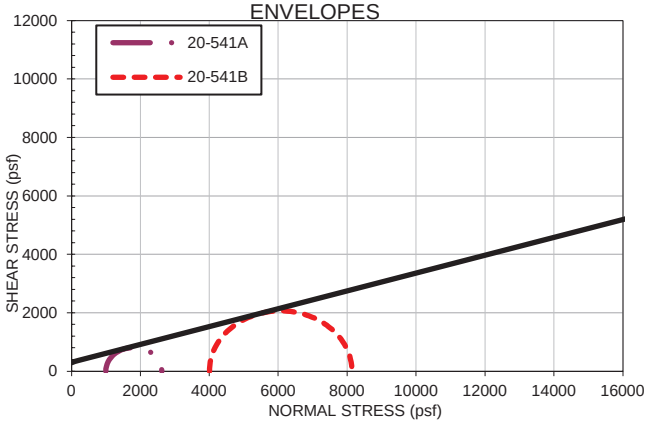
TRIAXIAL CU TESTS

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

EFFECTIVE (DRAINED) STRESS FAILURE ENVELOPE



TOTAL (UNDRAINED) STRESS FAILURE ENVELOPES



Sample Location	115B	115B
Sample Depth	19-21 ft	19-21 ft
Sample ID	20-541A	20-541B
Visual Classification	CL	CL

Sample ID:	Height (in)	Diameter (in)	Confining Pressure (psf)	Initial Moisture Content (%)	Initial Dry Density (pcf)	Saturation (%)	Strain Rate (%/hr)
20-541A	5.94	2.85	1000	29.5	91.5	99.8	0.6
20-541B	5.88	2.85	4000	24.9	97.7	100.0	0.6

Results:

	Drained	Undrained
Cohesion (c), psf	250	300
Phi, deg.	25	17

Comments: The sample in the tube had limite dlength to perform a third test.

Project Name	The Big Notch
Location	115B
Sample No:	20-541
Test Req. No:	20-18
Sample Type:	Shelby
Date:	2/1/2021

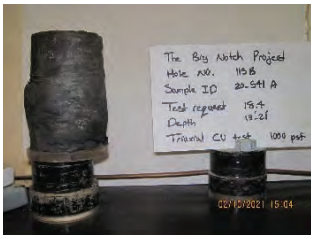
Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

	Sample A	Sample B
Confining Pressure (psf)	1000	4000
Location in tube (from bottom)	0-8.5 inches	8.5-15 inches
% fines (if tested)	99	99
Liquid Limit	43	43
Plastic Index	20	20
Applied Specific Gravity	2.7	2.7
measured or assumed?	Assumed	Assumed
Soil description	Lean Clay	Lean Clay
Comments		





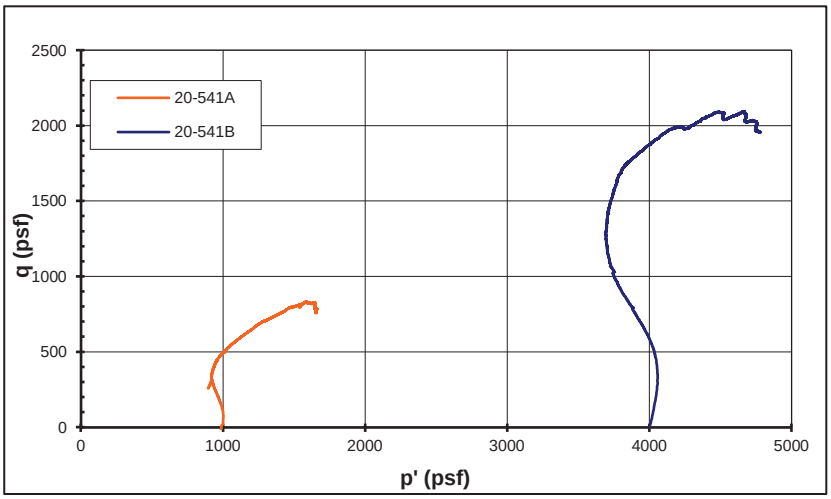


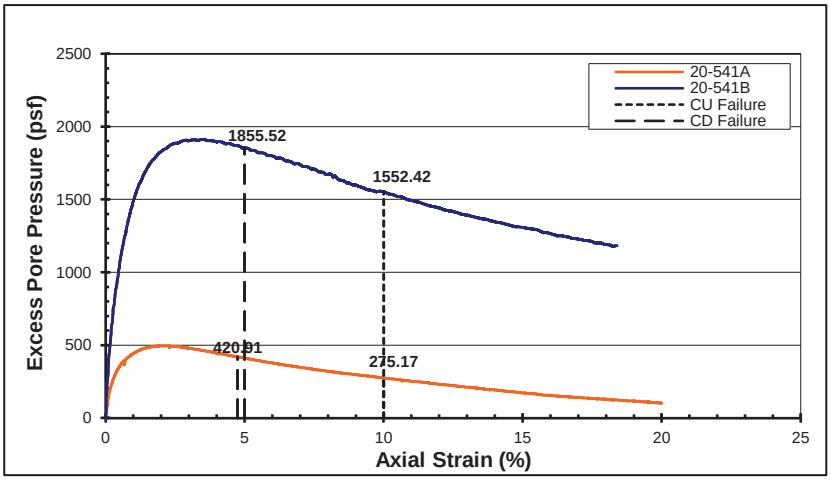


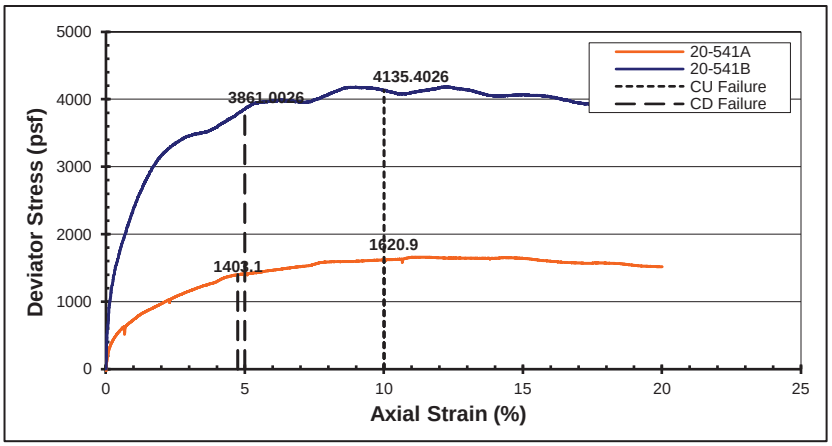
Project Name:	The Big Notch
Location	115B
Sample No:	20-541
Test Req. No:	20-18
Sample Type:	Shelby
Date:	2/1/2021

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF







Project Name:	The Big Notch
Location	115B
Sample No:	20-541
Test Req. No:	20-18
Sample Type:	Shelby
Date:	2/1/2021

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California 95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

Test Date - 2/10/2021

20-541A

Effective Confining Pressure (psf) = 999.7
Initial Dry Density (pcf) = 91.46
USCS Class = CL
LL = 43; PI = 20
% Fines = 99
Initial Water Content (%) = 29.5

Sample Height (in):	5.942
Sample Diameter (in):	2.848
Strain Rate During Shear	0.59

FAILURE CRITERIA SELECTION

Effective	
Failure Criteria (Strain @ PSR or 5%)	4.745
Dev. Stress @ Failure (psf)	1435.8
Excess Pore Pressure @ Failure (psf)	420.9
Total	
Failure Criteria (Strain @ PDS or 10%)	10
Dev. Stress @ Failure (psf)	1653.6

Axial Strain ε (%)	Excess Pore Pressure Δu (psf)	Effective Confining Stress σ3' (psf)	Stress Ratio σ3'/σ1'	Deviator Stress σ1 - σ3 (psf)
0	0.00	999.71	1.034	0.00
0.1	144.58	855.13	1.317	303.97
0.2	222.70	777.01	1.494	416.35
0.5	356.78	642.93	1.888	603.95
1	444.23	555.48	2.329	771.08
1.5	483.87	515.84	2.685	901.79
2	495.53	504.18	2.925	1003.28
3	480.38	519.33	3.235	1193.42
4	446.56	554.31	3.349	1334.92
4.745	420.91	571.79	3.454	1435.82
5	411.58	588.13	3.409	1449.42
6	377.77	621.94	3.359	1500.12
7	349.79	649.92	3.341	1553.92
8	320.64	679.07	3.339	1621.42
9	298.49	701.22	3.282	1632.52
10	275.17	724.54	3.237	1653.62
11	253.01	746.70	3.223	1692.72
12	233.19	766.52	3.157	1686.22
13	212.20	788.67	3.087	1678.42
14	193.55	806.16	3.039	1676.12
15	172.56	827.15	2.987	1676.32
16	156.24	844.64	2.896	1634.52
17	141.08	858.63	2.835	1608.22
18	129.42	870.29	2.810	1608.12
19	116.60	884.28	2.741	1572.32
20	103.77	895.94	2.694	1550.32
--	--	--	--	--

Test Date - 2/10/2021

20-541B

Effective Confining Pressure (psf) = 4000.0
Initial Dry Density (pcf) = 97.67
USCS Class = CL
LL = 43; PI = 20
% Fines = 99
Initial Water Content (%) = 24.9

Sample Height (in):	5.878
Sample Diameter (in):	2.853
Strain Rate During Shear	0.59

FAILURE CRITERIA SELECTION

Effective	
Failure Criteria (Strain @ PSR or 5%)	5.0
Dev. Stress @ Failure (psf)	3861.0
Excess Pore Pressure @ Failure (psf)	1855.5
Total	
Failure Criteria (Strain @ PDS or 10%)	10
Dev. Stress @ Failure (psf)	4135.4

Axial Strain ε (%)	Excess Pore Pressure Δu (psf)	Effective Confining Stress σ3' (psf)	Stress Ratio σ3'/σ1'	Deviator Stress σ1 - σ3 (psf)
0	0.00	4000.00	1.000	0.00
0.1	405.42	3594.60	1.251	903.68
0.2	607.55	3392.40	1.354	1202.10
0.5	1056.42	2943.50	1.596	1753.90
1	1498.32	2501.70	1.960	2400.60
1.5	1719.22	2280.70	2.252	2854.50
2	1832.02	2167.90	2.466	3178.20
3	1904.92	2095.10	2.650	3457.30
4	1896.72	2103.30	2.708	3591.40
5	1855.52	2144.40	2.801	3861.00
6	1799.12	2200.80	2.807	3977.80
7	1739.22	2260.80	2.752	3961.60
8	1675.72	2324.20	2.753	4074.90
9	1599.42	2400.60	2.741	4180.50
10	1552.42	2447.60	2.690	4135.40
11	1494.82	2506.30	2.636	4099.40
12	1452.52	2547.50	2.630	4152.00
13	1452.52	2547.50	2.630	4152.00
14	1452.52	2547.50	2.630	4152.00
15	1452.52	2547.50	2.630	4152.00
16	1452.52	2547.50	2.630	4152.00
17	1452.52	2547.50	2.630	4152.00
18	1452.52	2547.50	2.630	4152.00
19	1452.52	2547.50	2.630	4152.00
20	1452.52	2547.50	2.630	4152.00
--	--	--	--	--

Sample — Cells highlighted light green - data used in calculating mohrs circles for effective (drained) stress

Sample — Cells highlighted gray - data used in calculating mohrs circles for total (undrained) stress

Project Name:	The Big Notch
Location	115B
Sample No:	20-541
Test Req. No:	20-18
Sample Type:	Shelby
Date:	2/1/2021

Bryte Soils and Concrete Lab
1450 Riverbank Road
West Sacramento, California
95605
(916)375-6012

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

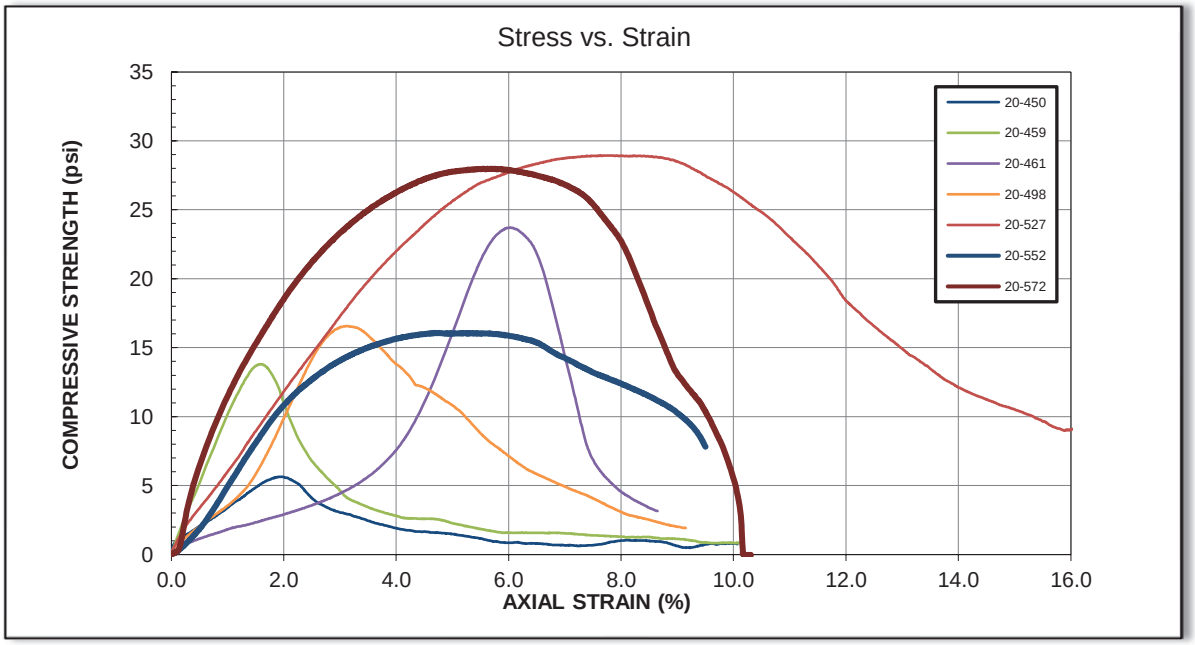
UNCONFINED COMPRESSIVE STRENGTH TESTS

DocuSign Envelope ID: B1793F00-BCC6-489A-8B9F-795CBAFBF4FF

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

DIVISION OF ENGINEERING
GEOTECHNICAL STRUCTURES BRANCH
BRYTE SOILS CONCRETE LABORATORY

UNCONFINED COMPRESSIVE STRENGTH
ASTM D2166



Sample ID	20-450	20-459	20-461	20-498	20-527	20-552	20-572			
Location	FW-103B	FW-106B	FW-106B	FW-105B	FW-118B	FW-119B	FW-108B			
Depth	17.0-19.0	10.0-12.0	20.0-21.8	20.0-22.0	10.0-12.0	14.0-16.0	19.0-21.0			
Sample Diameter (in)	2.88	2.88	2.88	2.86	2.88	2.88	2.88			
Sample Height (in)	5.97	5.61	5.63	6.05	5.71	6.45	6.28			
H/D Ratio	2.07	1.95	1.96	2.11	1.98	2.24	2.18			
Wet Density (pcf)	124.6	111.8	121.9	130.2	123.0	120.3	117.4			
Strain Rate (%/min)	1	1	1	1	1	1	1			
Strain at Failure (%)	1.91	1.58	6.01	3.13	7.78	4.74	5.76			
Unconfined Compressive Strength (psi)	6	14	24	17	29	16	28			
Poisson's Ratio										
Remarks/ Comments:										

NOTES:

Project Name:	Big Notch Project
Feature:	
Date:	3/12/2021

Bryte Soils and Concrete Lab
1450 Riverbank Road West
Sacramento, CA 95605
(916)375-6012