Subject:	**Southern Forebay Emergency Spillway Siting Analysis (Final Draft)**
Project feature:	Southern Forebay
Prepared for:	California Department of Water Resources (DWR) / Delta Conveyance Office (DCO)
Prepared by:	Delta Conveyance Design and Construction Authority (DCA)
Copies to:	File
Date/Version:	December 23, 2021
Reference no.:	EDM_FB_CE_TMO_SF-Emer-Spillway-Siting-Analysis_000960_V03_FD_20211223

1. Purpose and Introduction

The Delta Conveyance Project (Project) would include intakes along the Sacramento River between its confluences with American River and Sutter Slough, as well as a tunnel between the intakes and a forebay at the downstream terminus of the main tunnel (the Southern Forebay). Water would either flow by gravity or be lifted by the pumping plant from the tunnel into the Southern Forebay (SF). Discharge from the SF would occur through the Southern Forebay Outlet Structure, at the southern end of the forebay, into the South Delta Conveyance facilities (SDCF) for connection to the existing State Water Project Harvey O. Banks Pumping Plant and possibly the Central Valley Project C.W. Bill Jones Pumping Plant.

The SF would include a perimeter earthen embankment to retain the storage and an emergency spillway. This technical memorandum (TM) includes calculations to determine the conceptual length of the spillway weir, summaries of possible spillway sites along the SF perimeter embankment, criteria used to evaluate the sites, and a recommendation for the preferred location for the Southern Forebay Emergency Spillway.

2. Background

The SF would be an at-grade storage reservoir located on Byron Tract near the existing Clifton Court Forebay (CCF) (Figure 2-1). The forebay would be formed by an earthen embankment with a perimeter length of approximately 4.7 miles and a crest elevation of about Elevation (El) +28 feet. The elevations provided in this TM are based on the North American Vertical Datum of 1988 (NAVD88).

The California Department of Water Resources (DWR), Division of Safety of Dams (DSOD) is the State agency with jurisdiction over the design, construction, and operations of the planned SF. As mandated by DSOD, an emergency spillway would be required to safely convey excess reservoir inflows and prevent the perimeter embankment from being overtopped. It is anticipated that the controlling inflow for spillway design would be the normal maximum discharge capacity of the pumping plant under the option with a 7,500-cubic-feet-per-second (cfs) project design capacity when the gates at the Southern Forebay Outlet Structure were closed. Uncontrolled gravity flow through the system with the intake gates open would potentially result in a longer event but at lesser flow due to frictional head losses through the system.

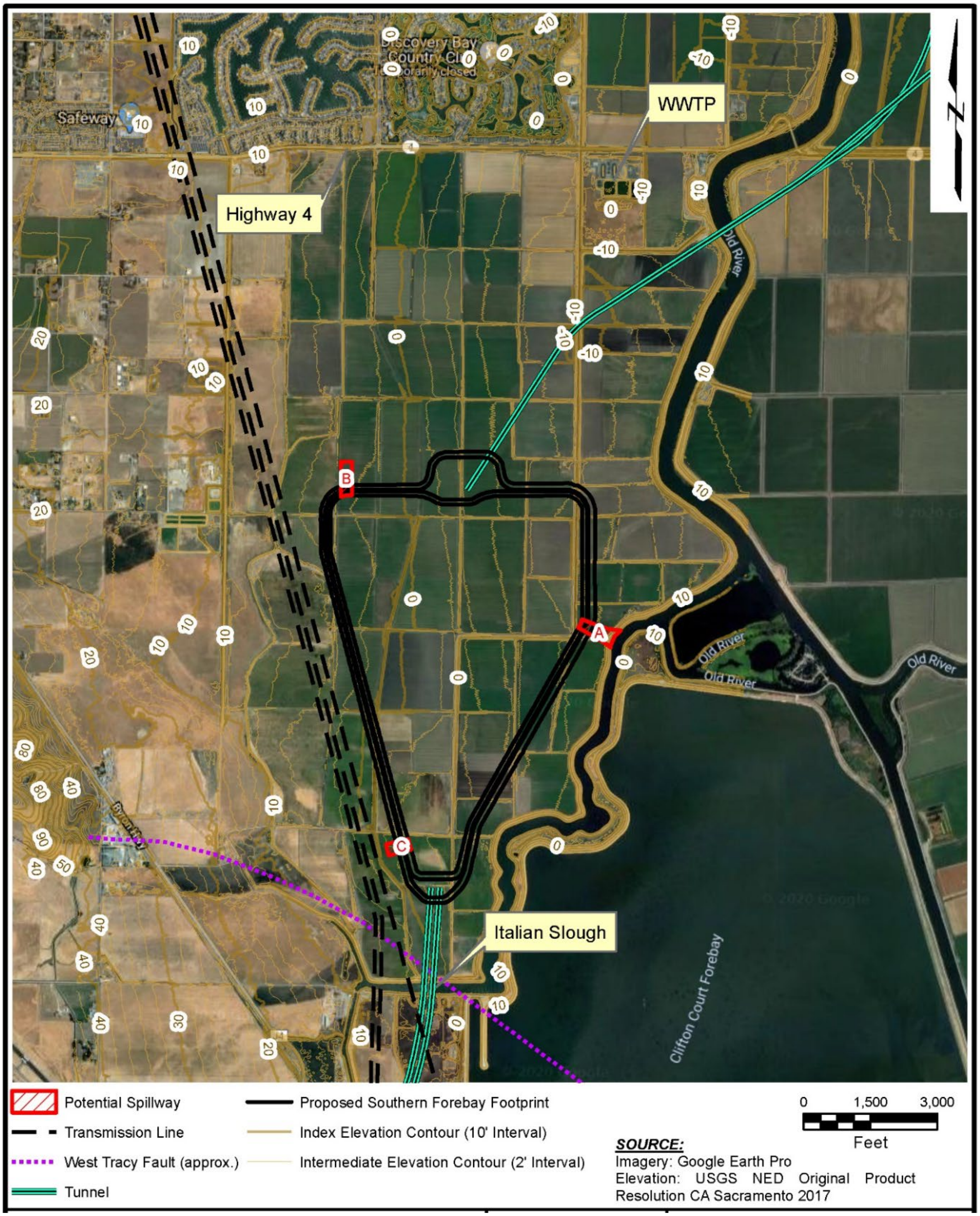

Figure 2-1. Southern Forebay Location

3. Conceptual Spillway Size and Configuration

To site the emergency spillway, it is anticipated that the spillway would be a concrete, labyrinth-type spillway with a total width of approximately 300 feet along the axis of the embankment crest. Attachment 1 provides the weir calculations for establishing the spillway weir length and configuration. A labyrinth configuration was selected to minimize the total length of the weir, recognizing that the spillway foundation may require significant ground improvement to minimize differential settlement and improve the structure's long-term performance.

As Attachment 1 shows, the approximate size of the spillway was conceptualized based on a maximum flow height over the spillway crest limited to 2.5 feet, to minimize the overall embankment height. The spillway would have a total length of approximately 200 feet measured from the inboard edge (near the embankment crest) to the outboard edge of the spillway (discharge end). Existing ground surface elevations within the proposed footprint of the SF embankment range between approximately El -8.0 feet along the eastern side and El +6.0 feet along the western side (Figure 3-1). The actual spillway foundation would depend on the selected site, since subsurface conditions and ground elevations vary around the perimeter of the reservoir. The proposed elevation at the spillway and weir crest would be El 21.0 feet, and training walls would extend to approximately El 29.0 feet at the crest of the spillway.

4. Criteria for Site Evaluation

The spillway siting selection was evaluated using available data summarized below to identify suitable sites along the proposed SF embankment. Potential sites for the emergency spillway were evaluated based on the conditions and general criteria described in Table 4-1.

Table 4-1. Emergency Spillway Site Evaluation Criteria

Criteria	Summary Description
Subsurface Soil Conditions	Deposits of soft, compressible clay and peat/organic soils of various thicknesses are anticipated to be common underlying the proposed SF site, with the greatest thicknesses along the eastern half of the site. Loading by the earthen embankment and spillway structure would compress these soft, compressible deposits, resulting in significant ground settlement; which, if not mitigated, could affect the stability and structural integrity of the Emergency Spillway.
Existing Topography	The existing ground surface within the footprint of the SF embankment varies. With the SF embankment crest set at El 28 feet, the height of the SF embankment will vary. Therefore, the existing ground surface would dictate the height of the proposed embankment/spillway. Sections of embankment having relatively greater heights would impose correspondingly larger loads on the embankment foundation materials (including soft, compressible clay and peat deposits) and result in relatively larger long-term settlements and increased potential for differential settlement of the concrete spillway.
Existing Infrastructure	Existing infrastructure present near the SF would include overhead and underground utilities, levee-contained sloughs/aqueducts, roadways/highways, and single-story buildings. The criticality of the existing infrastructure and potential need for mitigating measures to prevent damage/loss of use to existing infrastructure was considered.
Spillway Discharge Flow Path	Spillway discharge would flow into an overland basin or to an existing waterway. Flow paths that could efficiently convey flow and limit potential impacts to existing structures and SF facilities would be preferred.

Figure 3-1. Southern Forebay Potential Emergency Spillway Locations

Three potential sites for the Southern Forebay Emergency Spillway were selected based on these criteria. Engineering judgement was used to qualitatively evaluate each potential site. The evaluation criteria and development of recommendations for the Southern Forebay Emergency Spillway location are discussed here.

4.1 Subsurface Soil Conditions

Limited geotechnical data were available within the footprint of the SF embankment; however, data from nearby sites were available and used for this siting study. Based on the information in the *Southern Forebay Seismic Sensitivity Evaluation* TM (DCA, 2021a), the site is anticipated to contain varying thicknesses of soft, compressible clay, peat/organic deposits, and loose liquefiable sands. Along the eastern half of the SF embankment, near-site subsurface data indicated deposits of organic (peat) material ranging in thickness from about 5 to 20 feet, underlain by soft, compressible, fine-grained soil and liquefiable sands to total depths of about 30 feet. Along the western half of the SF embankment, the subsurface conditions are anticipated to consist of medium stiff, fine-grained soils with intermittent near-surface organic soil deposits on the order of 3 to 5 feet thick. Loose liquefiable sands were generally not observed in explorations along and near the western half of the SF embankment.

Based on the available geotechnical data, it is anticipated that significant settlement of the SF embankment would occur without improvement of the foundation soils. Based on the results of the *Southern Forebay Seismic Sensitivity Evaluation* TM (DCA, 2021a), foundation improvements along the SF embankment footprint are anticipated to reduce the potential for settlements, including settlement in soft clay and organic deposits and settlement (and strength loss) due to liquefaction. For the qualitative evaluation of subsurface conditions, it was assumed that ground improvement would be performed and static and seismic settlements underlying potential spillway locations would be significantly reduced (but not eliminated). Criteria for design and performance of ground improvement and the Southern Forebay embankment and Southern Forebay Emergency Spillway foundation materials would be developed during subsequent stages of design.

4.2 Existing Topography Considerations

As noted, the existing ground surface within the SF embankment footprint ranges from about El -8 feet to El +6 feet. With the anticipated crest elevation of the SF embankment at about El +28, the height of the proposed embankment would range from 22 to 36 feet in height. Greater heights correspond to greater loads imposed on weak and compressible subsurface soils that may be present. Even with the improvements to the foundation soils, settlements underlying the thicker clay and peat deposits would be greater with higher embankments (that is, greater loads), with increased potential for settlement to affect the performance of the concrete spillway.

4.3 Existing Infrastructure

The impact of the spillway location on existing infrastructure was considered during selection of specific spillway sites to be evaluated. The major existing infrastructure considered included linear infrastructure such as existing levees, sloughs, aqueducts, electrical and gas lines, roadways, and existing buildings. As Figure 2-1 shows, the following infrastructure is currently present near the proposed SF embankment:

- Active overhead electrical and underground gas lines along the western edge of the proposed SF embankment. If a spillway discharge inundated the area where overhead electrical lines are located, it would be difficult to perform maintenance work on these lines. In addition, the potential for erosion around existing utility poles during a spill event would need to be mitigated to prevent erosive damage to the utility pole(s).

- Italian Slough, an existing waterway with humanmade levees to contain its flow. Proximity to Italian Slough could be beneficial if spillway discharge could safely flow into the waterway without impacting the existing levee system.
- State Route 4 approximately 1.4 miles north of the proposed SF embankment and south of Discovery Bay residential development. If the elevation of the highway is lower than the inundation surface elevations from the design spillway discharge events, a levee or similar facility could be required to prevent flow encroachment onto State Route 4.
- The wastewater treatment plant (WWTP) that serves Discovery Bay approximately 1.3 miles north of the proposed SF embankment. Portions of the ground surface within the WWTP are as low as El -6 feet. A ring/perimeter levee or similar facility could be required to prevent flows from inundating WWTP.

4.4 Spillway Discharge Flow Path Considerations

Depending on the Emergency Spillway location along the SF embankment, flows could either be connected directly to the existing Italian Slough or be directed overland (for example, to a natural or humanmade basin).

Potential Emergency Spillway locations along the eastern SF embankment would be a relatively short distance from Italian Slough. A spillway could be designed through the existing levee and discharge directly into Italian Slough. Flows into the slough would be most advantageous where there are no levees on the opposing side of the slough that would be impacted by the velocity of the spillway discharge. The Italian Slough north of the CCF would be advantageous, since flows entering the slough in these areas would be able to flow into the adjacent low-lying wetland area without impacting existing humanmade levees adjacent to the CCF.

Spillway discharges could also be designed to flow overland away from the SF embankment. Given the existing topography and the relatively high ground about 600 feet from the western toe of the proposed SF embankment, discharges from potential spillway locations along the western perimeter of the SF embankment would flow to areas either north or south of the SF embankment (refer to the topographical contours included on Figure 3-1). Flows travelling south could enter Italian Slough through a designed pathway through the existing levee system. Discharges flowing north of the SF could be directed to a new channel north of the South Delta Pumping Plant to flow to the Italian Slough, or the northern flow could naturally travel northward towards the existing WWTP and State Route 4.

5. Potential Sites for Southern Forebay Emergency Spillway

Based on the general layout of the SF embankment, three general areas were selected for evaluation of potential Southern Forebay Emergency Spillway sites (Figure 3-1). The following specific sites within each of these general areas were evaluated using the criteria presented in Section 3:

- Spillway Location “A” – located on Italian Slough along the northeastern portion of the SF embankment
- Spillway Location “B” – located near the northwestern corner of the SF embankment
- Spillway Location “C” – located on the western side of the SF, near the southern end of the SF embankment

In general, the locations were chosen to be either as close to Italian Slough as possible (Spillway Locations "A" and "C") or in areas where overland flow could occur relatively unimpeded (Spillway Locations "B" and "C"). Figure 3-1 shows general existing ground surface elevations at each spillway location.

6. Evaluation of Southern Forebay Emergency Spillway Locations

Each potential Southern Forebay Emergency Spillway location was reviewed and qualitatively evaluated using the criteria presented in Section 3. Considerations for each potential spillway location are presented here, with the advantages and disadvantages of each potential location summarized in Tables 6-1 through 6-3.

6.1 Spillway Location "A"

Subsurface Soil Conditions: In general, more extensive zones of weaker and more compressible clay and organic soil deposits are anticipated to be encountered along the eastern side of the SF embankment. If no mitigation is performed, Spillway Location "A" is anticipated to have the greatest potential for significant long-term settlement. However, ground and foundation improvements would be included for the SF embankment to mitigate the potential for settlements and increase subsurface soil strengths. Remaining long-term settlement is assumed to be manageable and should not impact the integrity of the concrete spillway structure at Spillway Location "A."

Existing Topography: At Spillway Location "A," the existing ground surface along the proposed SF embankment is approximately El -8 feet. Given an SF embankment crest elevation of El +28, the height of the proposed embankment would be approximately 36 feet. Spillway Location "A" would have the tallest embankment (and height of spillway) and corresponding relatively large loads imposed on the foundation materials.

Existing Infrastructure: At Spillway Location "A," the only known infrastructure is an existing humanmade levee along Italian Slough. The Italian Slough levee would be approximately 600 feet from the toe of the SF embankment.

Flow Path for Spillway Discharge: Given its proximity to Italian Slough, discharge from a spillway at Location "A" would be designed to discharge directly to the slough. To accommodate this, a portion of the existing Italian Slough levee would be removed. New levees would be constructed to channelize and contain the spillway discharge flows between the outboard toe of the spillway and the existing levee along Italian Slough. The discharge channel and levees would be expected to settle and require maintenance over time.

The discharge into Italian Slough would initially be contained within the slough's existing levees but would, over a short distance, converge with Old River. A benefit of Location "A" is the connection to Old River and the broader Delta waterways that could absorb spillway flows during discharge. If alternative sites significantly south of Spillway Location "A" were considered, the levees along CCF would likely be impacted and would require an evaluation of potential levee mitigations. It is assumed that Italian Slough could accommodate both long- and short-duration spillway discharge flows. Hydrological and hydraulic evaluations would be required to confirm capacity of Italian Slough to handle these flows.

The probability of the spillway releasing water is very low due to Project operations and is assumed to be independent of hydrologic conditions. Water surface elevations (WSE) based on Mean Higher High Water (MHHW), and a 100-year flood event were used in a hydraulic model (refer to Attachment 2) to determine the potential range of impacts associated with spillway discharge into Italian Slough. This evaluation of spillway discharge is based on current levee conditions, which does not include future upgrades to levee geometry. It is anticipated that levee maintaining agencies will continue to maintain and raise levees to counter the effects of sea level rise and climate changes. Attachment 2 outlines this hydraulic analysis and results.

The channel upstream of the SF saw nominal increases in WSE due to the assumed inflows into Italian Slough from ephemeral streams from the nearby foothills. The maximum change in estimated WSE ranges from 0.16 feet to 0.67 feet for the MHHW event, and 0.13 to 0.44 feet for the 100-year event, depending on pumping flow scenario. Estimated WSE impacts would extend from 0.50 miles to 1.94 miles downstream from the spillway for the MHHW event and 0.31 miles to 1.55 miles downstream from the spillway for the 100-year event.

The WSEs were estimated to be contained within the Italian Slough and Old River levees for all scenarios. The most common levee standard for Delta islands protecting agricultural areas is Public Law 84-99 which requires 1.5 feet of freeboard. With the spillway, all scenarios modeled maintained at least 1.5 feet of freeboard along Italian Slough and Old River. The MHHW event resulted in levee freeboard along Italian Slough and Old River of 7 feet or greater. The 100-year event resulted in levee freeboard of 4 feet or greater on the Byron Tract levees and 2.5 feet or greater on the Clifton Court levees along Italian Slough, and 2.0 feet or greater on the Victoria Island Levees along Old River. A tributary to Italian Slough may see approximately a 0.4 ft WSE increase under the 100-year event. Minor freeboard encroachment and possible overtopping may occur but is not anticipated to impact any critical infrastructure or inhabited areas.

Table 6-1. Summary of Advantages and Disadvantages for Location “A”

Advantages	Disadvantages
• It is relatively close to Italian Slough. • Discharge would flow directly into Italian Slough with connection to broader Delta waterways. • Italian Slough has adequate capacity to convey spillway discharge flows and maintain freeboard under most hydrologic conditions. • No overhead or underground utilities are nearby.	• This location results in a spillway on a relatively tall section of the SF embankment (approximately 36 feet high). • Significant ground improvement would be required to improve performance of the embankment and spillway foundation materials. • This location would require the removal of a portion of Italian Slough levee and construction of a discharge channel from the SF embankment/Southern Forebay Emergency Spillway discharge to Italian Slough. • Spillway discharge channel levees would be expected to require long-term maintenance.

6.2 Spillway Location “B”

Subsurface Soil Conditions: Subsurface soil conditions along the northwestern corner of the SF embankment are anticipated to consist of relatively stiffer clay deposits, but may contain zones of organic soils up to 5 feet thick. Significant zones of soft, compressible clay, liquefiable sand, or thicker organic soil deposits are not anticipated. If compressible or liquefiable soils were encountered in this area, ground improvement would be performed to mitigate potential for significant long-term settlement. The integrity of the concrete spillway structure at Spillway Location “B” should not be impacted by the performance of the subsurface materials.

Existing Topography: At Spillway Location "B," the existing ground surface within the proposed SF embankment is approximately El +3 feet. Given an SF embankment crest elevation of El +28, the height of the proposed embankment would be approximately 26 feet. Spillway Location "B" would have the shortest embankment and spillway height of the three locations evaluated. Approximately 1,400 feet from the outboard toe, the ground surface west of the SF embankment increases to about El +10 feet. The elevations north of Spillway Location "B" decrease from about El +3 at Spillway Location "B" to about El -8 feet along the northeastern edge of the SF embankment (near Italian Slough).

Existing Infrastructure: An existing electrical and gas utility corridor runs along the northwestern corner of the SF, approximately 500 feet from the toe of the western side of the SF embankment. North of the SF embankment are the WWTP, State Route 4, and Discovery Bay.

Flow Path for Spillway Discharge: The flow path from Spillway Location "B" is overland, with most of the spillway discharge likely to flow naturally to the area north of the SF embankment. Two options for flow management were qualitatively evaluated. One option was to channelize the discharge, keep it relatively close to the northern end of the SF, and direct the flow east toward Italian Slough. A bridge would be required for vehicular access to the South Delta Pumping Plant across the discharge channel. Another option would be to allow the spillway discharge to flow further north towards State Route 4. Concerns with allowing spillway discharge to flow further north include the potential for inundating the existing WWTP (south of State Route 4) and State Route 4. Mitigations to allow for a more northerly flow path could include constructing levees around the WWTP and along State Route 4, to contain the spillway discharge within the agricultural areas north of the SF embankment.

Table 6-2. Summary of Advantages and Disadvantages for Location "B"

Advantages	Disadvantages
• The embankment height is shorter (about 28 feet). • Significant soft clay and peat/organic foundation soils are not anticipated, which would result in relatively low potential for long-term settlement impacts to the concrete spillway structure. • Spillway discharge flows would flow into surrounding agricultural lands; excavating through Italian Slough levee may not be required. • For shorter-duration flows, minimal impacts would be anticipated to existing structures.	• To reduce impacts to WWTP, State Route 4, and agricultural lands, a discharge channel would need to be constructed to guide flows into low elevation area northeast of SF (and possibly into Italian Slough). A bridge would need to be constructed over the discharge channel to provide access to the South Delta Pumping Plant during discharges. • For long duration flows, overland flows may not be confined to lowland areas and may result in the inundation of the WWTP and State Route 4. Mitigation would likely require a perimeter and ring levee protecting WWTP and a levee protecting State Route 4. • Overhead utilities and associated poles alongside western toe of embankment would need to be protected (such as from erosion) to prevent damage to utility corridor power system. • Need to confirm whether "People at Risk" are in the northern area and assess the impact that discharge flows would have for them.

6.3 Spillway Location "C"

Subsurface Soil Conditions: Subsurface soil conditions along the southwestern corner of the SF embankment are anticipated to generally consist of stiffer clays deposits but may contain zones of organic soils up to 5 feet thick. If compressible or liquefiable soils are encountered in this area, ground improvement would be performed to mitigate potential for significant long-term settlement. The integrity of the concrete spillway structure at Spillway Location "C" should not be impacted by the performance of the subsurface materials.

Existing Topography: At Spillway Location "C," the existing ground surface along the proposed SF embankment is at approximate El -2 feet. Given a SF embankment crest elevation of El +28, the height of the proposed embankment would be approximately 30 feet.

The ground surface increases in elevation west of the outboard embankment toe at Spillway Location "C," but south of this location, the area is relatively flat and ranges from about El -2 to +0 feet.

Existing Infrastructure: At Spillway Location "C," an existing utility corridor for electricity and gas is located approximately 500 feet from the toe of the western side of the SF embankment. South of the SF embankment is a humanmade levee along the Italian Slough.

Flow Path for Spillway Discharge: The flow path from Spillway Location "C" is overland, with most of the discharge likely flowing naturally south and southeast of the SF embankment. Two options for flow management were qualitatively evaluated. One option was to keep the flow close to the southern end of the SF and channelize the flow towards Italian Slough to the south. With this option there would be: (1) the potential for flow into the Italian Slough, possibly impacting the levee embankment (and CCF facilities) on the opposite side of the slough and (2) the need to confirm the capacity of (the relatively narrow width of) the Italian Slough south of Spillway Location "C."

Another option would be to allow the discharge to flow mostly south and southeast along the southern tip of the SF embankment. The main concern for this option would be the extent of the overland flow. From reviewing the topography of the area, the flow from Spillway Location "C" could surround the southern and eastern half of the SF embankment between the embankment and the Italian Slough levees. Management of the potential flood water at the outboard base of the SF could be a significant issue.

Table 6-3. Summary of Advantages and Disadvantages for Location "C

Advantages	Disadvantages
• It is relatively close to the Italian Slough, so it may be practical to construct a discharge channel to convey spillway discharge directly to Italian Slough. • Significant zones of soft clay and peat/organic soils are not anticipated, which corresponds to relatively low potential for long-term settlement impacts to the concrete spillway structure.	• If a spillway discharge flows south into the narrow section of the Italian Slough, the flow into the confined portion of the waterway may increase water levels in slough and/or impact the CCF, existing levees, and surrounding area. • Overland flow appears constrained due to the higher existing topography of surrounding areas. Overland flows would appear to extend south and east along the toe of the SF embankment due to higher ground west of spillway site. • Overhead utilities and associated poles exist alongside the western side of embankment. The poles will require protection to prevent damage to the utility corridor power system.

7. Recommended Location for Emergency Spillway

Based on qualitative evaluation, each potential spillway location could be acceptable with appropriate measures to reduce potential effects to other land uses. No “fatal flaws” were identified for any of the locations. The ground improvement anticipated before the SF embankment and Emergency Spillway construction would mitigate significant disadvantages for locations underlain by soft compressible clay and organic deposits (such as Spillway Location “A”).

The management of overland flows (at Spillway Locations “B” and “C”) by either constructing channels, managing nonchannelized flows, and/or fortifying existing structures against flow damage (such as utility lines, WWTP, roadways) appears to be more challenging than constructing a relatively short discharge flow corridor between the eastern side of the SF embankment and the Italian Slough (Spillway Location “A”). Therefore, based on the four criteria evaluated, Spillway Location “A” is recommended as the most appropriate location for the Southern Forebay Emergency Spillway.

Once site-specific geotechnical explorations are performed at the SF, the evaluations and conclusions presented in this TM should be reviewed and modified, as necessary.

8. References

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9. Document History and Quality Assurance

Reviewers listed have completed an internal quality review check and approval process for deliverable documents that is consistent with procedures and directives identified by the Engineering Design Manager (EDM) and the DCA.

Approval Names and Roles			
Prepared by	**Internal Quality Control review by**	**Consistency review by**	**Approved for submission by**
Michael Conant / EDM Senior Engineer	Graham Bradner / DCA Executive Director Craig Hall / Senior Geotechnical Engineer	Gwen Buchholz / DCA Environmental Consultant Phil Ryan / EDM Design Manager	Terry Krause / EDM Project Manager

This interim document is considered preliminary and was prepared under the responsible charge of Craig Hall, California Professional Engineering License GE2556.

Note to Reader

This is an early foundational technical document. Contents therefore reflect the timeframe associated with submission of the initial and final drafts. Only minor editorial and document date revisions have been made to the current Conformed Final Draft for Administrative Draft Engineering Project Report version.

Attachment 1
Spillway Weir Calculations

LABYRINTH WEIR DESIGN
No Approach Velocity

PROJECT:	Delta Conveyance	TIME:	08:55:03
PROJECT NO.	####	DATE:	02-Oct-20
FLOOD CRITERIA:	SDF	BY:	PDD

USER INPUT

Max. Res	Zr	23.5	ft	Thickness			
Crest el.	Zc	21.0	ft	Wall	tw	1.25	ft
Floor el.	Zf	17.5	ft	Slab	ts	1.25	ft
Spillway width	W	300.0	ft	Cutoff Depth			
Apex Width	A	3	ft	Sheet Pile	Ds	1	ft
No. of cycles	N	10		Conc Wall	Dc	1	ft
Magnification	L/W	2					

CHECK ON RATIOS

Ldc/B =	0.14	Ld/B RATIO IS OK
H_o/P =	0.71	Ho/P RATIO IS OK
α =	26.39	Angle IS OK

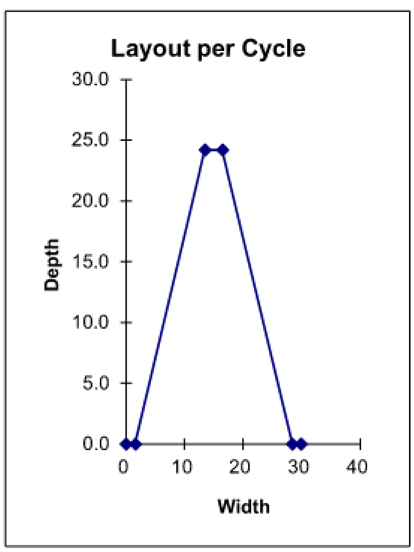
Note: L_{de}/B must be <= 0.35
Ho/P must be <= 0.9
α must be >= 6 deg

LABYRINTH DIMENSIONS (Per Cycle)

Wall Height	P	3.5	ft
Width	w	30.00	ft
Length	L	60.00	ft
Wall Length	B	27.00	ft
Depth	D	24.19	ft
Head max	H	2.50	ft
Wall Angle	α	26.39	deg
Length of Interference	L_{de}	3.88	ft

CREST LAYOUT
(One Cycle)

X	Y
0	0
1.50	0
13.50	24.19
16.50	24.19
28.50	0
30.00	0



DISCHARGE

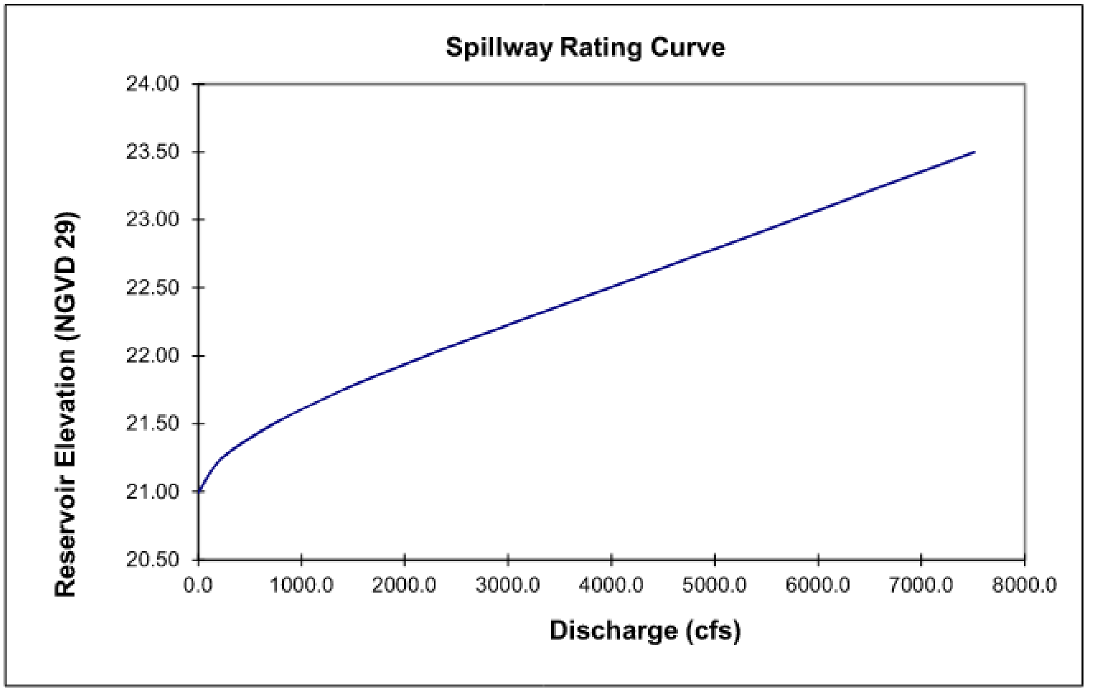
Qmax	7,509	cfs

COEFFICIENTS

Column	6.00
Cd lower	0.58
Cd Upper	0.66
Cd	0.59
Efficacy	1.58

RATING CURVE

HEAD	H_o/P	C_{lower}	C_{upper}	C_d	Q	RES	
2.50	0.71	0.58	0.66	0.59	7509	23.50	Top of Embankments
2.25	0.64	0.60	0.68	0.61	6633	23.25	
2.00	0.57	0.62	0.69	0.63	5756	23.00	
1.75	0.50	0.65	0.71	0.66	4868	22.75	
1.50	0.43	0.67	0.72	0.67	3970	22.50	
1.25	0.36	0.68	0.72	0.68	3072	22.25	
1.00	0.29	0.68	0.72	0.69	2203	22.00	
0.75	0.21	0.67	0.70	0.67	1404	21.75	
0.50	0.14	0.64	0.66	0.64	726	21.50	
0.25	0.07	0.58	0.59	0.58	233	21.25	
0.00	0.00	0.49	0.49	0.49	0	21.00	



Discharge Coefficient Table Tullis et al. (1995

	Angle wall makes with centerline α							
	6	8	12	15	18	25	35	90
	-------	-------	-------	-------	-------	-------	-------	-------
A0	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
A1	-0.24	1.08	1.06	1.00	1.32	1.51	1.69	1.46
A2	-1.20	-5.27	-4.43	-3.57	-4.13	-3.83	-4.05	-2.56
A3	2.17	6.79	5.18	3.82	4.24	3.40	3.62	1.44
A4	-1.03	-2.83	-1.97	-1.38	-1.50	-1.05	-1.10	

Attachment 2
Spillway Riverine Hydraulic Impacts

Attachment 2. Spillway Riverine Hydraulic Impacts

To assess hydraulic impact of operating the Southern Forebay Spillway, at Location 'A', on the existing levee system of Italian Slough, a 1-Dimensional (1D) model was developed of the channel and levees using the United States Army Corps of Engineers (USACE) software, Hydrologic Engineering Center's River Analysis System (HEC-RAS). The program utilizes the channel terrain, channel roughness, and geometric (plan view) layout to calculate a user-defined water surface profile via the standard step method. The 1D model terrain was built using 2017 United States Geological Survey (USGS) ground surface LiDAR (USGS, 2020) and 2017 USGS San Francisco Bay-Delta Bathymetry (Fregoso et. al, 2017), both sources utilize the North American Vertical Datum of 1988 (NAVD 88). The ground surface LiDAR has a gridded resolution of 1m (3.281ft) and the bathymetry has a gridded resolution of 10m (32.81 ft). The model extends from the Lazy M Marina on the upstream end to the State Route 4 bridge crossing of Old River on the downstream end, a map of the model extents is presented in Figure A2-1. The model did not extend along the southern fork of Old River due to limited hydraulic effect. This additional channel area may help to dissipate increased stages downstream of Spillway Location 'A', but effects downstream of the spillway are limited regardless. The 'North' and 'South' channels seen on Figure A2-1 are small, leveed tributaries upstream of Italian Slough; these channels were analyzed for levee freeboard impacts but were not included in the HEC-RAS model. The most upstream model stages were projected upstream along the 'North' and 'South' channel eastern levees. Modeling of these tributaries is not necessary because this area will have a low hydraulic gradient and in turn a level water surface. An example of the model terrain and cross sections is presented in Figure A2-2.

The modeling extent was developed so that the computed change in water surface elevation resulting from use of the Southern Forebay Spillway will not be affected by the model boundary conditions; the model boundaries are located sufficiently far enough upstream and downstream to minimize influencing the computational results in the area of interest, 2.47 miles and 2.97 miles, respectively. The channel roughness (Manning's N-value) utilized for this modeling effort was 0.037; this value is consistent with an unlined channel which may have weedy or rocky banks and may not be maintained regularly (Chow, 1959). Inflow boundary conditions for the 100-year event was developed using USGS Stream Stats. USGS Stream Stats (USGS, 2016) is an online application which is used to estimate recurrence level flows for ungagged or unmonitored drainage areas based on regression equations developed by USGS for characteristic hydrologic areas throughout the United States (Gotvald et. al, 2012).

Figure A2-1. Model extents and river stationing (ft)

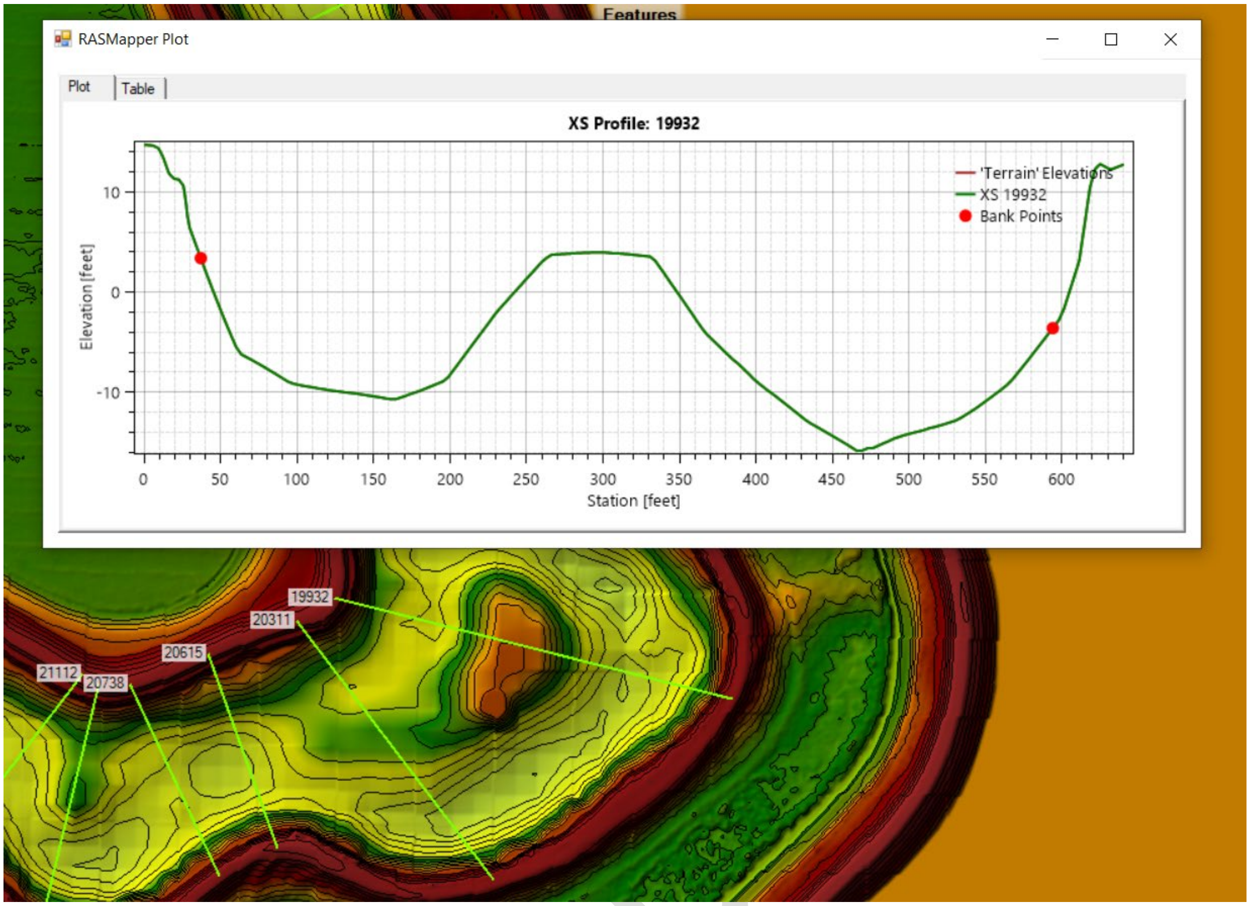


Figure A2-2. Model terrain and cross section example, combined USGS 2017 LiDAR and bathymetry

The Southern Forebay would be an off-stream reservoir (i.e. there would be no watershed contributing to the reservoir storage.) The probability of the spillway being operated is very low due to Project operations as described in the Forebay Conceptual Design Criteria TM (DCA, 2021b) and is assumed to be independent of hydrologic conditions. However, two hydrologic conditions were analyzed to estimate a potential range of WSE impacts: a 100-year flood event and a Mean Higher High Water (MHHW) event. The downstream WSE on Old River was assumed to be 10 feet for the 100-year event (DWR, 2020) and 5 feet for the MHHW event. Since the probability of the spillway releasing water is very low, the most likely scenario in which the spillway would be used would be under MHHW or lower elevation hydrologic conditions. A range of operational scenarios were modeled to assess potential impacts to the existing levee system during a Southern Forebay spill event. A summary of the model scenarios is provided in Table A2-1. After analyzing the scenarios with HEC-RAS, the changes in WSEs were assessed. Spillway releases were assumed to be equal to the project pumping capacities of 3,000, 4,500, 6,000, and 7,500 cfs over a 12 hour period.

Table A2-2 lists the change in WSE in Italian Slough and Old River relative to the baseline and the extent that impacts would be observed from spillway operation upstream and downstream from the spillway location. Plots of the change in available freeboard along the left and right levees (orientation facing downstream) have been provided for the MHHW and 100-year events in Figures A2-3, A2-4, A2-5, and A2-6. Although the spillway was assumed to flow for 12 hours, peak WSE's were achieved in 2 hours or less for the scenarios modeled. No line is shown in the right levee freeboard plots between stations 11,800 ft and 15,000 ft because this area is adjacent to Widdows Island, a submerged, in-channel island with no flood control infrastructure. In the scenarios modeled, the peak WSE was located upstream of the

Spillway Location 'A' due to backwater effects from the additional flow entering Italian Slough from the spillway.

While the two channel reaches upstream of the Lazy M Marina, the north channel and south channel in Figure A2-1, were not analyzed as part of the model, the maximum upstream WSE was projected along their eastern levee profiles in Figures A2-7, A2-8, A2-9, and A2-10 to verify backwater impacts along these sections. None of the scenarios analyzed resulted in overtopping levees of the main Italian Slough channel or Old River due to the releases from the Southern Forebay spillway.

Minor impacts were observed at the upstream end (approximately at stationing 3,800 in Figure A2-10) of the south channel due to limited existing levee height at an earth filled agricultural channel crossing. This only occurs during low frequency flood events which, as discussed previously, are assumed to be independent from potential releases from the spillway. Overtopping of this low point would only occur during spillway releases of 7,500 cfs coinciding with a 100-year inflow and stage. The existing freeboard during the 100-year event and 100-year stage is only 0.4 ft in this area. The depth of potential flooding was very shallow (approximately 0.2 ft). Any potential spilling would occur in unpopulated areas, and would not impact the Skinner Fish Facility and other critical infrastructure associated with the intake channel to Banks Pumping Plant.

Table A2-1. Hydraulic Modeling Impact Scenarios

Spillway Location 'A' Outflow cfs	Spillway Outflow Duration hrs	Downstream Boundary Stage ft, NAVD 88	Upstream Boundary Inflow (Italian Slough) cfs
0 (Baseline)	0	MHHW El. 5	No Inflow
3,000	12	MHHW El. 5	No Inflow
4,500	12	MHHW El. 5	No Inflow
6,000	12	MHHW El. 5	No Inflow
7,500	12	MHHW El. 5	No Inflow
0 (Baseline)	0	USACE 100-yr Gage El. 10	USGS Stream Stats 100-yr recurrence flow: 2100 cfs
3,000	12	USACE 100-yr Gage El. 10	USGS Stream Stats 100-yr recurrence flow: 2100 cfs
4,500	12	USACE 100-yr Gage El. 10	USGS Stream Stats 100-yr recurrence flow: 2100 cfs
6,000	12	USACE 100-yr Gage El. 10	USGS Stream Stats 100-yr recurrence flow: 2100 cfs
7,500	12	USACE 100-yr Gage El. 10	USGS Stream Stats 100-yr recurrence flow: 2100 cfs

Table A1-1. Hydraulic Modeling Impact Results

Spillway Location 'A' Outflow cfs	Scenario -	Max Change in WSE ft	Extent Impacted Upstream of Spillway mi	Extent Impacted Downstream of Spillway mi
0 (Baseline)	No Inflow, MHHW El. 5	0	0	0
3,000	No Inflow, MHHW El. 5	0.16	2.47	0.50
4,500	No Inflow, MHHW El. 5	0.28	2.47	0.98
6,000	No Inflow, MHHW El. 5	0.46	2.47	1.61
7,500	No Inflow, MHHW El. 5	0.67	2.47	1.94
0 (Baseline)	100-year Inflow, USACE 100-yr Gage El. 10	0	0	0
3,000	100-year Inflow, USACE 100-yr Gage El. 10	0.13	2.47	0.31
4,500	100-year Inflow, USACE 100-yr Gage El. 10	0.21	2.47	0.50
6,000	100-year Inflow, USACE 100-yr Gage El. 10	0.31	2.47	1.15
7,500	100-year Inflow, USACE 100-yr Gage El. 10	0.44	2.47	1.55

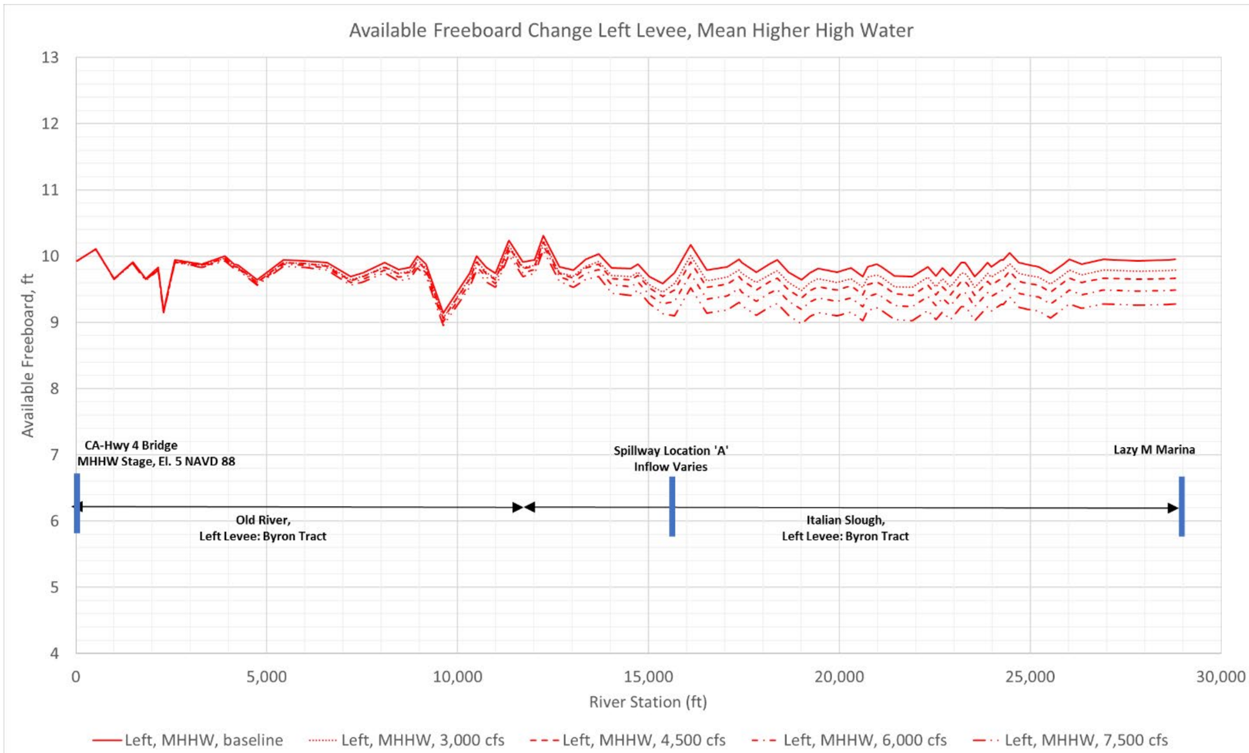


Figure A2-3. Available freeboard change - left levee, MHHW

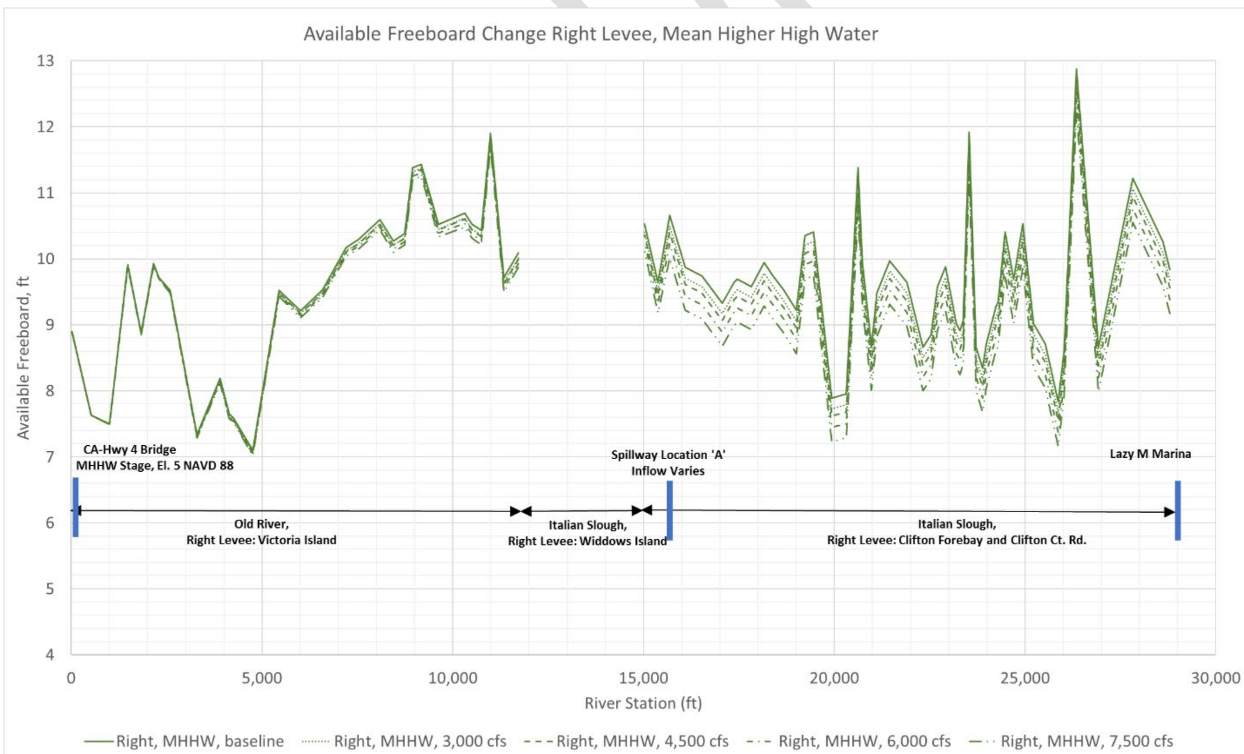


Figure A2-4. Available freeboard change - right levee, MHHW

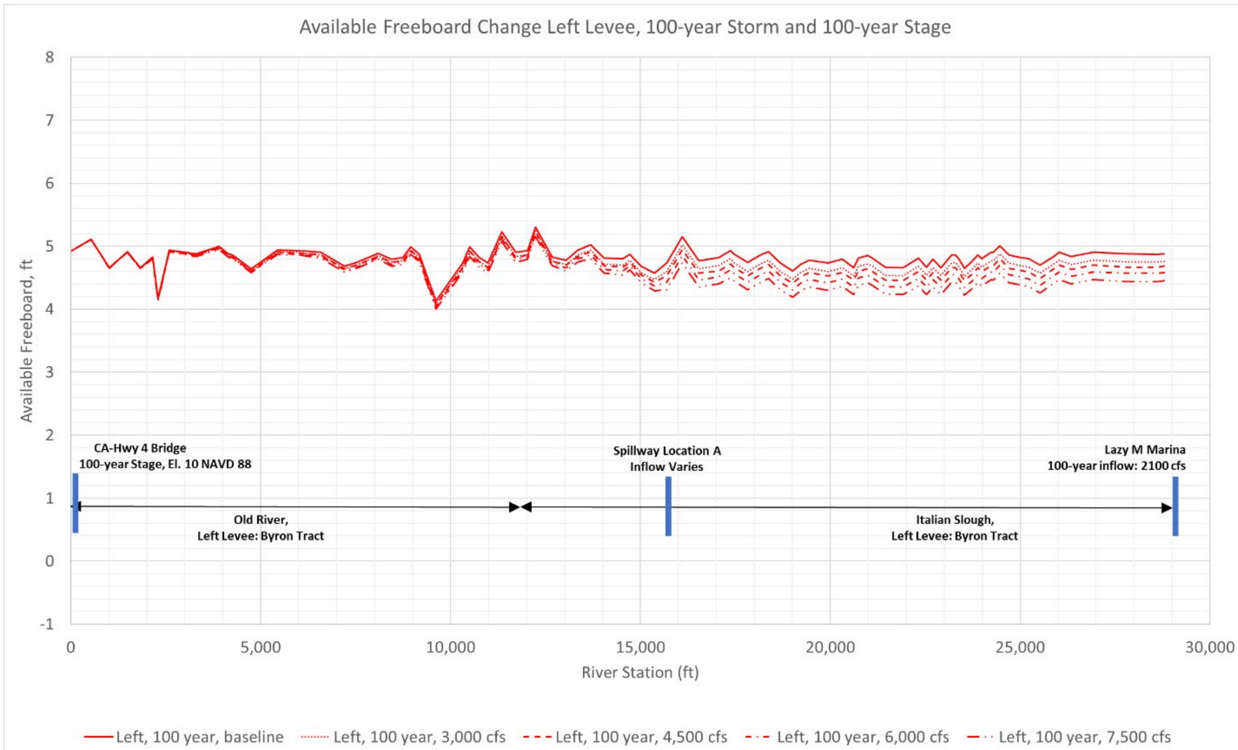


Figure A2-5. Available freeboard change - left levee, 100-year storm and 100-year stage

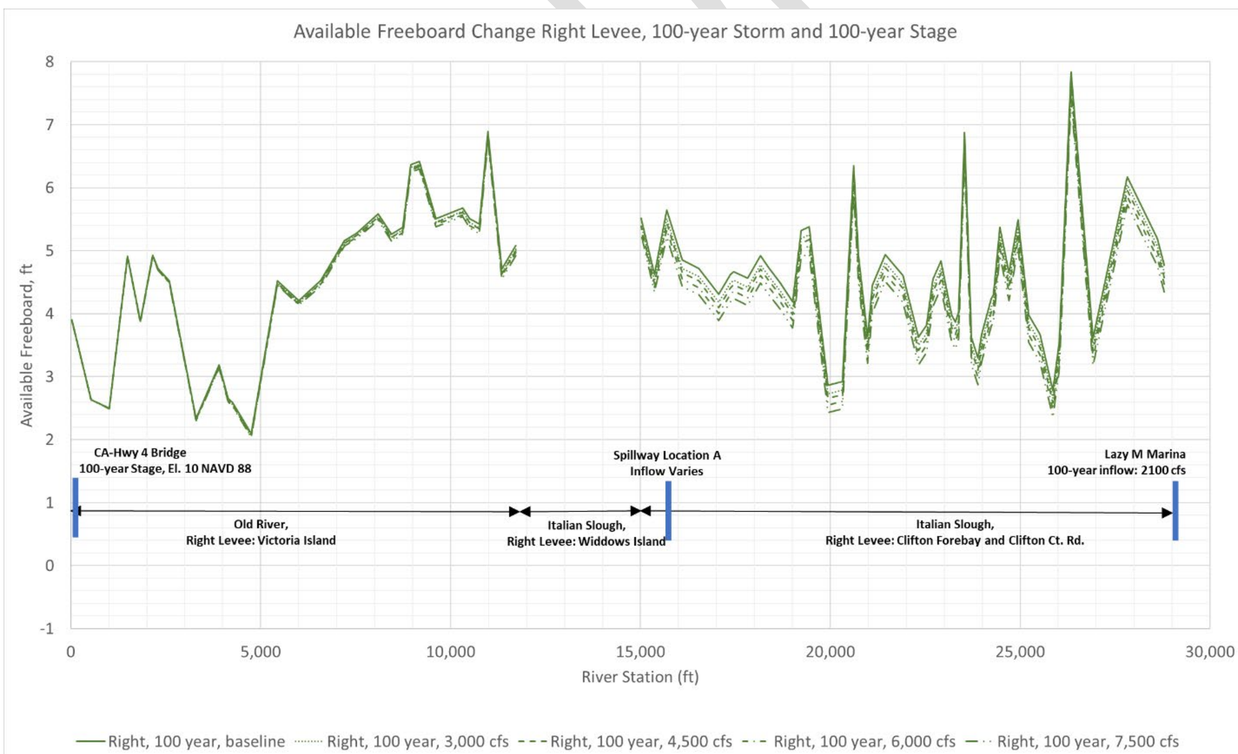


Figure A2-6. Available freeboard change - right levee, 100-year storm and 100-year stage

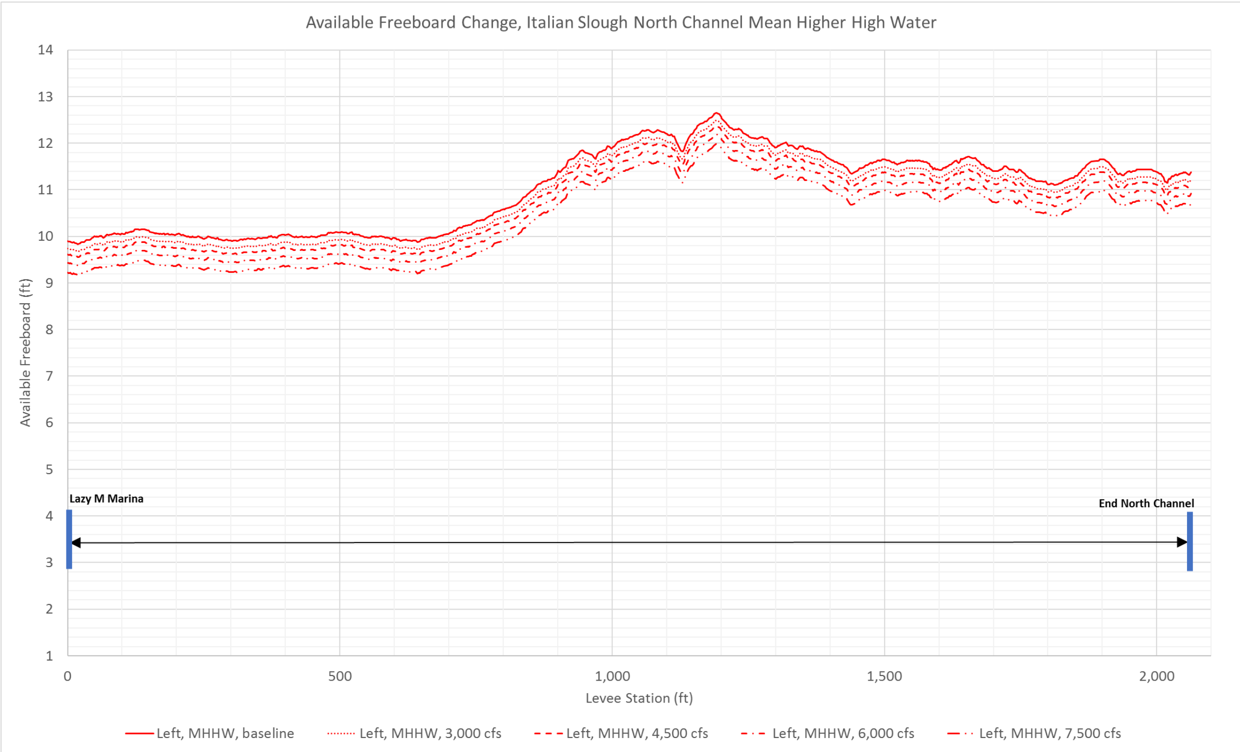


Figure A2-7. Available freeboard change – left levee of north channel, MHHW

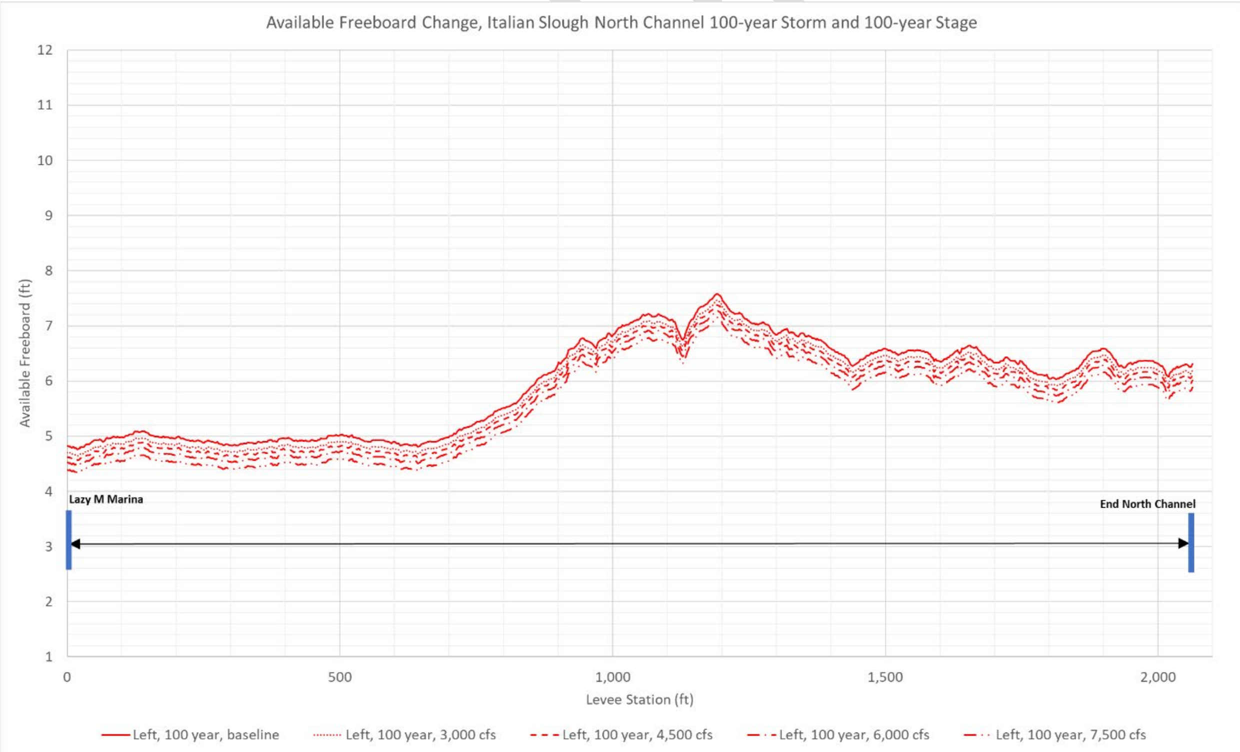


Figure A2-8. Available freeboard change – left levee of north channel, 100-year storm and 100-year stage

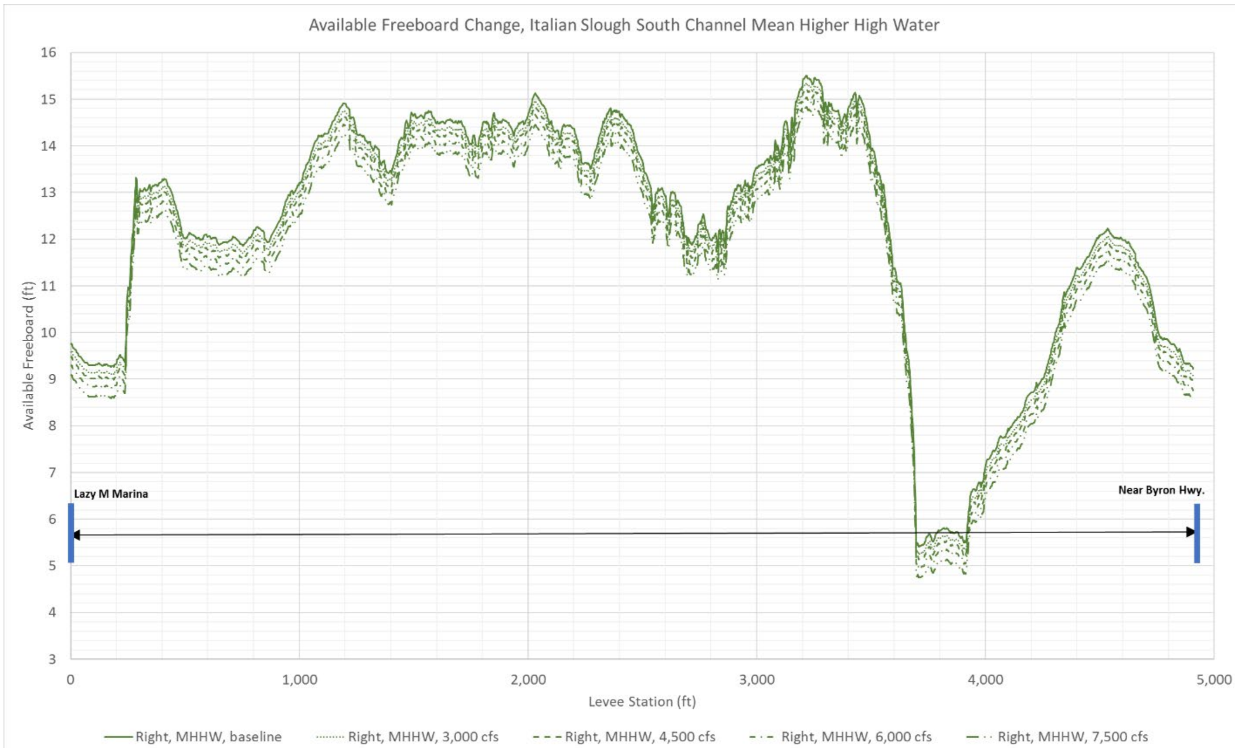


Figure A2-9. Available freeboard change – right levee of south channel, MHHW

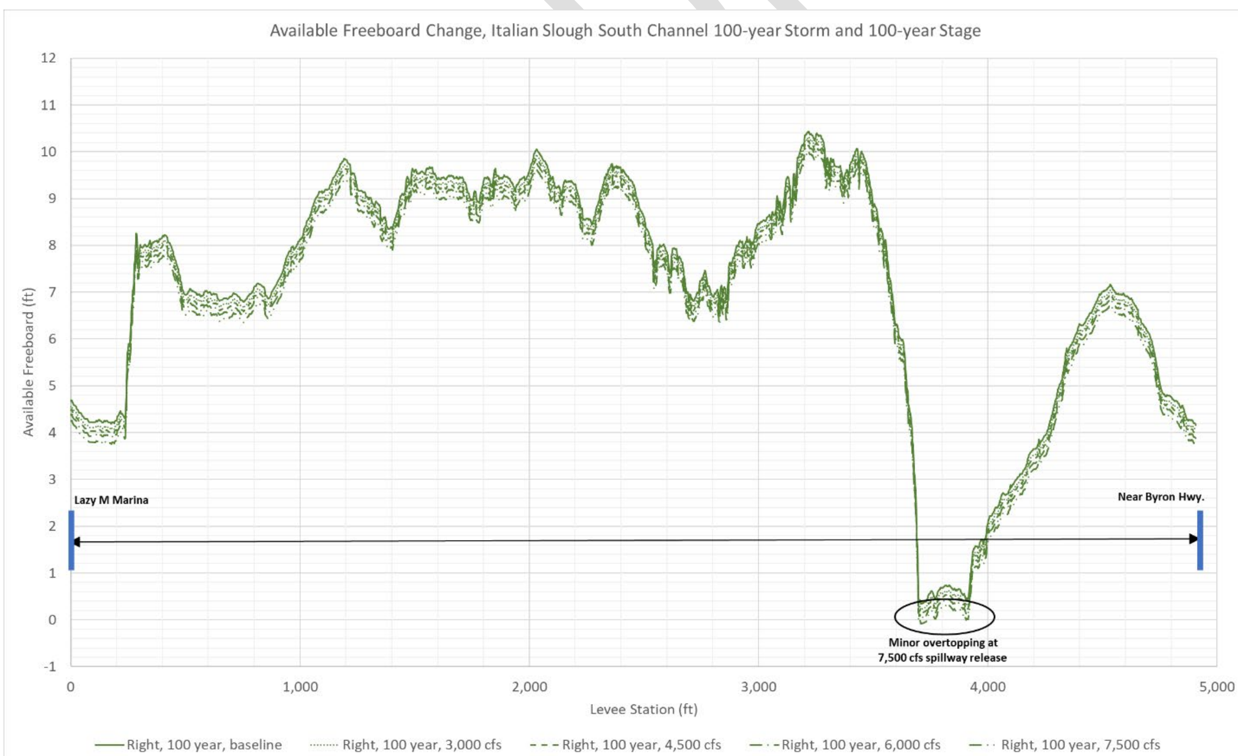


Figure A2-10. Available freeboard change – right levee of south channel, 100-year storm and 100-year stage