MBK ENGINEERS

Water Resources ◆ Flood Control ◆ Water Rights

TECHNICAL MEMORANDUM

DATE: September 18, 2023

TO: Westervelt Ecological Services

PREPARED BY: Patrick Ho, P.E. and Michael Archer, P.E. MBK Engineers

SUBJECT: **FINAL -** Little Egbert Multi-Benefit Project - Feasibility Evaluation of Water Control Structure

Introduction and Purpose

The Little Egbert Joint Power Authority (LEJPA) and the California Natural Resources Agency (CNRA), in partnership with the state Department of Water Resources (DWR) is preparing a feasibility study for the Little Egbert Multi-Benefit Project (Project) on Little Egbert Tract (LET). These properties are located within the Yolo Bypass immediately upstream of Rio, Vista, California in Solano County. The Project has undergone various study phases since 2018 and have advanced four alternatives for further evaluation. Alternative 17, Alternative 19, and Alternative 24 of the LEMBP proposes a water control structure on Watson Hollow Slough (WHS) in order to provide a continuous line of levee between the Reclamation District (RD) 536 and the Solano County 44 Levee (Figure 1)

. The purpose of this technical memorandum is to document the hydraulic analyses prepared in the selection of a feasible water control structure for Alternative 17, Alternative 19, and Alternative 24.

Background and Related Work

WHS serves as water conveyance for agricultural use during the irrigation season and runoff drainage during the wet season. WHS joins with Cache Slough at the most southeastern corner of the LET through four (4) existing 60 inch culverts. An existing tide gate with two (2) 36” culverts are used by the local landowners for irrigation. The reconfiguration of WHS was initially evaluated during the study phase that began in 2021. An interior drainage analysis of WHS was prepared (MBK, 2022) and several hydrologic events from flood to tidal level events were selected to identify potential design constraints and design flows for the reconfiguration of the slough. A key observation from the review of historical stage on the Sacramento River at Rio Vista is that the occurrence of high-stage on the Sacramento River after a local rainfall-event is lagged by a duration in excess of 24-hour and the time-of-concentration of the WHS watershed is less than 24-hours. In other words, WHS would derive a peak runoff at Cache Slough before a coinciding high stage on the Sacramento River would arrive from the system.

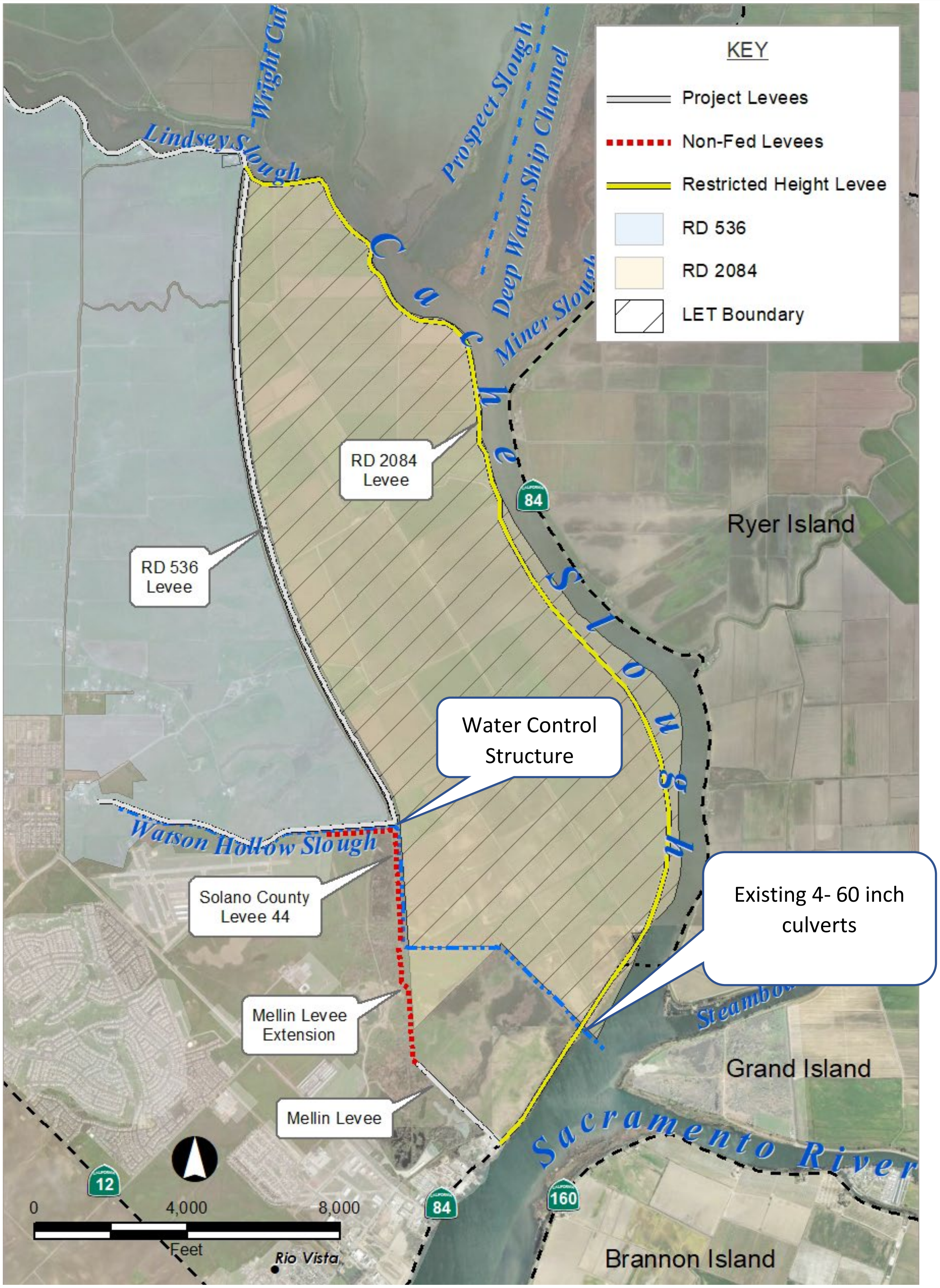

Figure 1. Watson Hollow Slough – Location of Water Control Structure

Cache Slough would typically be tidal while WHS is exhibiting flood level rainfall-runoff. The 100-Year, 24-hour rainfall-runoff generated by the 17 square mile watershed of WHS developed from the initial study (MBK, 2022) coupled with a 2-Year flood on Cache Slough was selected for the design of the water control structure in this phase of the feasibility evaluation. The simulated 2-Year event on the Sacramento River system produces a water surface elevation (WSE) on WHS at the southern end of the RD 536 levee at WHS of about 7.5 feet which is not significantly different than the peak high tides that would occur under tidal conditions. Tidal elevation at LET tend to range between 2 and 7 feet NAVD 88.

Water Control Structure - Selection Criteria

The Project proposes to abandon the existing configuration of WHS between Cache Slough and the RD 536 levee. The Project proposes to grade an intake channel which would draw water from the proposed subtidal swale. As described, three alternatives of the Project will have a water control structure to check water from flowing upstream into the interior side of WHS. The criteria identified for the selection of this water control structures are as follows.

The water control structure shall:

1. Pass the 100-Year rainfall flood generated by rainfall-runoff from the WHS watershed without significantly increasing the existing interior floodplain extent.
2. Produce stage effects that are less than significant on WHS during tidal conditions such that agricultural irrigation can continue post-Project.
3. Reduce the effects of high tailwater during more frequent floods once the restricted height levee on LET is breached.

The selection of the water control structure would be measured by its hydraulic performance during a 100-Year rainfall-runoff and would be sized such that WSE's under the Project would have minimal effects on the WHS 100-Year floodplain. The control structure would also require gates that would be closed during high water events in the Sacramento River system to prevent the high water in LET from affecting the WHS floodplain. In the event that the gates are closed due to high flow on LET, a pump or pumps would be required to discharge WHS runoff into LET.

Hydraulic Model

The hydraulic analysis was performed using a modified version of the Central Valley Floodplain Evaluation and Delineation (CVFED) TO34 Sacramento River Basin HEC-RAS model, MBK version 202004, which runs in HEC-RAS version 6.3.1. The model extent was reduced, and refinements were made to capture localized hydraulics at LET, improve calibration, improve efficiency, and reduce execution time. The model includes the Sacramento River, from the Sacramento River at Freeport to Collinsville; the distributaries of the Sacramento River downstream of Freeport and the Yolo Bypass downstream of I-80. The hydraulic model calibration and verification checks are documented in the Little Egbert Tract Multi-Benefit Project – Flood Hydrology & Hydraulic Feasibility Analysis Technical Memorandum (MBK, 2023). For this analysis, the model was further reduced to the 2D extents only.

Hydrology

Sacramento River System

The Sacramento River hydrology is from the Central Valley Hydrology Study (CVHS), which was commissioned by the California Department of Water Resources (DWR) and prepared by the U.S. Army Corps of Engineers USACE (USACE, 2020). The CVHS defines a procedure in which a scaled flood event, with a pattern based on a historical flood event, is selected to represent the flood of a specific frequency at a specific location. This specific location is also referred to as the “centering” of the flood event. The analysis presented herein used hydrology based on a CVHS event selection performed by USACE (USACE, 2020). This event selection determined flood events for two centerings:

1. Sacramento River at Verona
2. American River at Fair Oaks and Sacramento River at the latitude of Sacramento

For this analysis, MBK selected and simulated only the 2-Year flood from the Sacramento River at Verona centering, as this centering has a higher flow in the Yolo Bypass. The Sacramento River hydrology is the driver of tailwater conditions on Watson Hollow Slough.

Watson Hollow Slough

The Watson Hollow Slough hydrology was developed during the 2022 Interior Drainage Hydrology and Hydraulic Analysis (MBK, 2022) and was derived using a 100-Year, 24-hour duration precipitation rainfall on the 17 square mile watershed. Table 1 summarizes the hydrologic events used in this analysis.

Table 1. Hydrologic Centerings and Concidence

	Flood Source	
Flood Centering	**Yolo Bypass/Cache Slough Complex**	**Watson Hollow Slough**
Sacramento River System	1-in-100-Year Flood Event	Baseflow
Watson Hollow Slough (WHS) Rainfall	1-in-2 Year Flood Event	1-in-100 Year, 24-hour Rainfall Runoff Event

Design Approach

Per the selection criteria, the water control structure shall pass the 100-Year rainfall flood generated by rainfall-runoff from the WHS watershed without significantly increasing the existing interior floodplain extents. A hydraulic impacts analysis approach would fit this design approach. In a hydraulic impacts analysis, an existing condition is first established and then used to measure performance against a Project condition that includes a proposed water control structure. Changes in flood hydraulics are then measured to gage their adequacy in addressing the selection criteria. The Project conditions selected for this analysis is the LEMBP Alternative 24 which features a 2,500 feet inlet berm and a 2,500 feet outlet berm on the LET restricted height levee, a subtidal habitat swale, and an intake channel that leads into the water control structure at WHS. While Alternative 17 and Alternative 19 will feature the water control structure, they were not included in the design. Drainage features, specifically the intake channel that draws water away from WHS, have similar alignments across Alternative 17, Alternative 19, and Alternative 24. Therefore, only Alternative 24 was selected for the design analysis.

Future without Project Conditions

The Future without-Project (FWOP) condition generally represents today's conditions in 2023. Future projects adjacent to Watson Hollow Slough is the Cache Slough Mitigation Bank Project (CSMB). The FWOP includes CSMB. A comprehensive description can be found in the Flood Hydrologic and Hydraulics Analysis (MBK, 2023). Using the 100-Year WHS flood with a 2-Year Sacramento River system tailwater (2-Year flood), a floodplain is computed and shown in Figure 2. Alignments along the northerly and southerly segments of WHS and Maximum WSE profiles along the northerly and southerly alignments of WHS were overlaid to develop for the profile lines shown in Figure 3 are provided for the WHS north channel in Figure 4 and the WHS south channel in Figure 5.

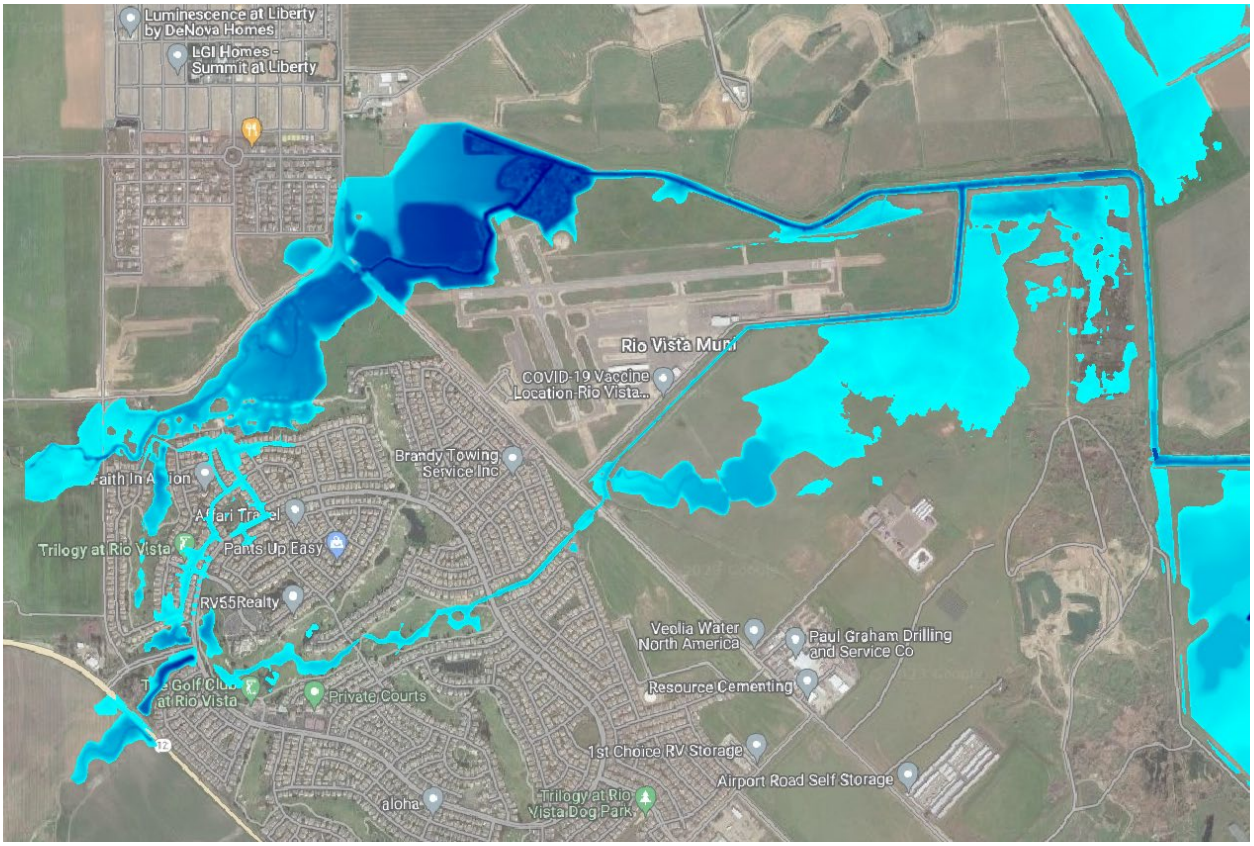

Figure 2. WHS Rainfall Flood Centering (Future without Project Condition)-100Year Floodplain

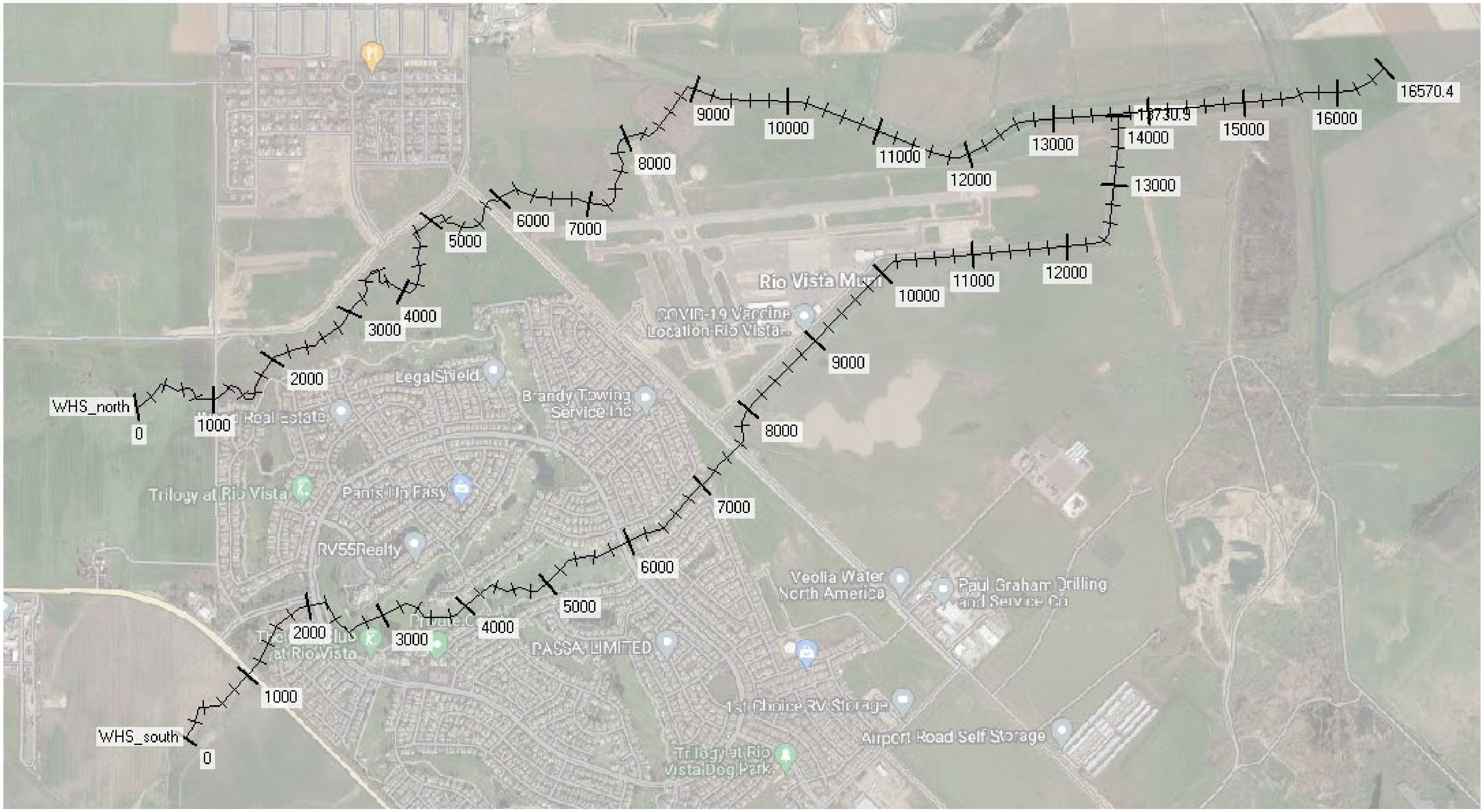

Figure 3. WHS Channel Profile Stationing

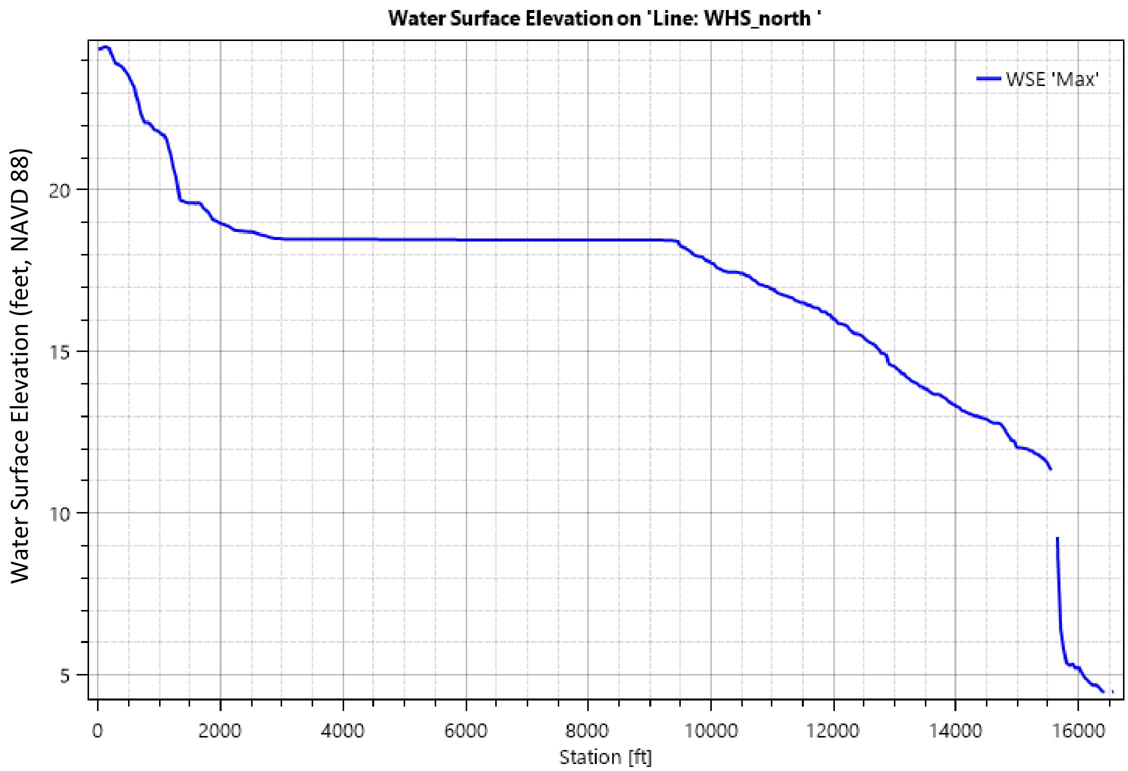

Figure 4. Future-without Project Condition Maximum WSE Profile in North Channel (WHS Rainfall Flood Centering)

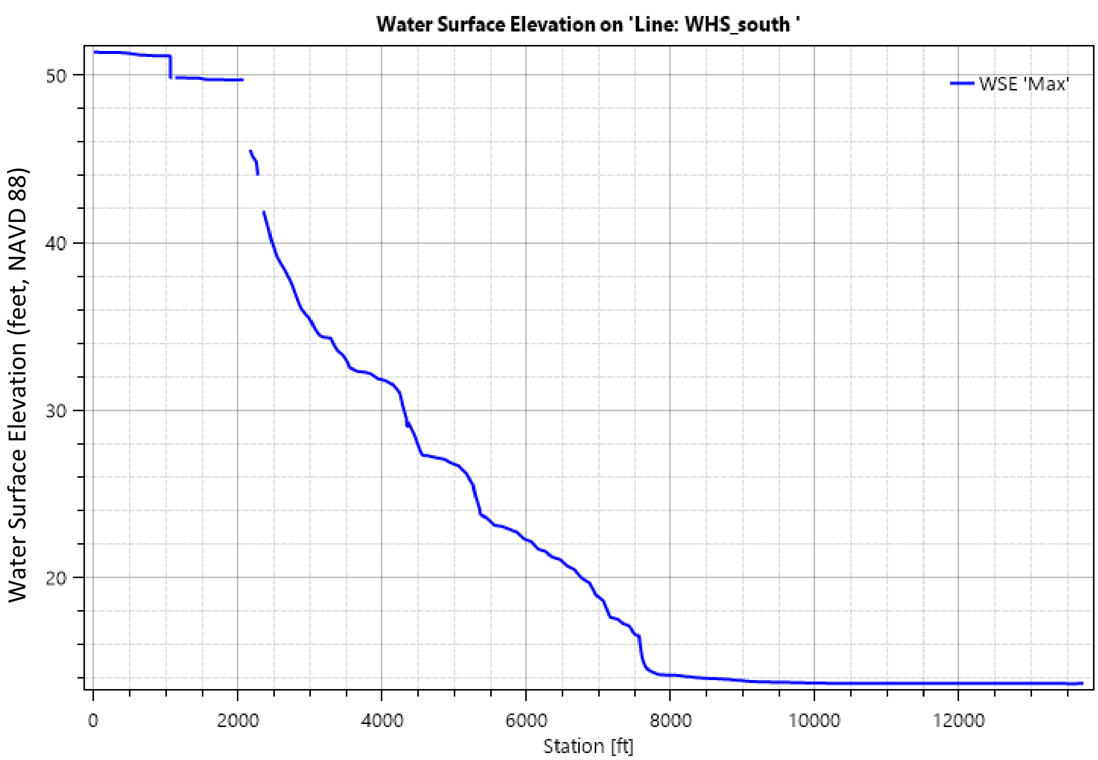

Figure 5. Future-without Project Condition Maximum WSE Profile in South Channel (WHS Rainfall Flood Centering)

Design Analysis

Four potential water control structures were simulated to show the relative effects of the different gates and culverts. The results of this analysis are presented as follows:

Scenario 1: Three culverts: 4-foot diameter

Scenario 1 represents the smallest possible footprint required for implementation and performed to determine the sensitivity between the culvert size and the interior floodplain. Three 4-foot diameter pipe culverts are provided through the new levee along WHS, and the proposed pipe inverts are at elevation 2 feet, NAVD 88. The culverts will provide flow through for the purpose of drainage and irrigation; no controls or flap gates are proposed in this configuration. This culvert configuration is not sufficient to pass the 100-Year WHS flood with minimal impact (Criteria 1) as illustrated on the interior side of the levee shown in Figure 6. Figure 7 and Figure 8 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS. Inundation on the LET side is due to the LEMBP project and not driven by Scenario 1. Three 4-foot culverts do not have sufficient conveyance capacity to drain the 100-Year rainfall event. However, the impact in tidal conditions is less than 0.05 feet which satisfies Criteria 2. Since meeting Criteria 1 is going to require larger gates, Criteria 2 will not be an issue henceforth on sizes larger than three 4-foot diameter culverts.

Red (▬) shows additional inundation (interior side) due to three 4-foot culverts.
Cyan (▭) shows inundation under the FWOP.

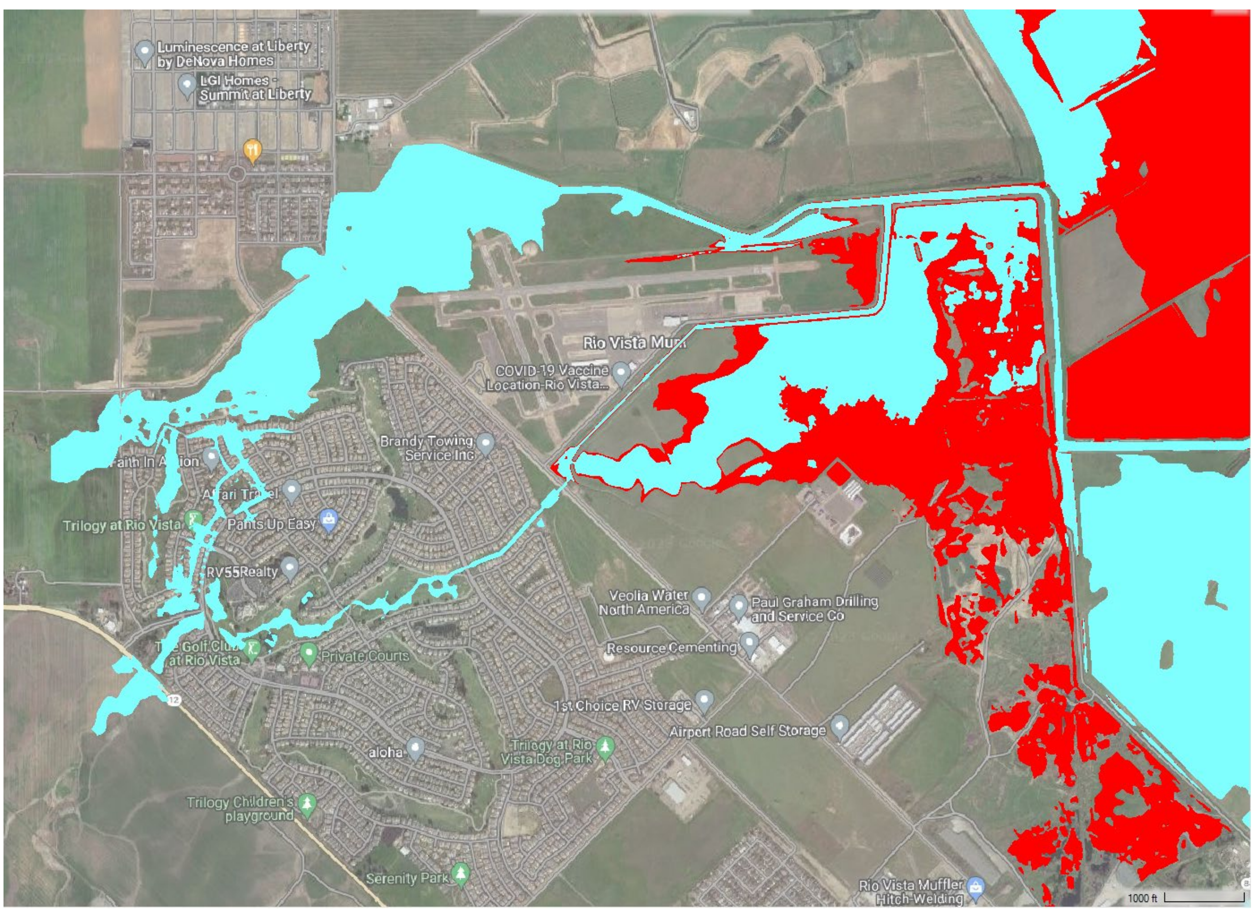

Figure 6. Effects of Three 4-foot Diameter Culverts on Inundation Area (WHS Rainfall Flood Centering)

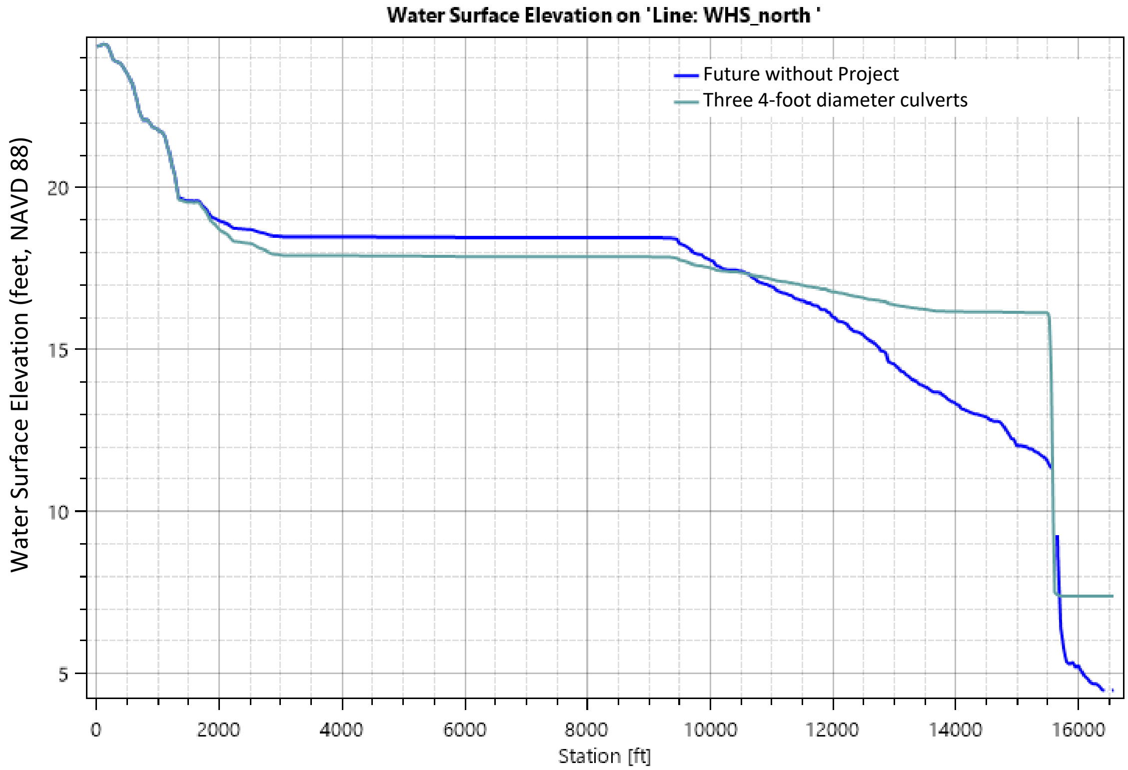

Figure 7. Maximum WSE Profile, WHS North Channel, With Three 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

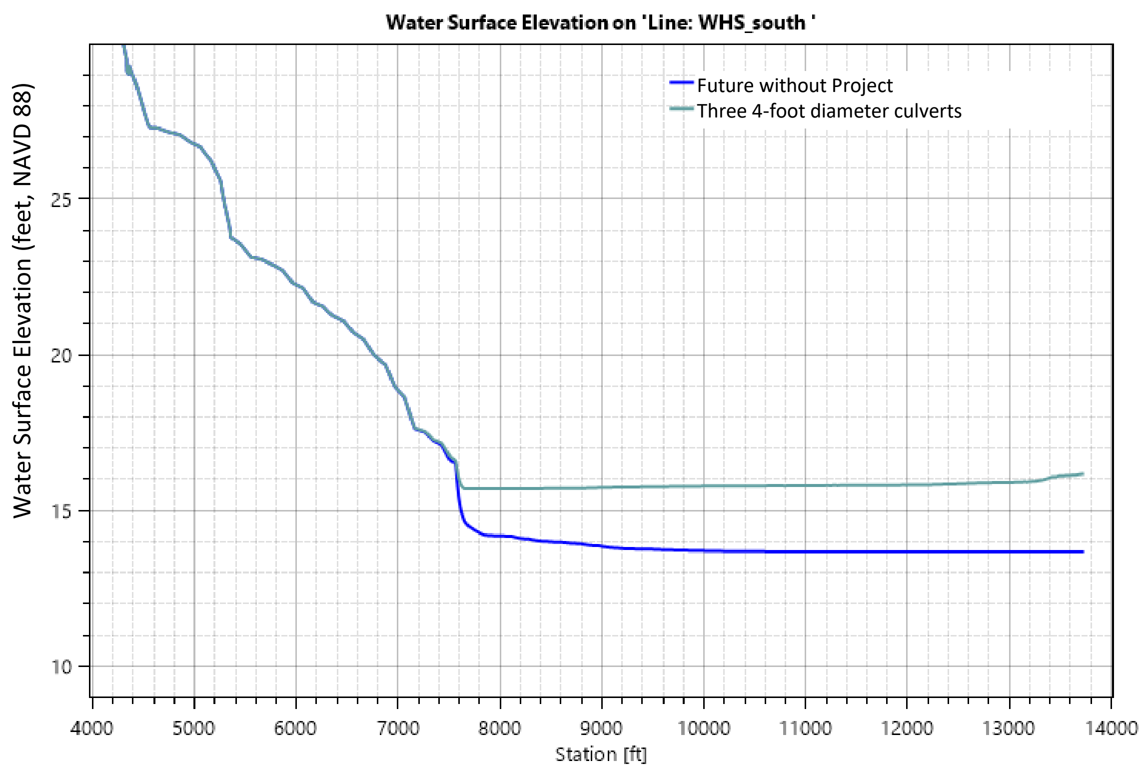

Figure 8. Maximum WSE Profile, WHS South Channel, With and Without Three 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

Scenario 2: One gate: 5 feet high by 15 feet wide

Scenario 2 proposes a 5 feet high by 15 feet wide box culvert configuration fitted with an operable gate. The operable gate is simulated as radial gates and assumed open throughout the simulation period. At this time, the operations of the radial gates were not configured in the hydraulic model as this analysis focuses on sizing the opening to pass flows from the upstream watershed. This also applies to Scenario 3 and 4. Further evaluation on the operation of box culverts and gates are recommended if scenarios with automated radial gates are pursued.

The operable gate can be used for various hydrologic conditions including closing off hydraulic connectivity into Watson Hollow Slough in the event that LET and the bypass is flooded during high flows. The invert elevation of the proposed box culverts are at elevation 2 feet, NAVD 88. Again, due to the magnitude of flow peaks from the 100-Year WHS flood, this configuration is not sufficient to pass the 100-Year WHS flood without impacts to the existing floodplain (Criteria 1) as illustrated on the interior side of Figure 9. Figure 10 and Figure 11 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS. Inundation on the LET side is primarily driven by features from the LEMBP project and not driven by Scenario 2. Increases in water surface elevation were calculated along the northerly (east of station 120+00) and southerly segment (east and north of station 78+00) of WHS which is generally along the north-northeastern property line of the Rio Vista Municipal Airport showing increases.

Red (▬) shows additional inundation due to culverts (interior side) with culverts open.
Cyan (▬) shows inundation under the FWOP.

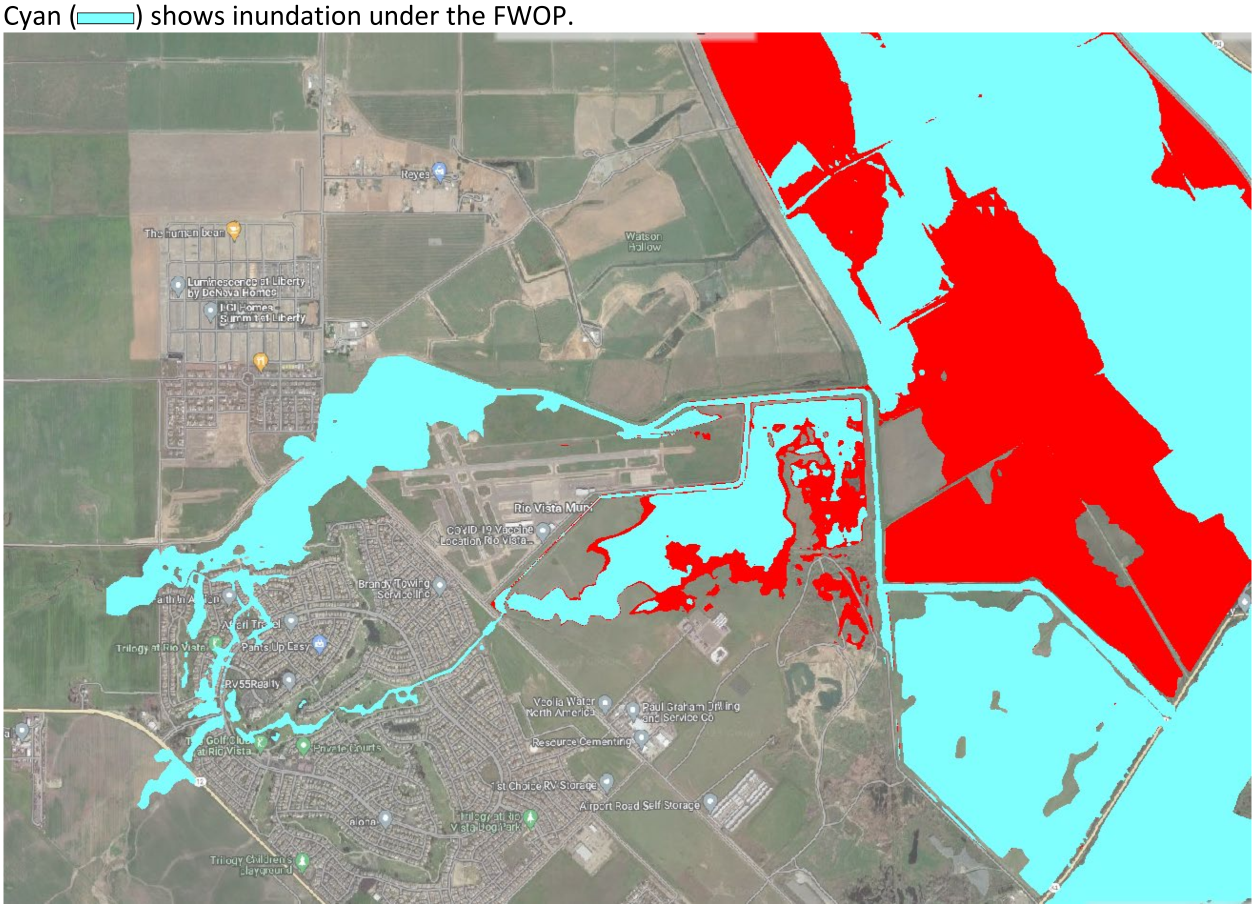

Figure 9. Effect of Single 5-foot high by 15-feet wide gate on Inundation Area (WHS Rainfall Flood Centering)

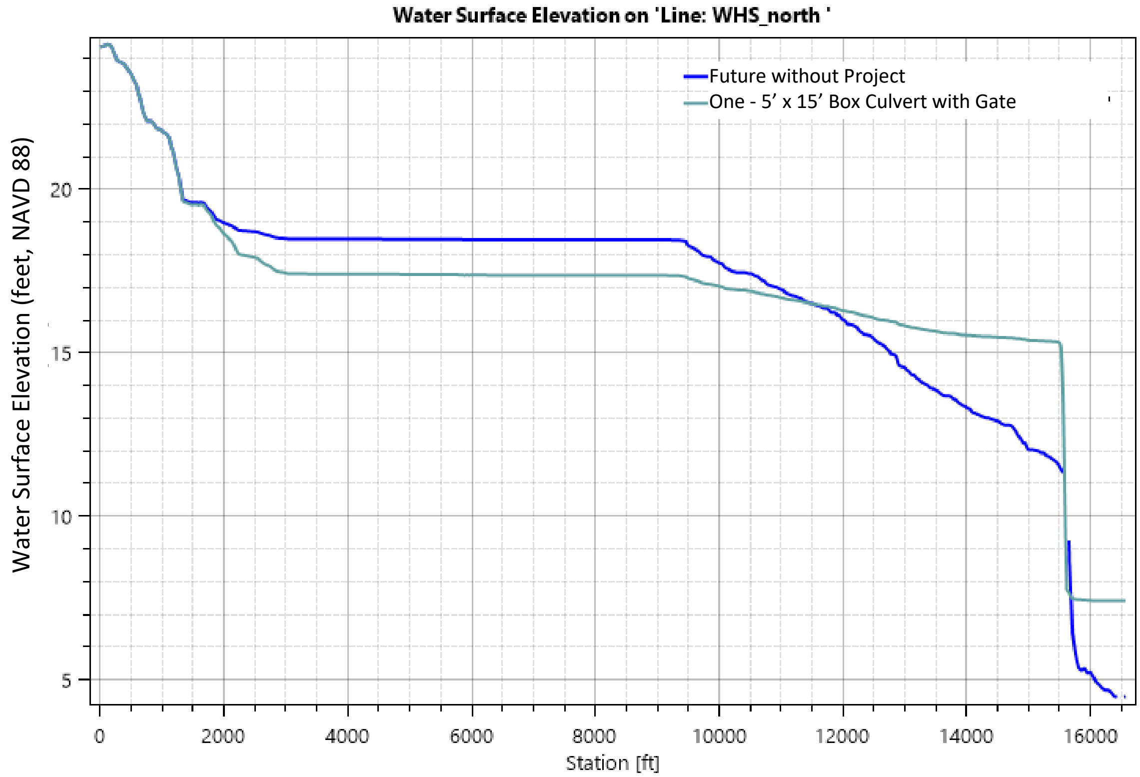

Figure 10. Maximum WSE Profile, WHS North Channel, With and Without One -5’ x 15’ gate (WHS Rainfall Flood Centering)

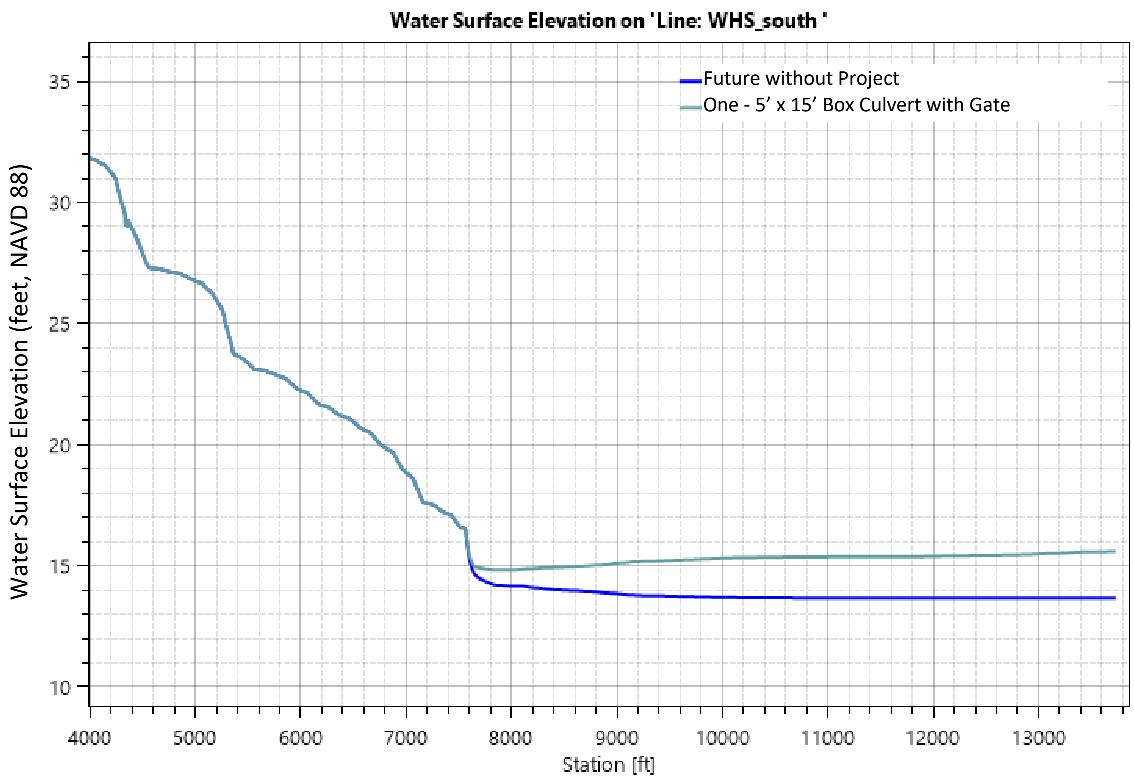

Figure 11. Maximum WSE Profile, WHS South Channel, With and Without One - 5’ x 15’ gate (WHS Rainfall Flood Centering)

Scenario 3: Two gates: 5 feet high by 15 feet wide

Scenario 3 proposes two 5 feet high by 15 feet wide box culvert configuration fitted with operable gates. The operable gates are simulated as radial gates and assumed open throughout the simulation period. Similar to Scenario 2, the operable gate provides flexibility with controlling water through Watson Hollow Slough. In general, this configuration is sufficient to pass the 100-Year WHS flood without impacts to the existing floodplain (Criteria 1) as illustrated in Figure 12. Figure 13 and Figure 14 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS.

Red (▬) shows additional inundation of FWOP with two 5’ x 15’ culverts open. The inundation extent is entirely covered by the future without Project inundation extent.
Cyan (▭) shows inundation under the FWOP.

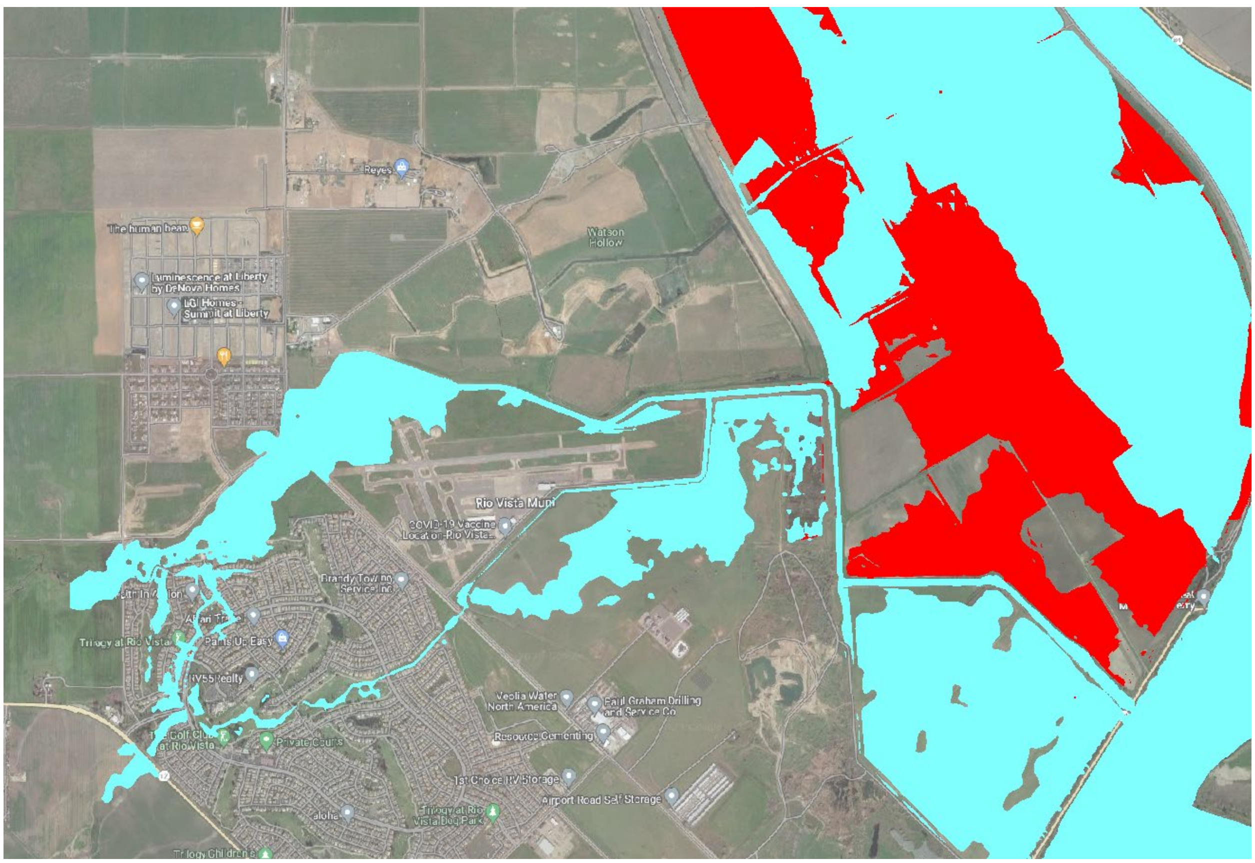

Figure 12. Effect of Two 5-foot high by 15-feet wide gates on Inundation Area (WHS Rainfall Flood Centering)

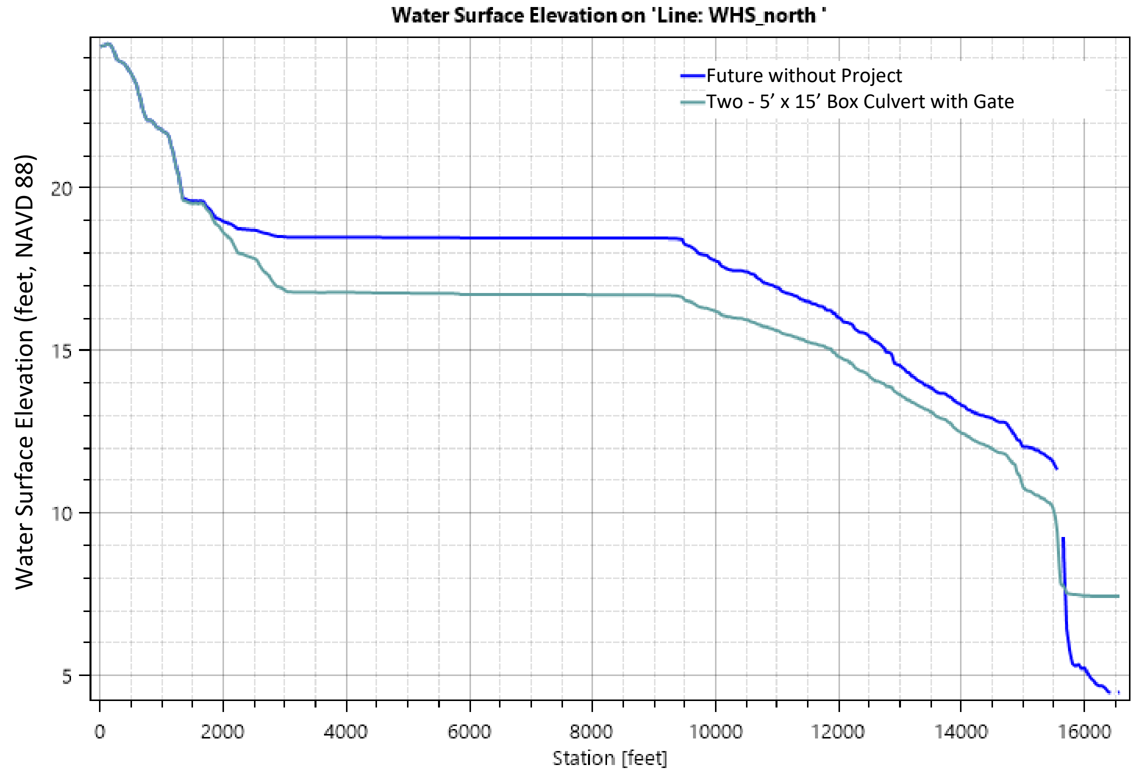

Figure 13. Maximum WSE Profile, WHS North Channel, With and Without Two 5' x 15' gates (WHS Rainfall Flood Centering)

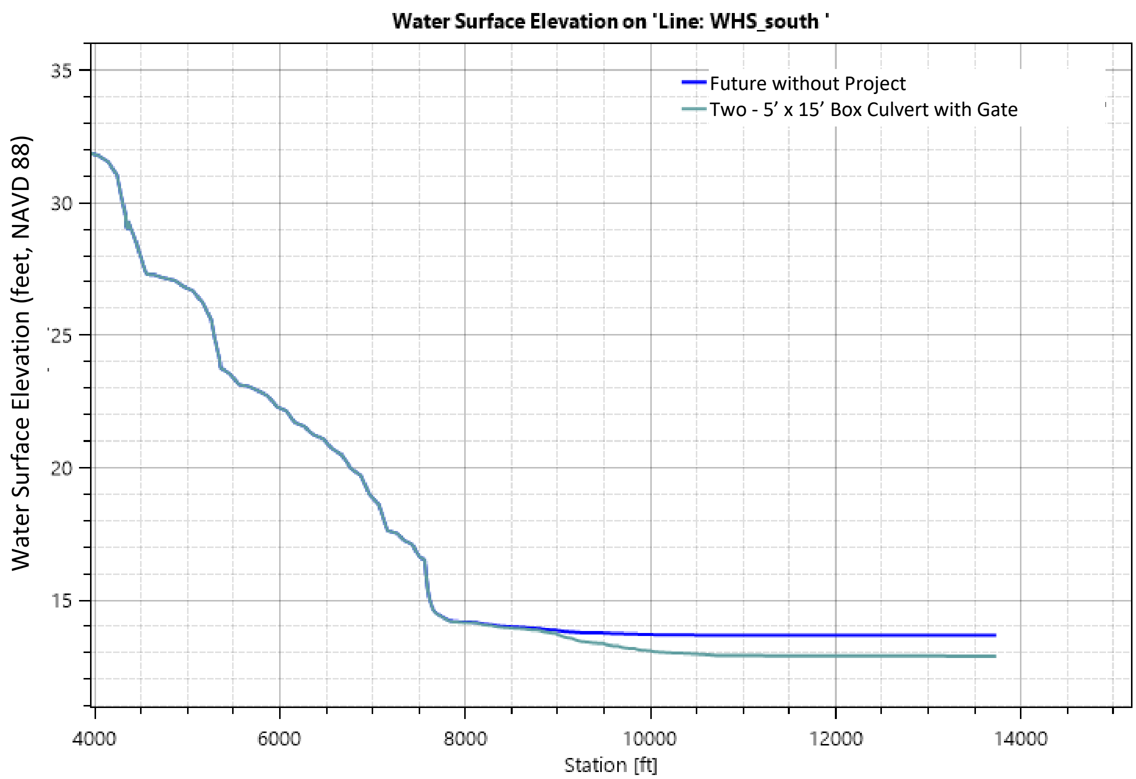

Figure 14. Maximum WSE Profile, WHS South Channel, With and Without Two 5' x 15' gates (WHS Rainfall Flood Centering)

Scenario 4: One gate: 5-feet high by 20-feet wide

Scenario 4 proposes one 5 feet high by 20 feet wide box culvert configuration fitted with operable gates. The operable gates are simulated as radial gates and assumed open throughout the simulation period. This scenario was developed to determine whether an intermediate configuration exists between Scenario 2 (1 – 5’ x 15’ box) and Scenario 3 (2 – 5’ x 15’ box) and understand the sensitivity to the sizing and the floodplain. In general, this configuration will also be sufficient to pass the 100-Year WHS flood without impacts to the existing floodplain (Criteria 1) as illustrated in Figure 15. Figure 16 and Figure 17 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS.

Red (▬) shows additional inundation (interior side) due to culverts even though culverts are open.
Cyan (▭) shows inundation under the FWOP.

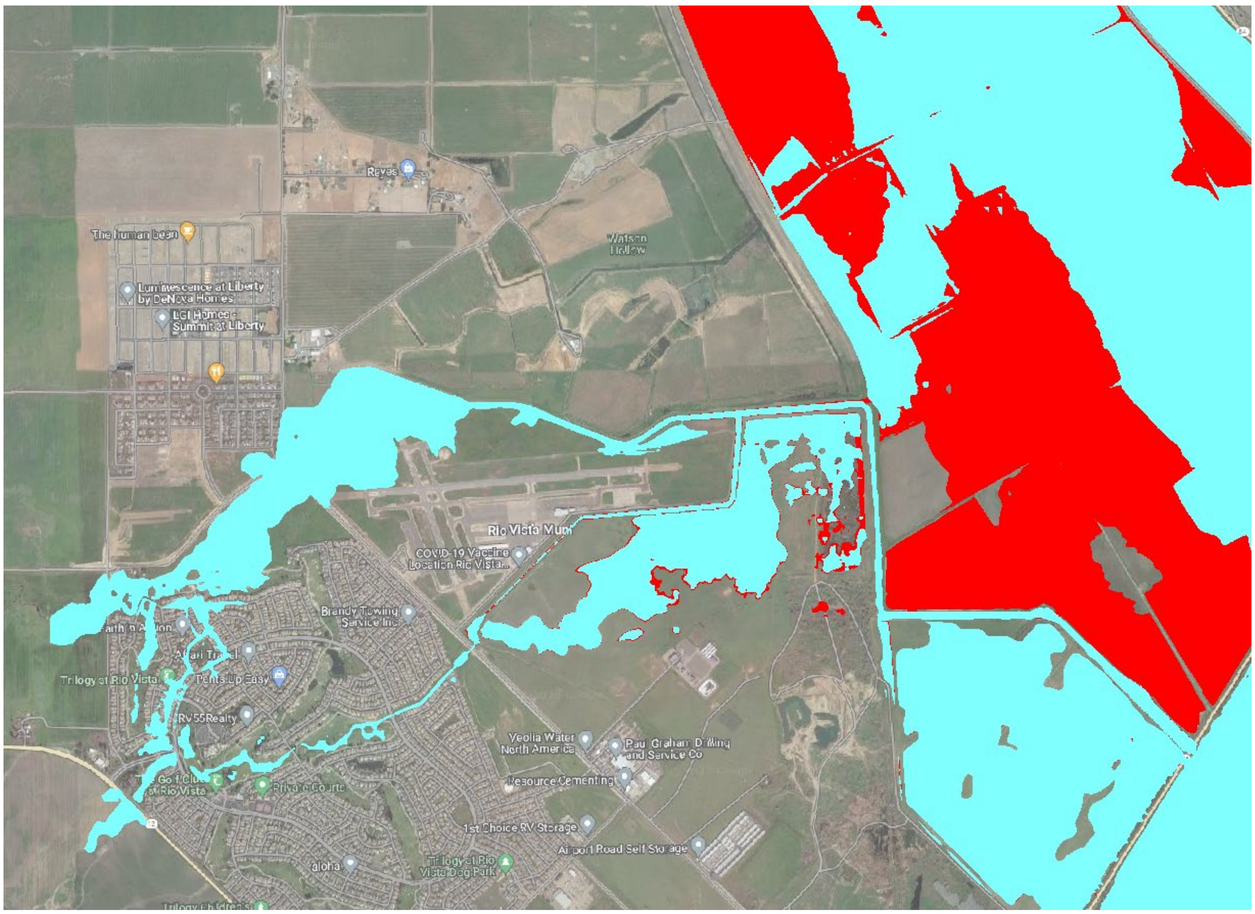

Figure 15. Effect of One 5-foot high by 20-feet wide gates on Inundation Area (WHS Rainfall Flood Centering)

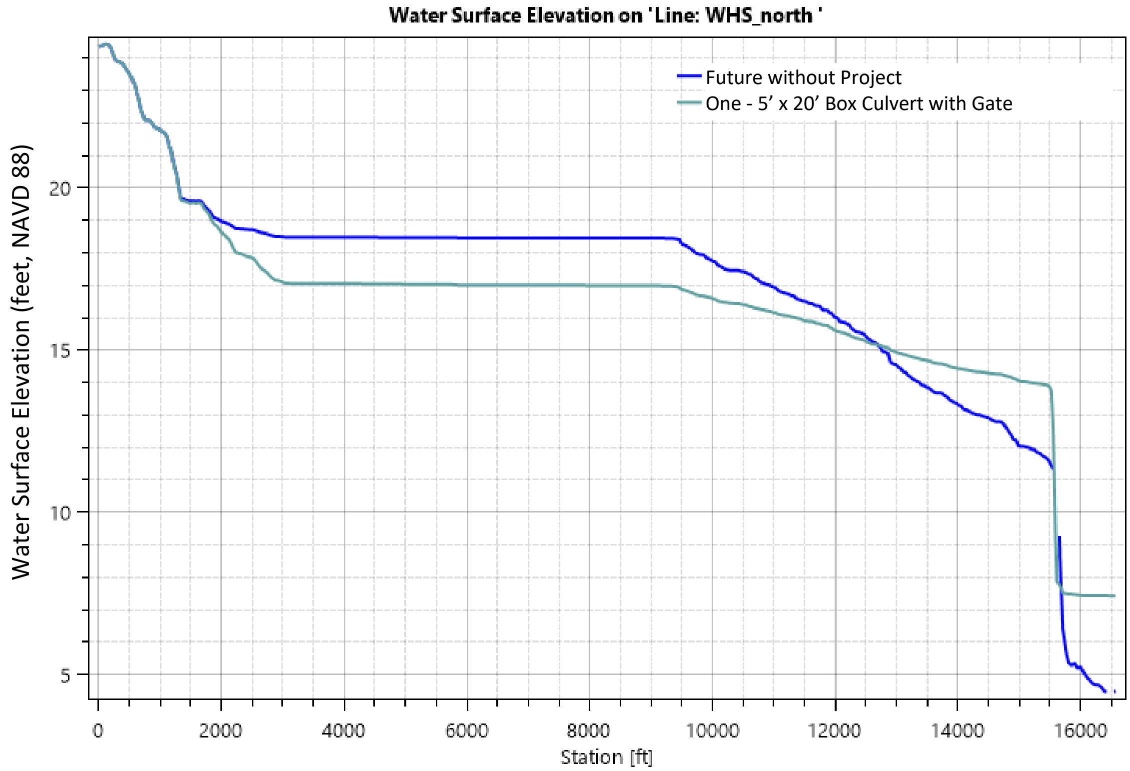

Figure 16. Maximum WSE Profile, WHS North Channel, With and Without One - 5' x 20' gate (WHS Rainfall Flood Centering)

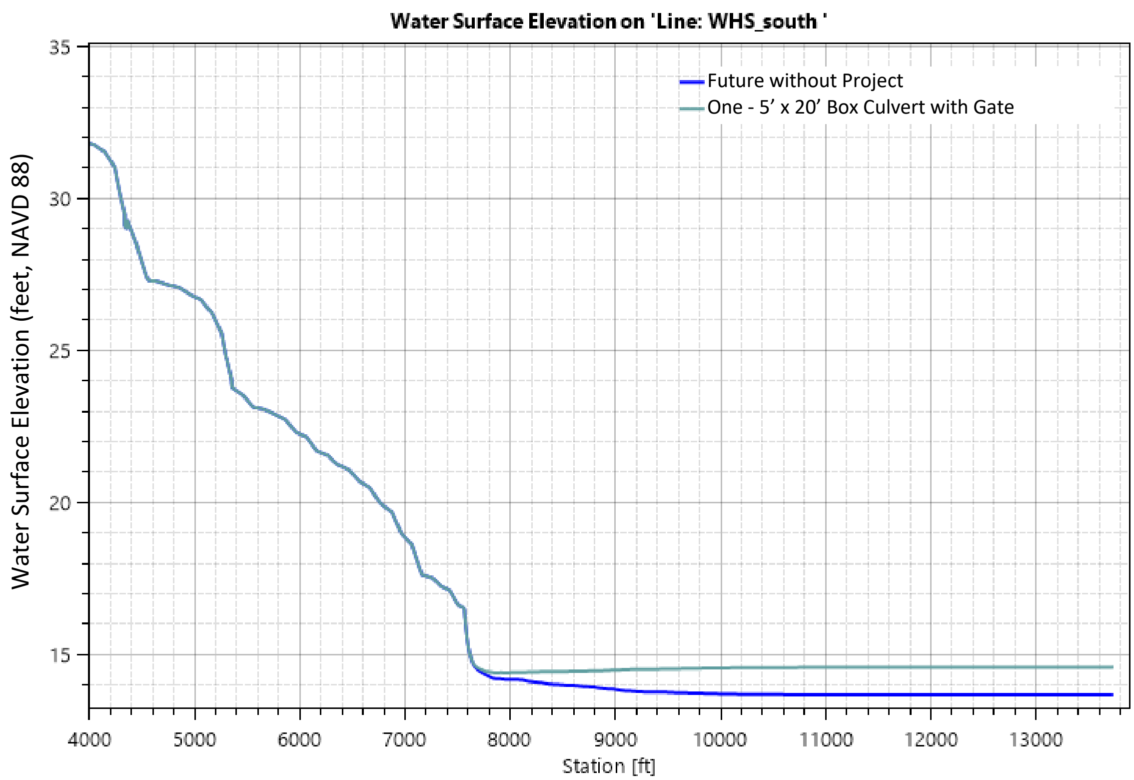

Figure 17. Maximum WSE Profile, WHS South Channel, With and Without One – 5' x 20' gate (WHS Rainfall Flood Centering)

Table 2 and Table 3 summarizes the changes in water surface elevations along the Watson Hollow Slough North Channel for the scenarios analyzed.

Table 2. Summary of Water Control Structure Sizing Results at 120+10 (WHS Rainfall Flood Centering)

Scenario	Structure	Number	Size	Peak WSE near airport, WHS North Channel profile line station 120+10	
				WSE (feet, NAVD88)	Change from FWOP (feet)
FWOP	None	---	---	16.0	---
1	Culvert	3	4’ diameter	16.8	+0.8
2	Gate	1	5’ H x 15’ W	16.3	+0.3
3	Gate	2	5’ H x 15’ W	14.8	-1.2
4	Gate	1	5’ H x 20’ W	15.6	-0.4

Table 3. Summary of Water Control Structure Sizing Results at 155+05 (WHS Rainfall Flood Centering)

Scenario	Structure	Number	Size	Peak WSE near airport, WHS North Channel profile line station 155+05	
				WSE (feet, NAVD88)	Change from FWOP (feet)
FWOP	None	---	---	11.5	---
1	Culvert	3	4’ diameter	16.1	+4.6
2	Gate	1	5’ H x 15’ W	15.3	+3.8
3	Gate	2	5’ H x 15’ W	10.0	-1.5
4	Gate	1	5’ H x 20’ W	13.8	+2.3

Isolating the Drainage and Irrigation Use of Watson Hollow Slough

Upon completion of the water control structure design analysis, the next step in this feasibility evaluation is to identify a preliminary operations and contingency plans for operating the gates. During high flows on the Yolo Bypass, the proposed gates on WHS will be closed and pumps will be needed to discharge any baseflow or WHS runoff into the proposed intake channel on LET. In addition, a proposed detention basin would likely be required to maintain stable operable water levels of the drainage lift station.

A project design team meeting was held to discuss these potential next steps and a team decision was made to isolate the utilization between drainage and irrigation on WHS. The water control structure would serve solely to drain water from the WHS watershed and provide positive drainage only--drain east onto LET. This can be achieved by installing a check or flap gate on the downstream end or on the LET side of the water control structure. During high flows on the Yolo Bypass, flood waters would not be able to enter WHS. The irrigation water will be provided to RD 536 by a proposed lift station that will have an intake on the proposed LET intake channel. The sizing and design of the proposed irrigation lift station is provided by the civil engineer on the project design team.

A design analysis focused on a water control structure using pipe culverts and flap gates are provided in the following sections.

Scenario 5: Five culverts: 4-foot diameter

Scenario 5 increases the number of 4-foot pipes from three to five when compared to Scenario 1. Five 4 foot diameter pipes are provided through the proposed levee with pipe inverts set at elevation 2 feet, NAVD 88 and flap gates installed on the downstream ends. This culvert configuration is not sufficient to pass the 100-Year WHS flood with minimal impact (Criteria 1) as illustrated on the interior side of the levee shown in Figure 18. Figure 19 and Figure 20 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS. Inundation on the LET side is due to the LEMBP project and not driven by Scenario 5. Five 4-foot culverts do not have sufficient conveyance capacity to drain the 100-year rainfall event.

Red (▬) shows additional inundation (interior side) due to culverts even though culverts are open.
Cyan (▭) shows inundation under the FWOP.

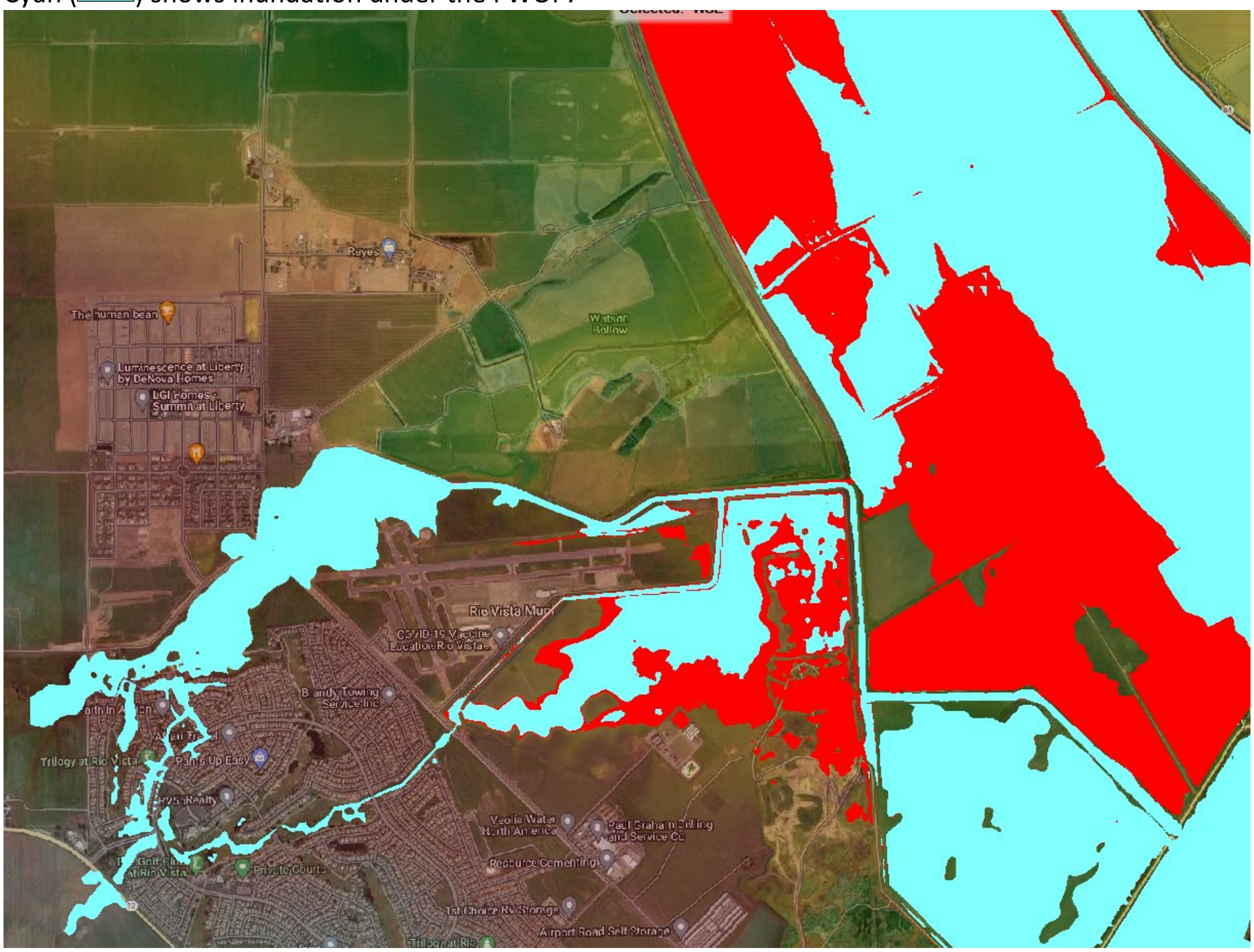

Figure 18. Effects of Five 4-foot Diameter Culverts on Inundation Area (WHS Rainfall Flood Centering)

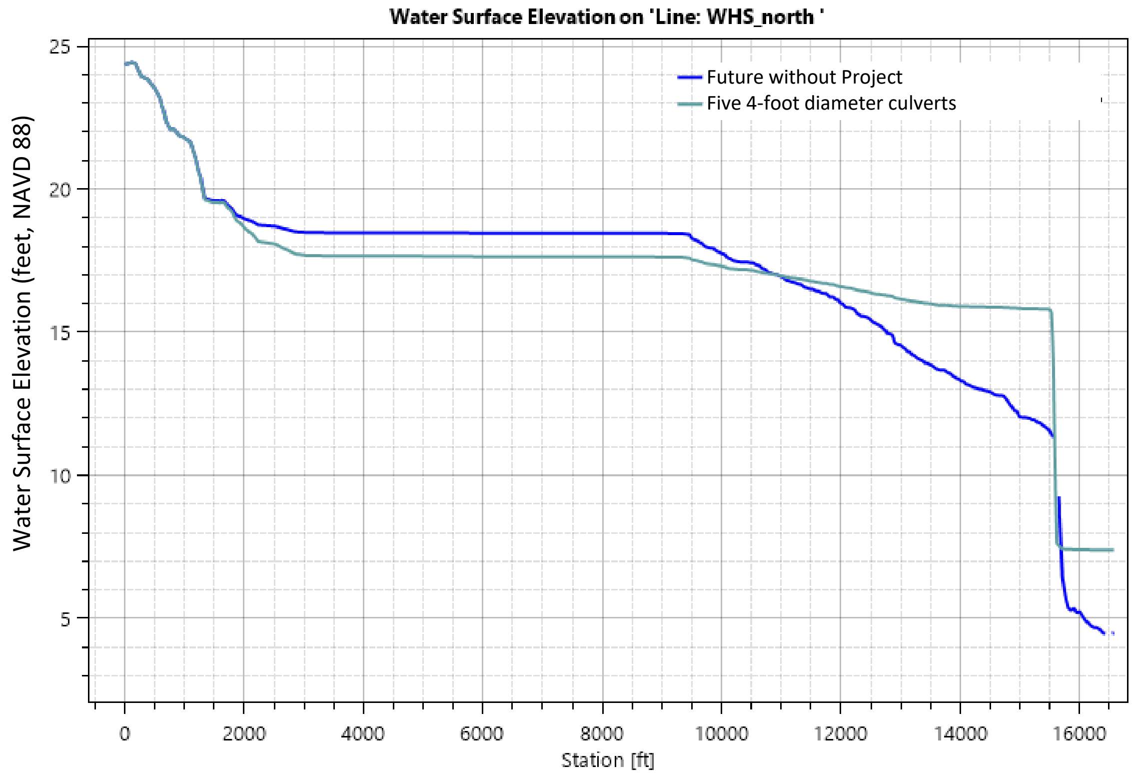

Figure 19. Maximum WSE Profile, WHS North Channel, With Five 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

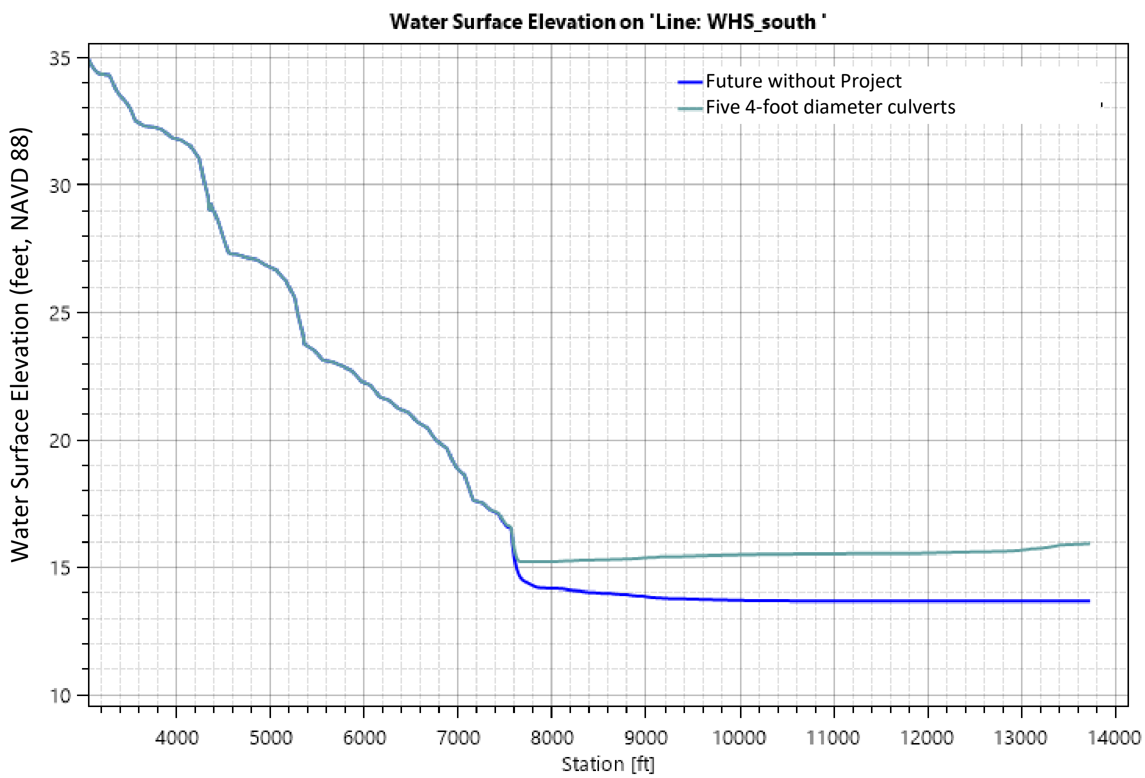

Figure 20. Maximum WSE Profile, WHS South Channel, With Five 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

Scenario 6: Eight culverts: 4-foot diameter

Scenario 6 increases the number of pipes to eight 4-foot diameter pipes with invert elevations set at elevation 2 feet, NAVD 88. This culvert configuration is sufficient in passing the 100-Year WHS flood with minimal impact (Criteria 1) as illustrated on the interior side of the levee shown in Figure 21. Figure 22 and Figure 23 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS. Inundation on the LET side is due to the LEMBP project and not driven by Scenario 6.

Red () shows additional inundation (interior side) due to culverts even though culverts are open.
Cyan () shows inundation under the FWOP.

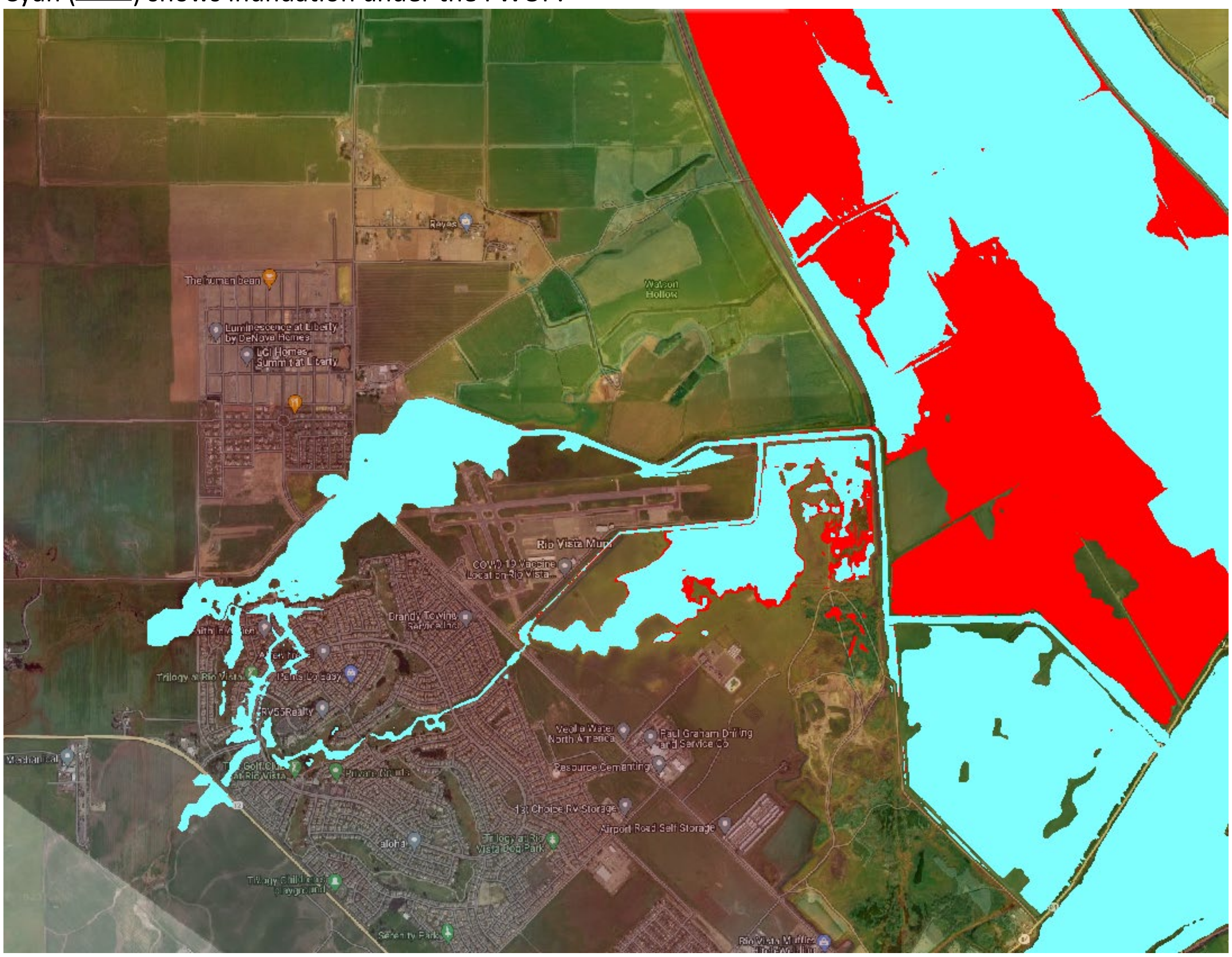

Figure 21. Effects of Eight 4-foot Diameter Culverts on Inundation Area (WHS Rainfall Flood Centering)

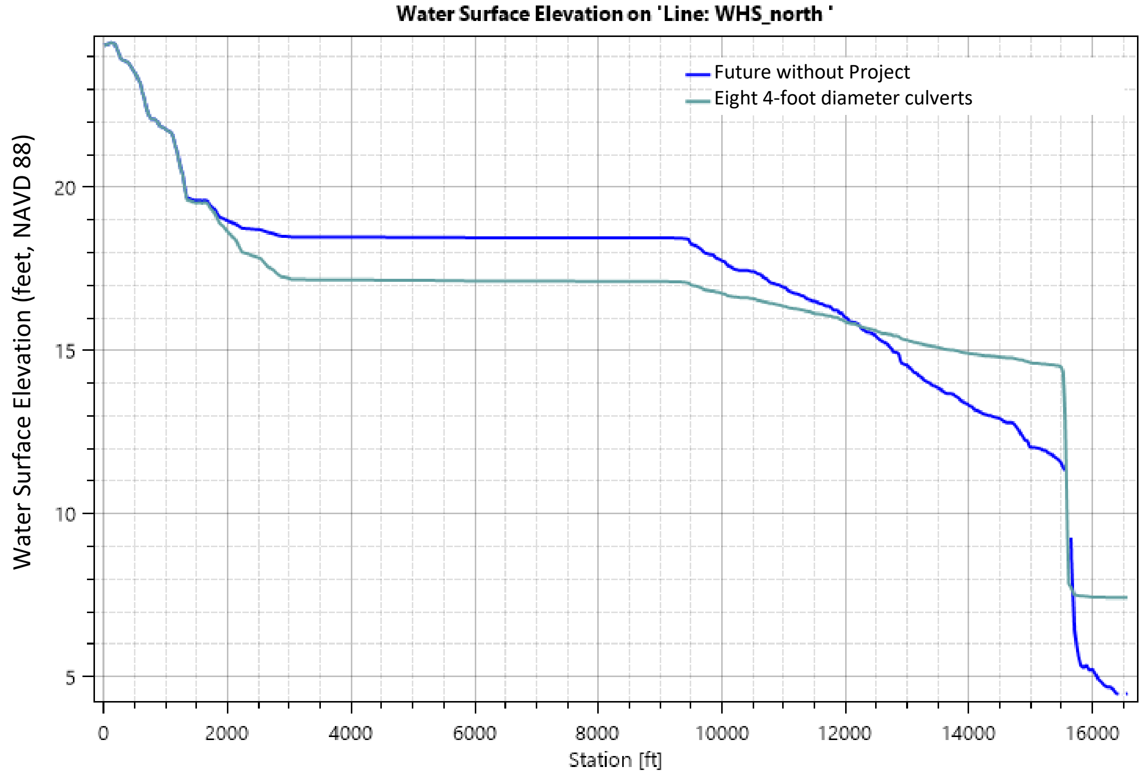

Figure 22. Maximum WSE Profile, WHS North Channel, With Eight 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

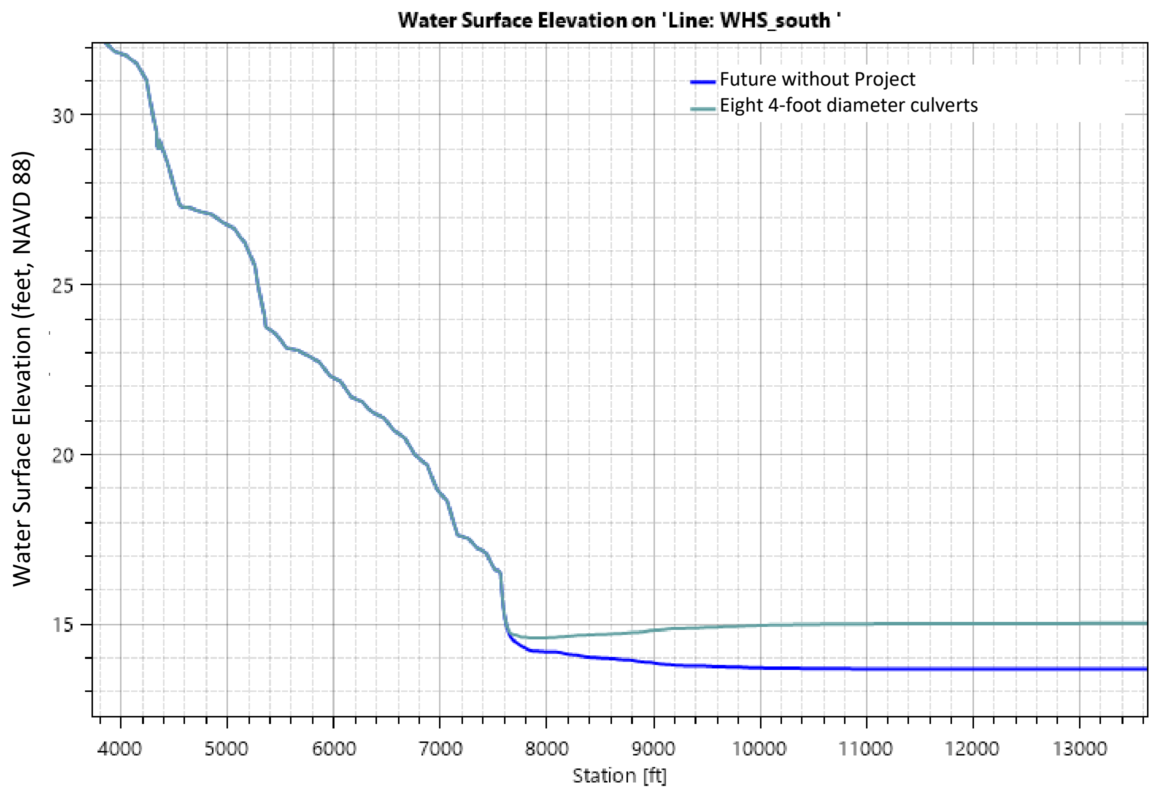

Figure 23. Maximum WSE Profile, WHS South Channel, With Eight 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

Scenario 7: Ten culverts: 4-foot diameter

Scenario 7 increases the number of pipes to ten 4-foot diameter pipes with invert elevations set at elevation 2 feet, NAVD 88. This culvert configuration is also sufficient in passing the 100-Year WHS flood with minimal impact (Criteria 1) as illustrated on the interior side of the levee shown in Figure 24. Figure 25 and Figure 26 shows the maximum water surface elevation profiles along the northerly and southerly segments of WHS. Inundation on the LET side is due to the LEMBP project and not driven by Scenario 7.

Red () shows additional inundation (interior side) due to culverts even though culverts are open.
Cyan () shows inundation under the FWOP.

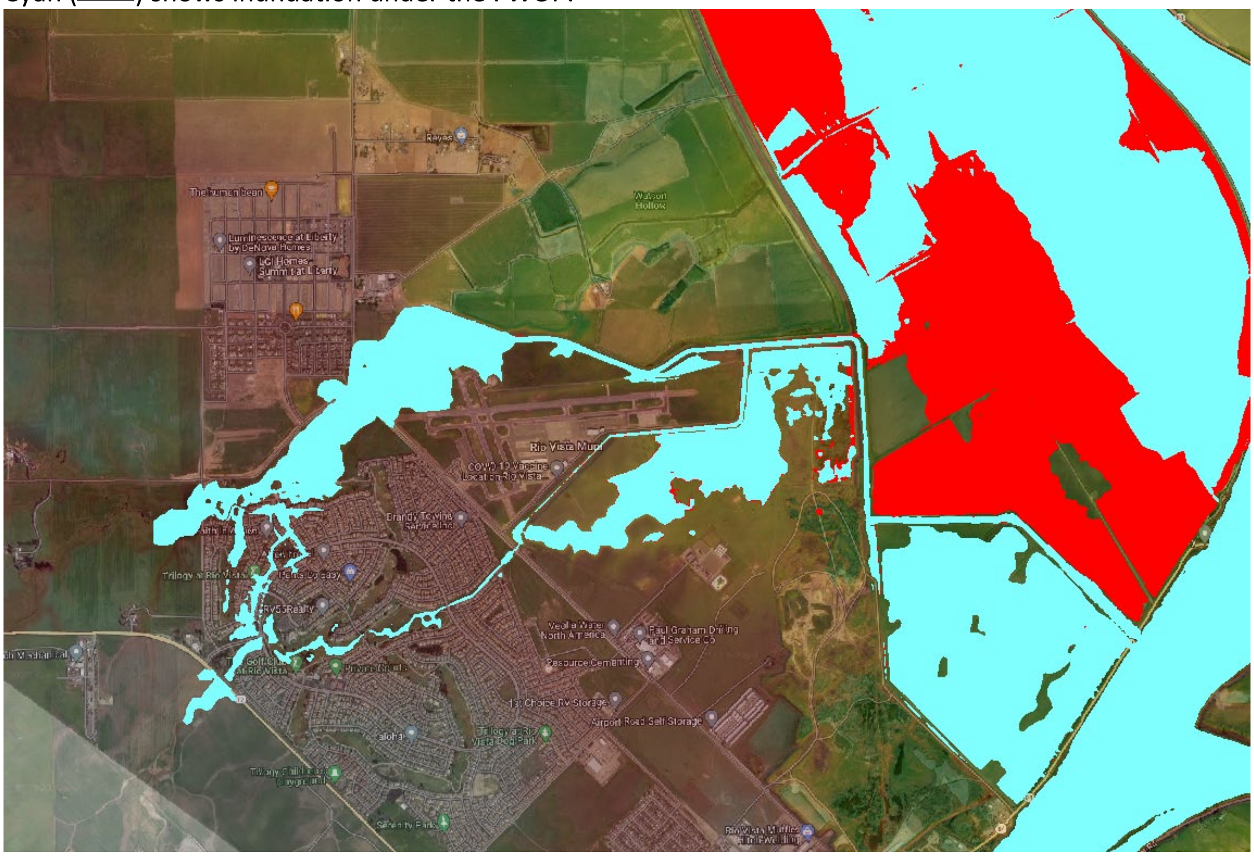

Figure 24. Effects of Ten 4-foot Diameter Culverts on Inundation Area (WHS Rainfall Flood Centering)

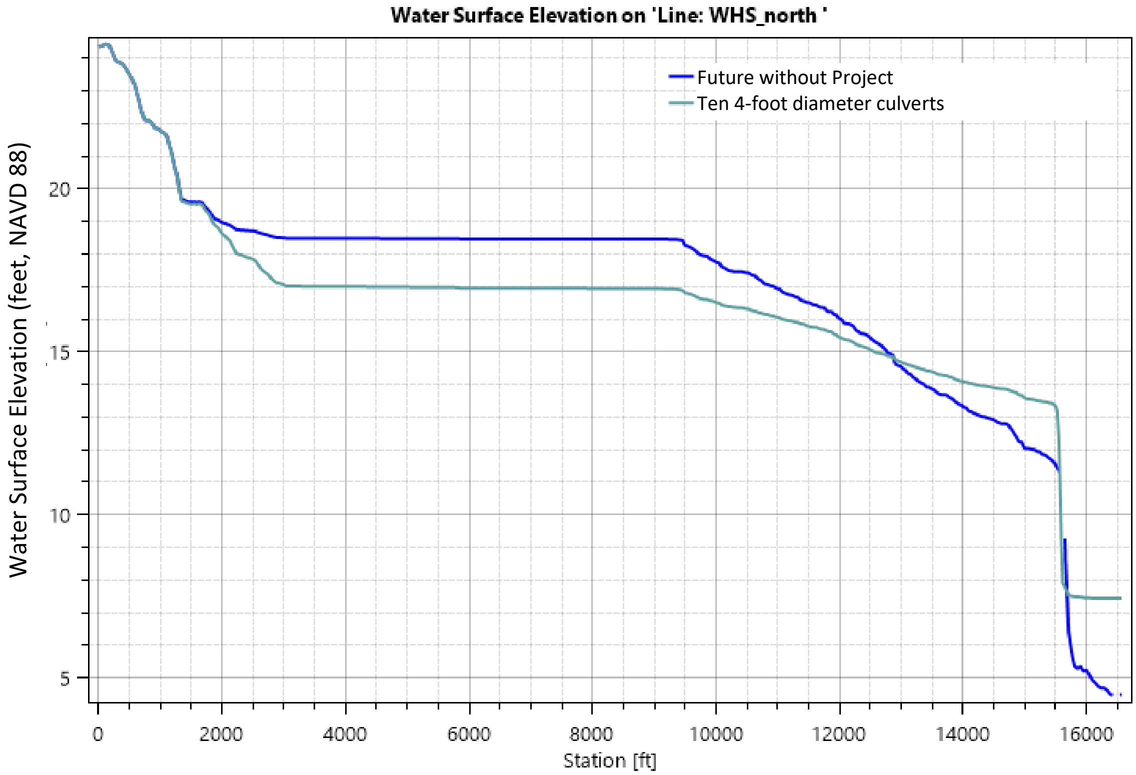

Figure 25. Maximum WSE Profile, WHS North Channel, With Ten 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

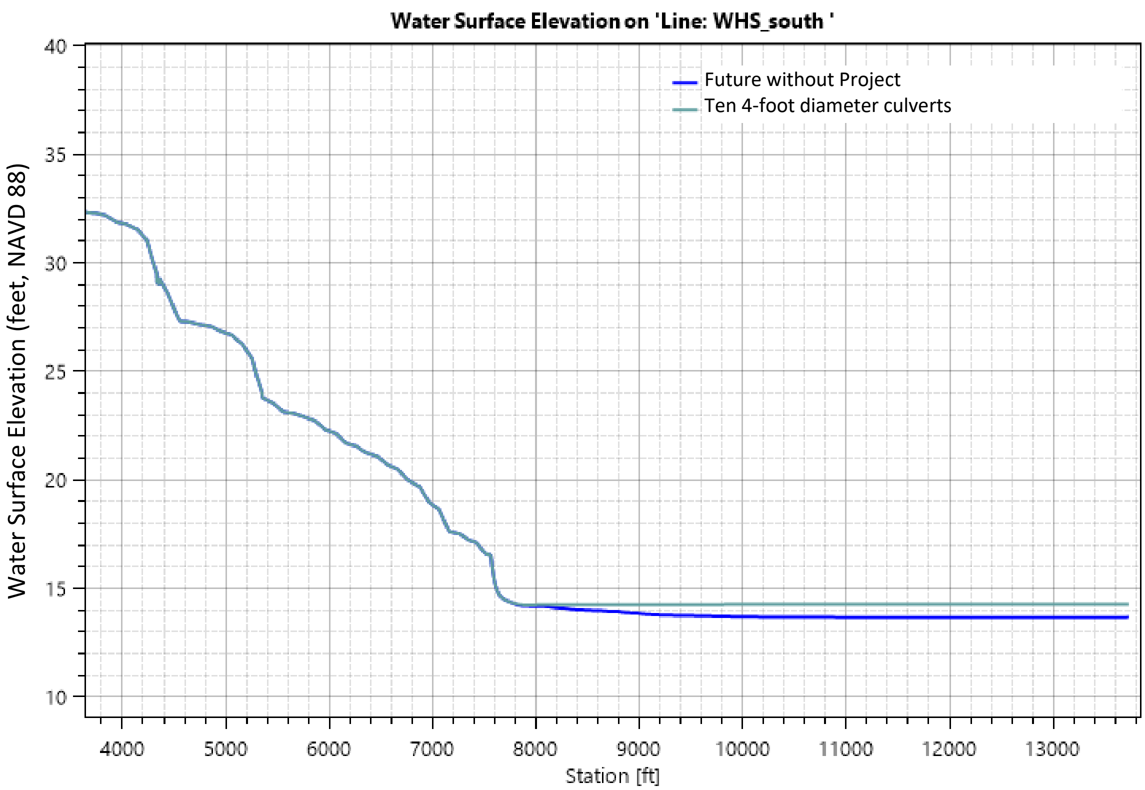

Figure 26. Maximum WSE Profile, WHS South Channel, With Ten 4-foot Diameter Culverts (WHS Rainfall Flood Centering)

Table 4 and Table 5 summarizes the changes in water surface elevations during the 1-in-100 year WHS flood along the Watson Hollow Slough North Channel for the positive drainage scenarios analyzed.

Table 4. Summary of Water Control Structure Sizing Results at 120+10 (WHS Rainfall Flood Centering)

Scenario	Structure	Number	Size	Peak WSE near airport, WHS North Channel profile line station 120+10	
				WSE (feet, NAVD88)	Change from FWOP (feet)
FWOP	None	---	---	16.0	---
1	Culvert	3	4’ diameter	16.8	+0.8
5	Culvert	5	4’ diameter	16.6	+0.6
6	Culvert	8	4’ diameter	15.9	-0.1
7	Culvert	10	4’ diameter	15.4	-0.6

Table 5. Summary of Water Control Structure Sizing Results at 155+05 (WHS Rainfall Flood Centering)

Scenario	Structure	Number	Size	Peak WSE near airport, WHS North Channel profile line station 155+05	
				WSE (feet, NAVD88)	Change from FWOP (feet)
FWOP	None	---	---	11.5	---
1	Culvert	3	4’ diameter	16.1	+4.6
5	Culvert	5	4’ diameter	15.7	+4.2
6	Culvert	8	4’ diameter	14.5	+3.0
7	Culvert	10	4’ diameter	13.3	+1.8

Recommendations

Throughout this design analysis formulation of the water control structure on WHS, the project design team has moved towards a configuration that will provide positive drainage only for WHS. This configuration can be achieved by installing a check or flap gate on the downstream end or on the LET side of the water control structure. During high flows on the Yolo Bypass, flood waters would not be able to enter WHS while irrigation water will be provided to RD 536 by a proposed lift station. Selection criteria 3 is met by implementing a water control structure that facilitates positive drainage only. Selection criteria 2 is met by implementing an irrigation lift station—this design is provided by others. Selection criteria 1 is directly influenced by the size and number of the culverts. Based on this design sizing analysis, criteria 1 can be met using eight to ten 4 foot diameter pipes because the interior floodplain from these configurations yield the least hydraulic impacts. Another data point to support selection of a water control structure configuration is to examine the existing connection between WHS and Cache Slough. The existing WHS is connected to Cache Slough through four 5 foot diameter pipes. The conveyance area of four 5-foot diameter pipe is approximately 80 square foot. A replace in-kind water control structure should have a similar magnitude of opening. Using the opening of a 4-foot diameter pipes, 80 square foot is equivalent to approximately seven 4-foot diameter pipes. Therefore, eight 4-foot diameter pipes with flap gates at the downstream ends are recommended for design.

References

(MBK, 2022). Little Egbert Tract Multi-Benefit Project – Interior Drainage Hydrology & Hydraulic Analysis. April 8, 2022.

(MBK, 2023). Little Egbert Tract Multi-Benefit Project – Flood Hydrology & Hydraulics Feasibility Analysis. MBK Engineers. June 2023.

(USACE). Hydrology Technical Memorandum for Developing WRDA 2016 Water Surface Profiles. USACE. April 10, 2020.