MBK ENGINEERS

Water Resources ◆ Flood Control ◆ Water Rights

TECHNICAL MEMORANDUM

DATE: September 14, 2023

TO: Mark Young, Westervelt Ecological Services

PREPARED BY: Don Trieu, P.E.

SUBJECT: Little Egbert Tract Multi-Benefit Project – Flood Hydrology & Hydraulics Feasibility Analysis

Introduction

The intent of the Little Egbert Multi-Benefit Project (LEMBP) is to Enhance Public Safety, Protect and Enhance Natural Ecosystem Process, and Protect and Enhance Opportunities for Recreation. These goals will be achieved through the implementation of landscape-level design features that require detailed engineering and environmental analyses. The project is in Solano County on approximately 3100 acres of Little Egbert Tract (LET), and is bounded by the levees of Reclamation District (RD) 536, RD 2084, Solano County Levee 44 (County Levee 44), Mellin Levee Extension, Mellin Levee, and Highway 84 (Figure 1).

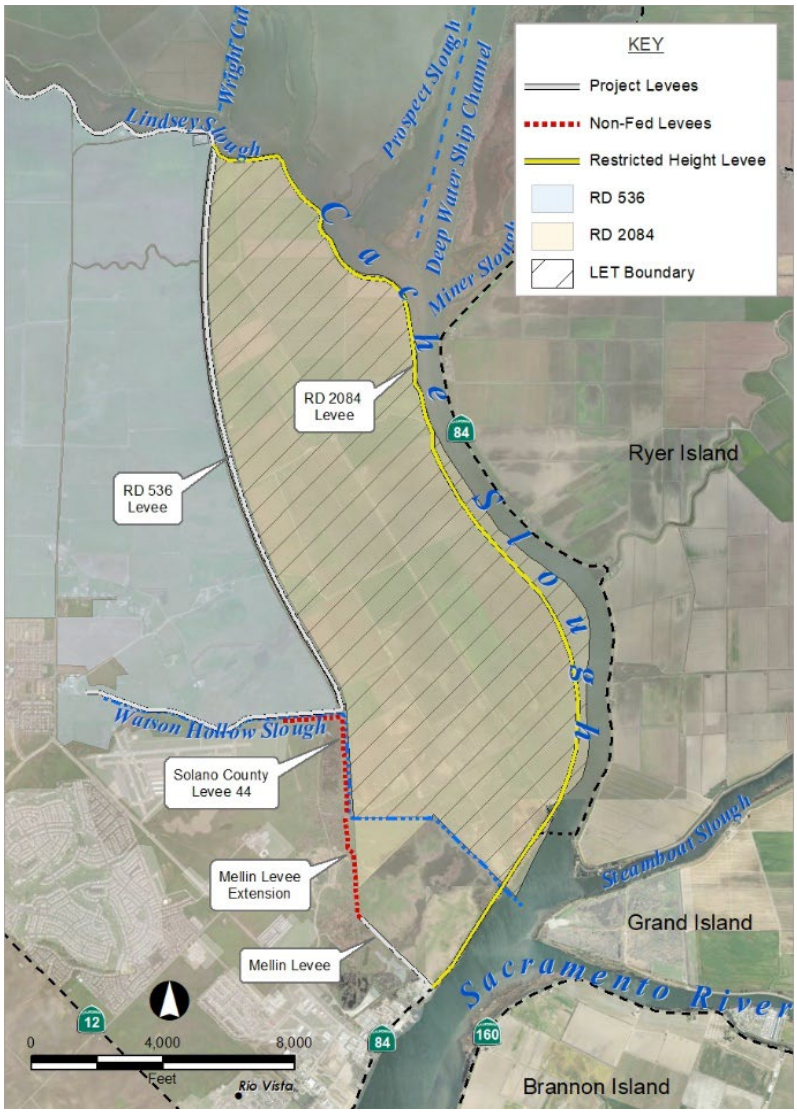


Figure 1. Location Map

As part of a feasibility study MBK Engineers (MBK) has been tasked to:

1. Evaluate the performance of four alternative berm openings on LET.
2. Determine the hydraulic impacts/benefits compared to a without project condition.

Methodology

The methodology used to analyze the tasks listed above was to configure a hydraulic model for a future without project (FWOP) condition and various with-project conditions. Output from the project condition simulations will be compared to the FWOP condition to determine the hydraulic effects. Change in peak stage in the system is the key metric used as a performance indicator of the alternatives. A description of the hydrology and hydraulic model used in the hydraulic analysis follows.

Hydrology

The hydrology used for this analysis 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)[1]. 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 Sacramento River at Verona centering, as this centering has a slightly higher flow in the Yolo Bypass at I-80 for the 10-Year and 200-Year events.

The flood events simulated in the analysis presented herein, and the corresponding CVHS pattern and scaling factor, are summarized in Table 1.

Table 1. CVHS Flood Patterns and Scaling Factors

Flood Frequency (Annual Exceedance Probability)	Sacramento River at Verona Centering	
	CVHS Pattern	CVHS Scale Factor
1/10 (10-Year)	1997	50% with 20% on American River
1/200 (200-Year)	1997	100%

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 simulation 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. All elevations in the hydraulic model are referenced to the North American Vertical Datum of 1988 (NAVD-88). A schematic of the model extent is shown in Figure 2.

[1] (USACE, 2015)

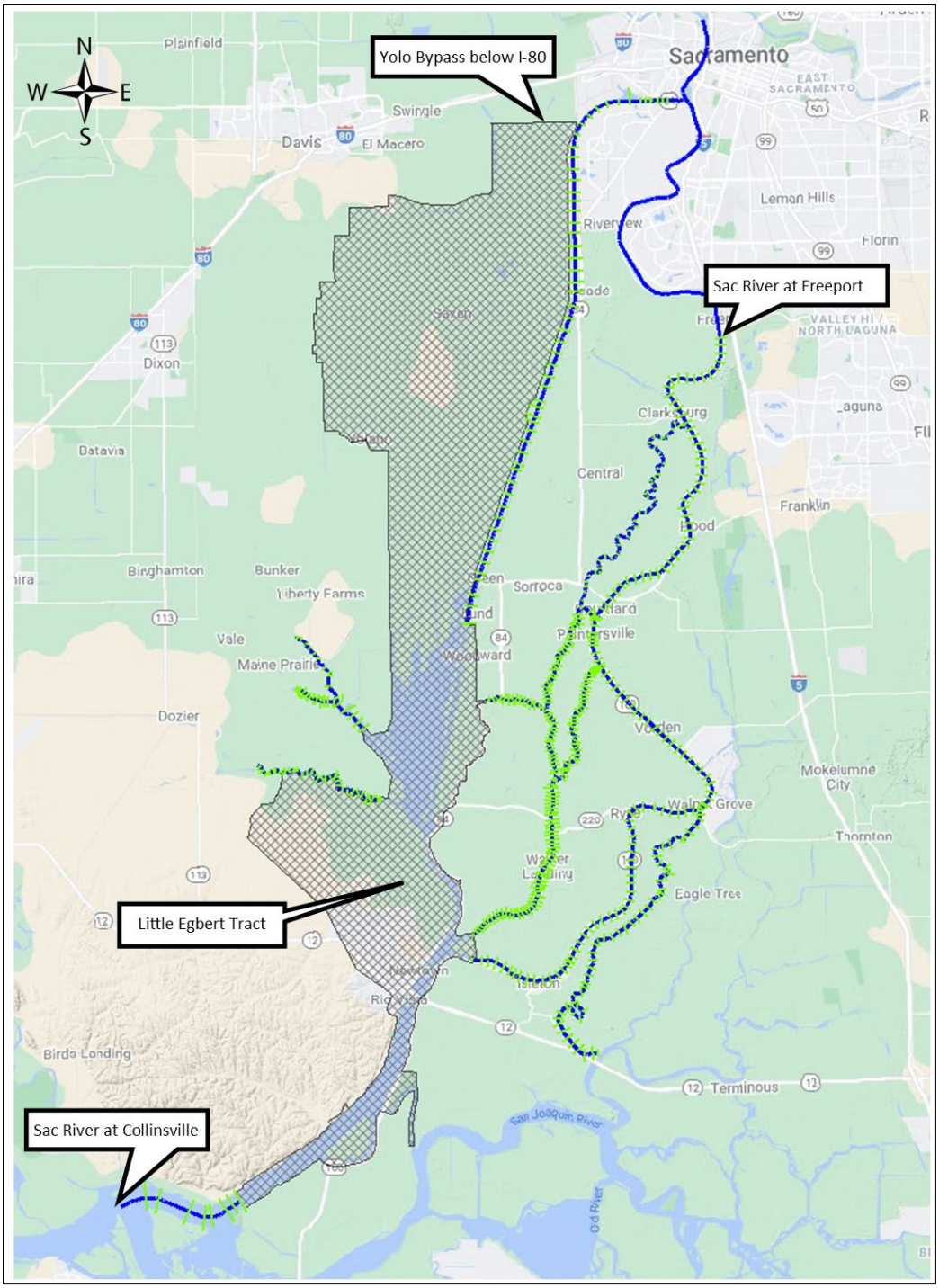


Figure 2. HEC-RAS Flood Model Schematic

Hydraulic Model Calibration

The modified flood model was calibrated to the 2017 event and verified with the 2006 event and the 1997 event. Calibration is the process of adjusting model parameters, such as Manning's n-values and weir coefficients, until the model reasonably reproduces a historical event. Once calibrated, the model is

verified by simulating a different flood event to verify that it can reasonably reproduce a different flood event. The quality of the calibration and verification are measured by comparing computed data with available observed data. Typical observed data include stage and flow records measured by stream gages. Further documentation of the model development, calibration and verification is documented in (MBK 2023).

Alternative Analysis

In concept, the LEMBP consists of some or all of the following components:

1. Berm openings (upstream, mid-channel and downstream) in the RD 2084 Cache Slough restricted-height levee.
2. Levee improvements to the RD 536, Mellin Levee, Mellin Levee Extension, and Solano County Levee 44.
3. A multi-function tide gate structure at Watson Hollow Slough.
4. Approximately 3500 acres of habitat restoration including sub-tidal channels and habitat berms. Tidal channels and openings at the downstream end of the RD 2084 Cache Slough restricted-height levee.

MBK evaluated four with-project alternative configurations to evaluate the performance of these features relative to a future without project condition. Each of the with-project alternatives and the future without-project condition are described in detail in the following sections. A summary of alternatives and their components are shown in Table 2.

Table 2. Alternative Features

	Inlet Berm	Outlet Berm	Balance Breaches	Tide Gate Structure	Tidal Opening	RD 536 Levee, Mellin Levee, Mellin Levee Extension, and County Levee 44 Improvements
Alternative 17	2,500 ft. @ Elev. -4	2,500 ft. @ Elev. -10 to -4	✓	✓	✓	✓
Alternative 19	2,500 ft. @ Elev. +7.5	2,500 ft. @ Elev. -10 to -4	✓	✓		✓
Alternative 24	2,500 ft. @ Elev. +7.5	2,500 ft. @ Elev. -10 to +7.5		✓		✓
Alternative 26	2,500 ft. @ Elev. -4	2,500 ft. @ Elev. -10 to -4			✓	✓

Future Without-Project Condition

Each of the alternatives will be compared to a FWOP condition to assess the hydraulic impact/benefit of the alternative. The FWOP simulation assumes the following projects in the Yolo Bypass (listed below) are already constructed as of 2023, or will be constructed by the time LEMBP is constructed:

1. Sacramento Weir Widening/Sacramento Bypass Expansion

2. Lower Elkhorn Basin Levee Setback
3. Fremont Weir Big Notch and Adult Fish Passage
4. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project
5. Lower Yolo Ranch Tidal Restoration and Yolo Flyway Farms Tidal Habitat Restoration Projects
6. Southport Setback Levee
7. Yolo Bypass Wildlife Area Habitat and Drainage Improvements
8. Lindsey Slough Tidal Restoration Project
9. Decker Island Tidal Habitat Restoration Project
10. Liberty Island Conservation Bank
11. North Delta Fish Conservation Bank
12. Prospect Island Restoration Project
13. Cache Slough Mitigation Bank

Alternative 17

Alternative 17 consists of a 2,500 ft. inlet berm constructed at an elevation of -4 ft. at the upstream end of the RD 2084 restricted height levee. A downstream outlet berm would be constructed with elevations ranging from -10 ft. to -4 ft. for a total length of approximately 2,500 ft. This alternative also consists of two balancing breaches with a bottom width of 530 ft. constructed to elevations ranging from -4 ft. to +7.5 ft. The RD 536 Levee, Mellin Levee, Mellin Levee Extension, and County Levee 44 would be improved to pass the 200-Year flood event. A multi-function water control structure would be constructed at the mouth of Watson Hallow Slough, which would be closed during flood events. The RD 2084 restricted height levee and the RD 536 levee would be reinforced with wide habitat berms and LET would be graded to include sub-tidal swales and shoals. LET would be revegetated with plantings ranging from sub-tidal habitat to riparian habitat (See Figure 7). The features of Alternative 17 are shown in Figure 3.

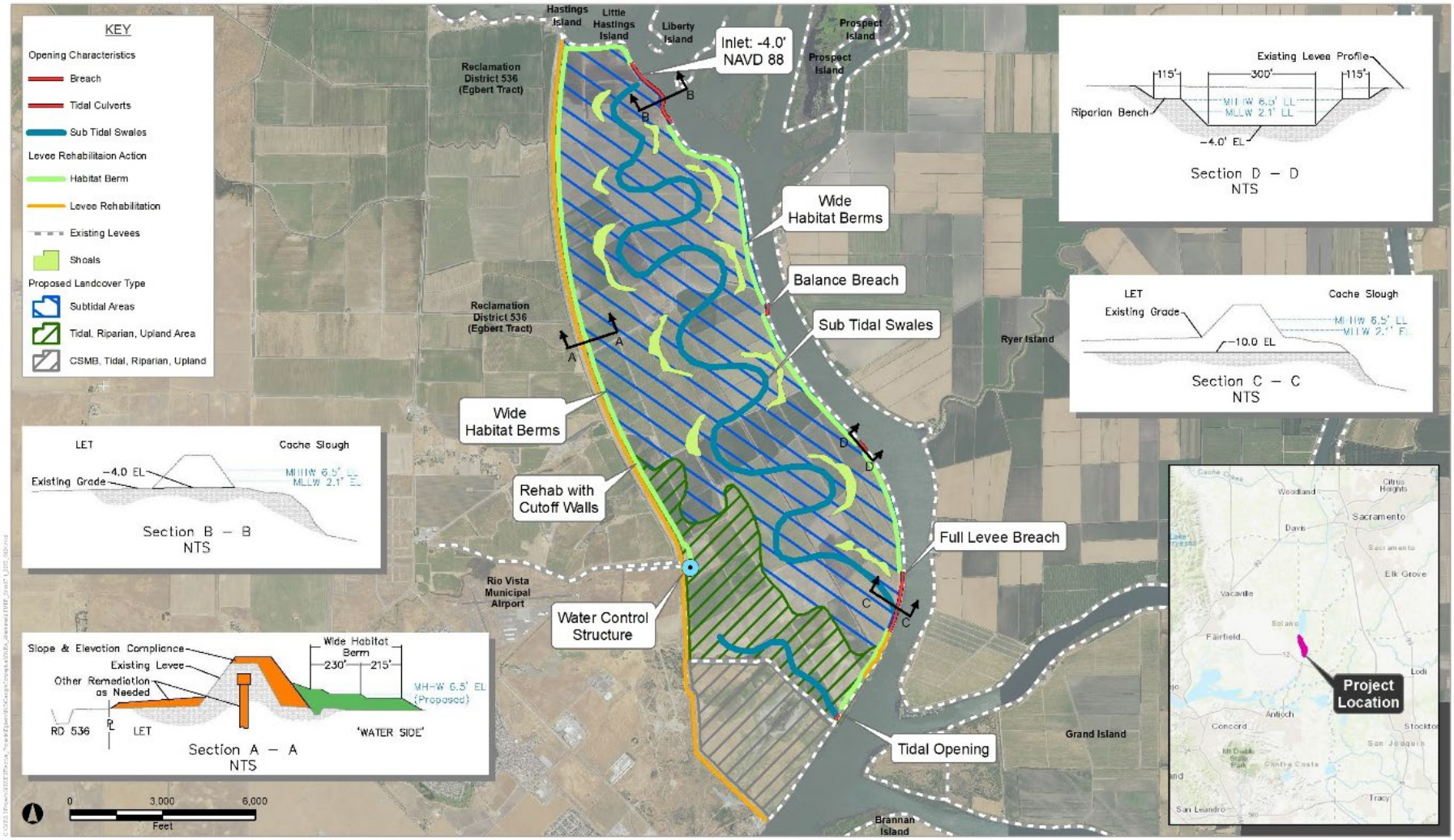


Figure 3. Alternative 17 Project Features

Alternative 19

Alternative 19 consists of a 2,500 ft. inlet berm constructed at an elevation of +7.5 ft. at the upstream end of the RD 2084 restricted height levee. A downstream outlet berm would be constructed with elevations ranging from -10 ft. to -4 ft. for a total length of approximately 2,500 ft. This alternative also consists of two balancing breaches with a bottom width of 530 ft. constructed to elevations ranging from -4 ft. to +7.5 ft. The RD 536 Levee, Mellin Levee, Mellin Levee Extension, and County Levee 44 would be improved to pass the 200-Year flood event. A multi-function water control structure would be constructed at the mouth Watson Hallow Slough, which would be closed during flood events. The RD 2084 restricted height levee and the RD 536 levee would be reinforced with narrow habitat berms and LET would be graded to include sub-tidal swales and shoals. A smaller tidal opening is included in the downstream portion of the RD 2084 restricted height levee near Highway 84, which is connected to a sub-tidal swale. LET would be revegetated with plantings ranging from sub-tidal habitat to riparian habitat (See Figure 8). The features of Alternative 19 are shown in Figure 4.

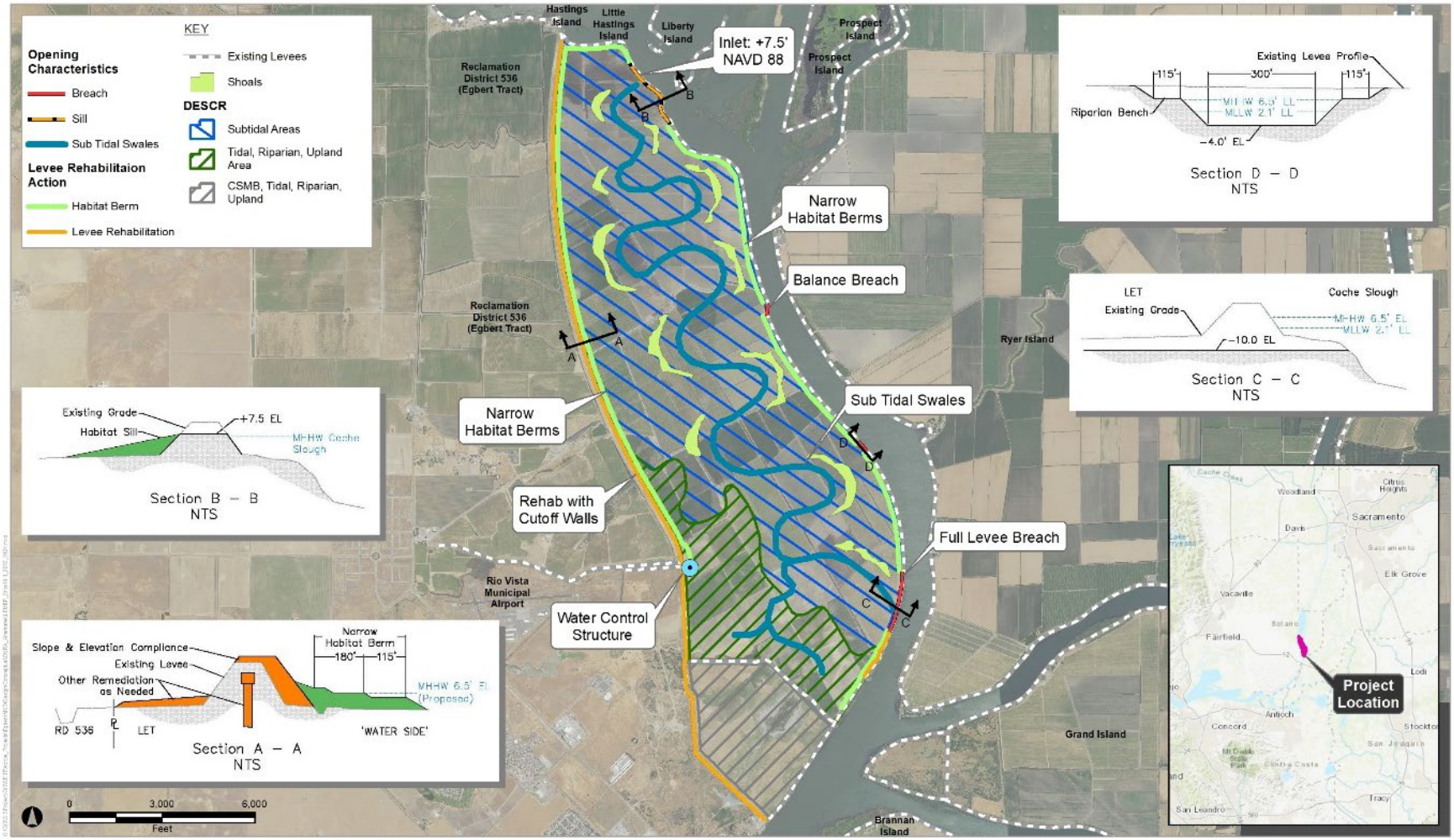


Figure 4. Alternative 19 Project Features

Alternative 24

Alternative 24 consists of a 2,500 ft. inlet berm constructed at an elevation of +7.5 ft. at the upstream end of the RD 2084 restricted height levee. A downstream compound outlet berm would be constructed at elevation -10 ft. for a length of 300 ft. and +7.5 ft. for a length of 2,200 ft., for a total length of 2,500 ft. The RD 536 Levee, Mellin Levee, Mellin Levee Extension, and County Levee 44 would be improved to pass the 200-Year flood event. A multi-function water control structure would be constructed at the mouth of Watson Hallow Slough, which would be closed during flood events. The RD 2084 restricted height levee and the RD 536 levee would be reinforced with wide habitat berms and LET would be graded to include sub-tidal swales and shoals. LET would be revegetated with plantings ranging from sub-tidal habitat to riparian habitat (See Figure 9). The features of Alternative 24 are shown in Figure 5.

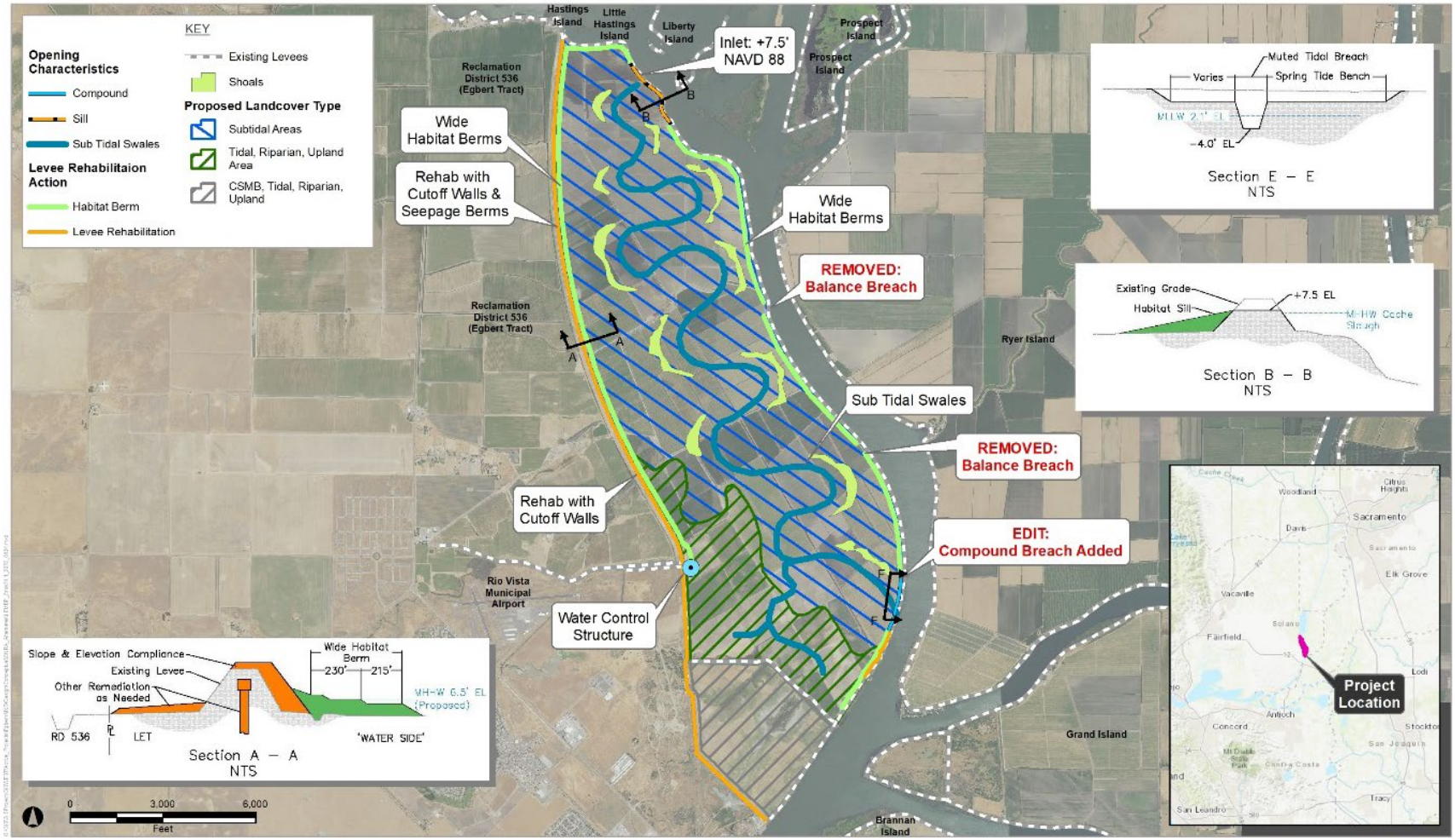


Figure 5. Alternative 24 Project Features

Alternative 26

Alternative 26 consists of a 2,500 ft. inlet berm constructed at an elevation of -4 ft. at the upstream end of the RD 2084 restricted height levee. A downstream outlet berm would be constructed with elevations ranging from -10 ft. to -4 ft. for a total length of approximately 2,500 ft. The RD 536 Levee, Mellin Levee, Mellin Levee Extension, and County Levee 44 would be improved to pass the 200-Year flood event and reinforced with narrow habitat berms. LET would be graded to include sub-tidal swales and shoals and would be revegetated with plantings ranging from sub-tidal habitat to riparian habitat (See Figure 10). The features of Alternative 26 are shown in Figure 6.

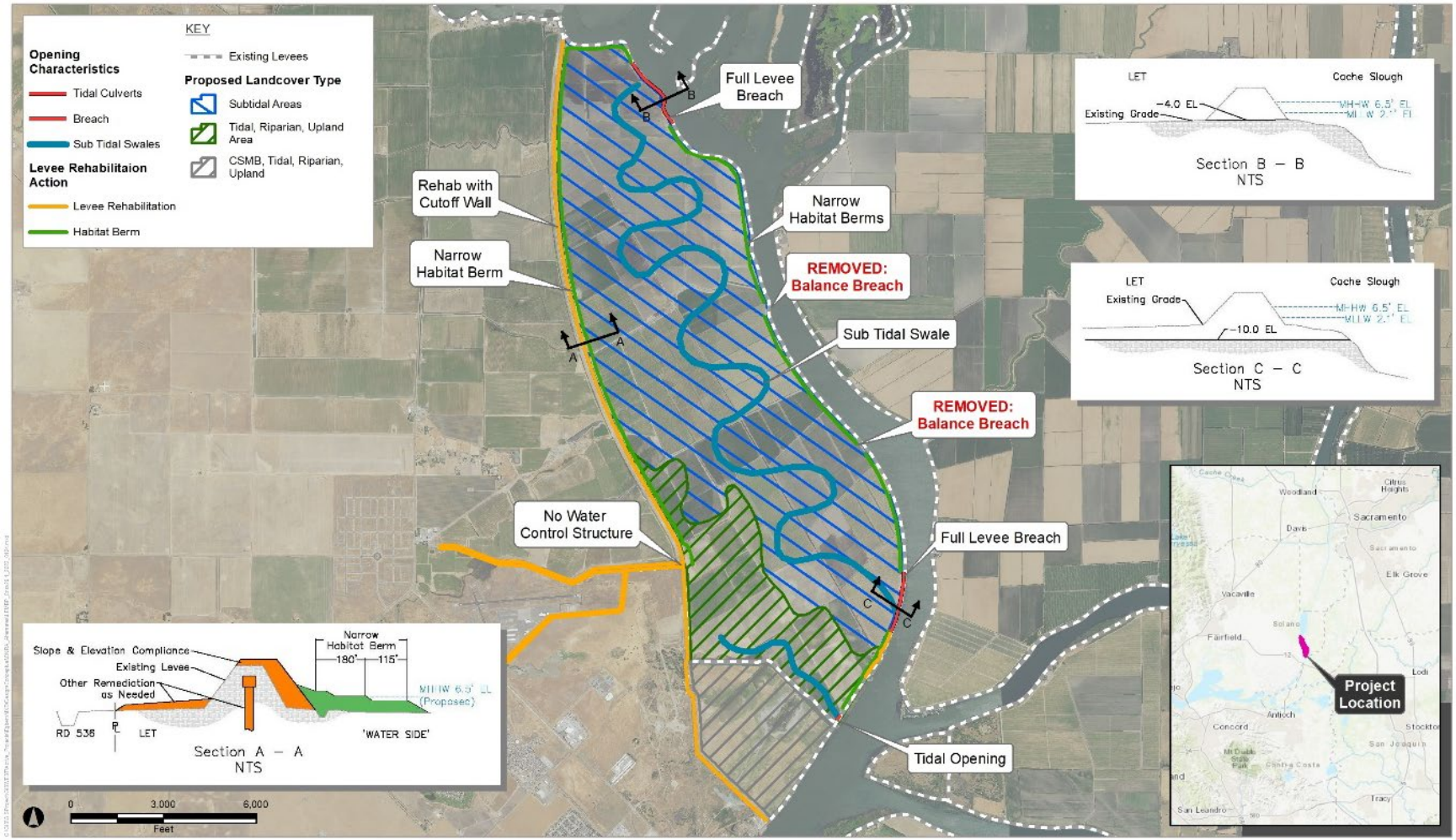


Figure 6. Alternative 26 Project Features

Habitat Restoration Feature

Each project alternative contains habitat improvement features including sub-tidal and tidal grading, habitat berms, shoals, and tidal swales, which vary in extent for each alternative. Project specific vegetation that may be established as a direct result of the project are represented in the hydraulic model using Manning's n-value roughness coefficients. The land cover types and Manning's roughness coefficients selected to represent project vegetation within the tract are listed in Table 3. Each alternative has variations in the locations and extents of the habitat restoration features and vegetation types. Figures 7 through 10 shows the Manning's roughness coefficients used in the hydraulic model in the project vicinity for Alternative 17, 19, 24, and 26, respectively.

Table 3. Project Land Cover Types and Manning's n-value Roughness Coefficients

Project Specific Land Cover Type	Manning's n-value
Sub-tidal Unvegetated	0.025
Sub-tidal Vegetated	0.04
Grassland-Ruderal	0.04
Emergent Marsh	0.045
Riparian	0.085

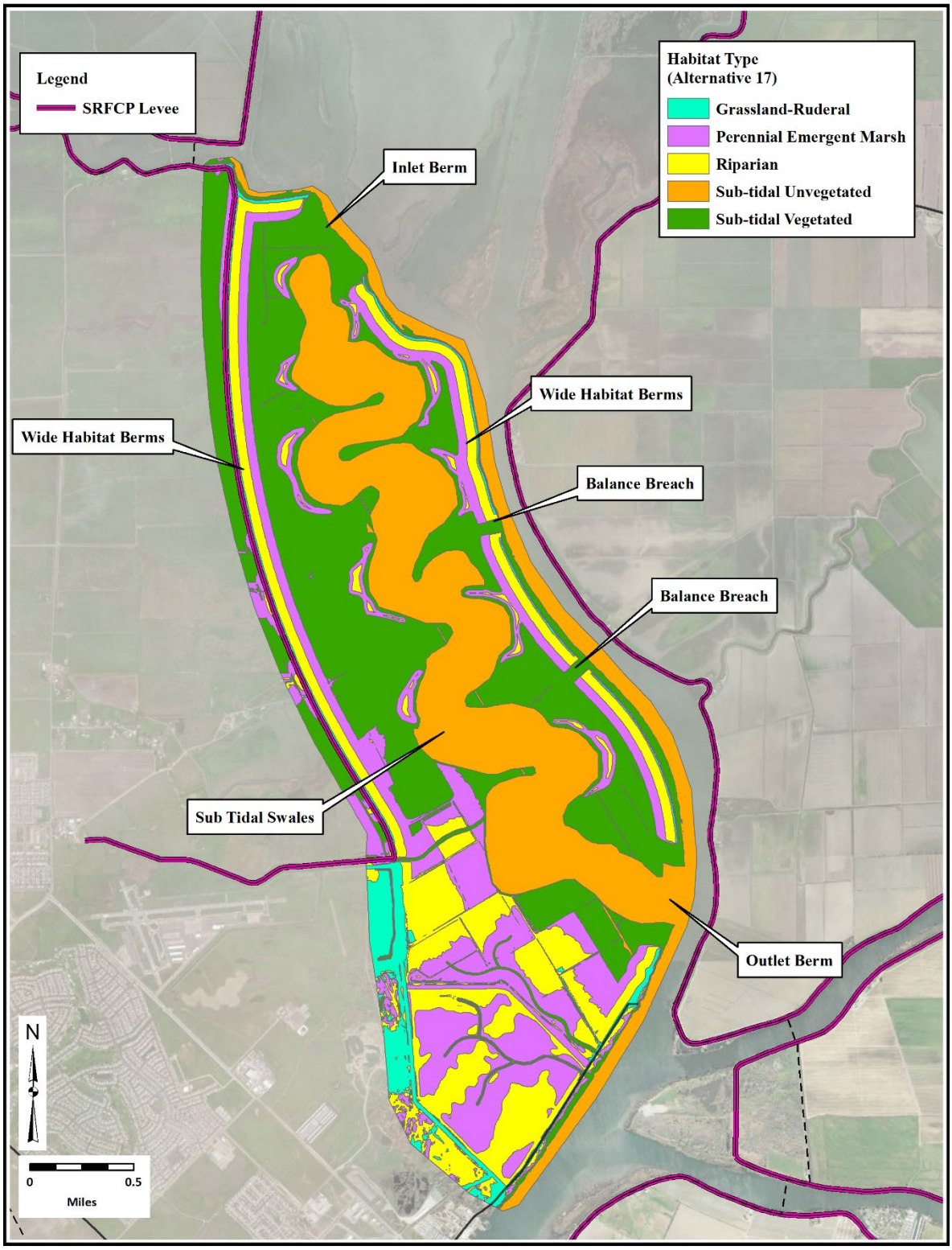


Figure 7. Alternative 17 Habitat Restoration Features

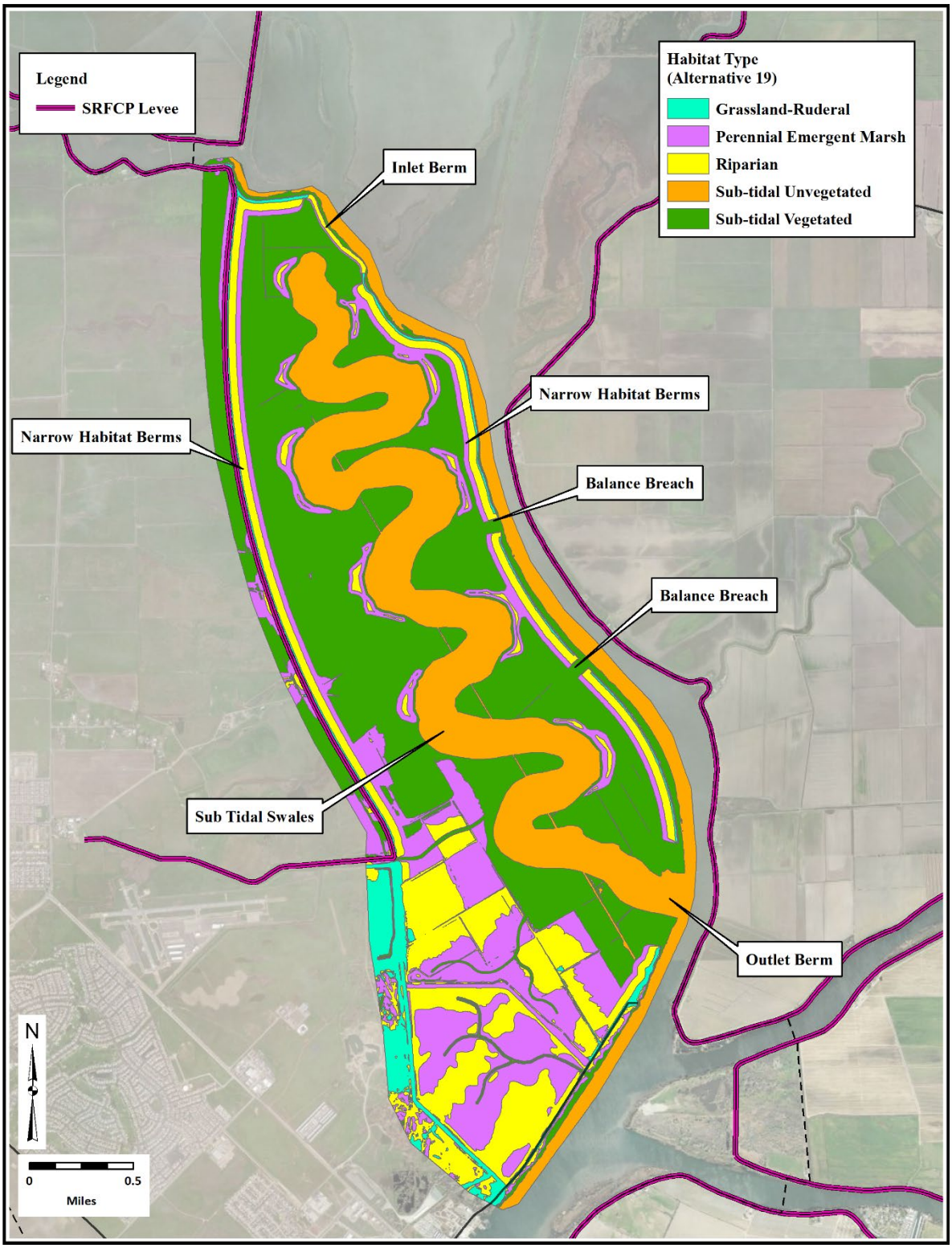


Figure 8. Alternative 19 Habitat Restoration Features

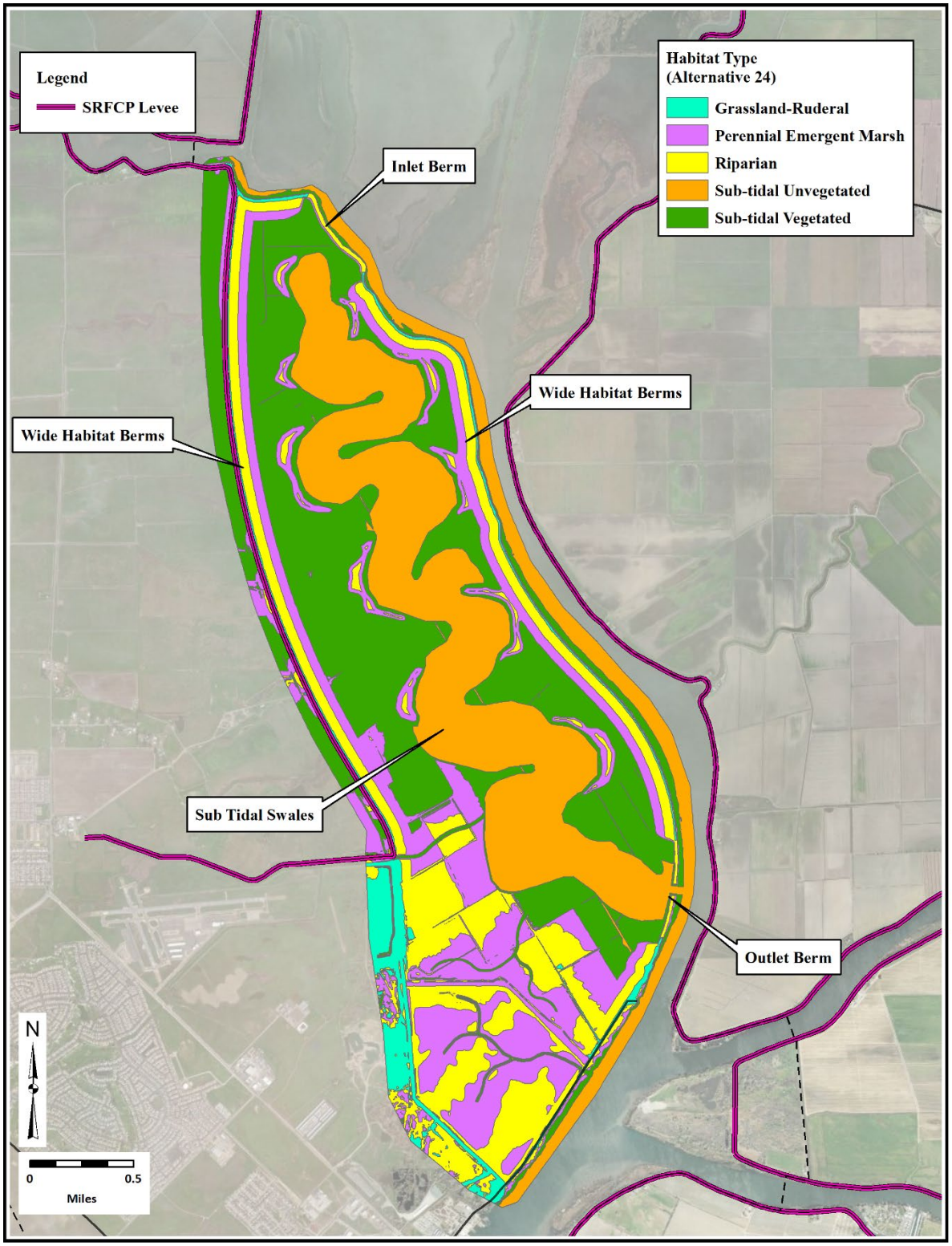


Figure 9. Alternative 24 Habitat Restoration Features

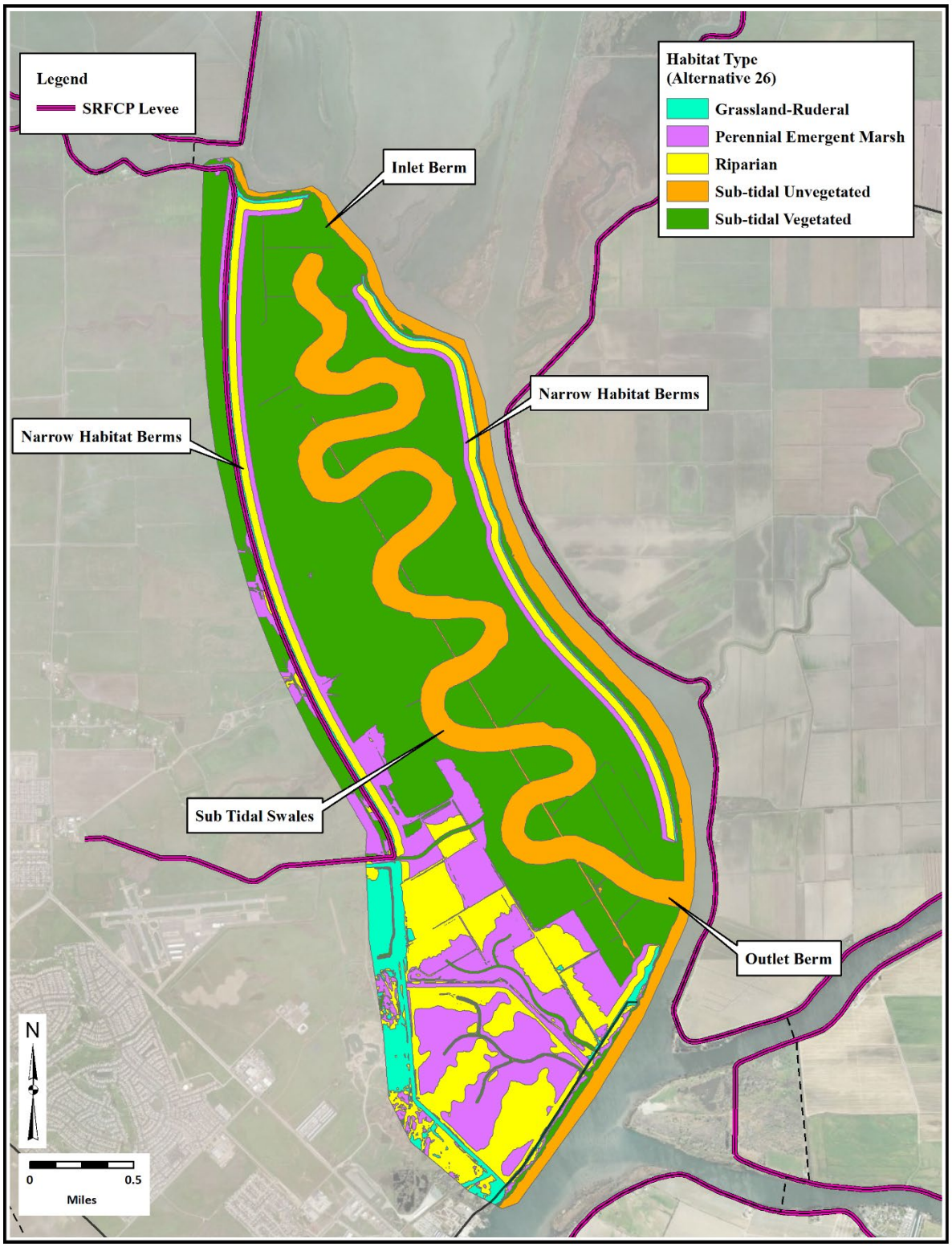


Figure 10. Alternative 26 Habitat Restoration Features

RD 2084 Restricted Height Levee Performance Assumptions

RD 2084 maintains a restricted height levee along the right bank of Cache Slough that is restricted in elevation by deed restrictions enacted when flowage easements were purchased by the State of California. The levee elevation restriction is 15.3 ft. at the north end of RD 2084 and 10.3 ft. at the south end. This levee elevation restriction allows for the levee to overtop during periods of high flows in the Yolo Bypass, allowing for flood waters to convey across a 7500 ft. floodway versus 1000 ft. prior to overtopping (Figure 11).

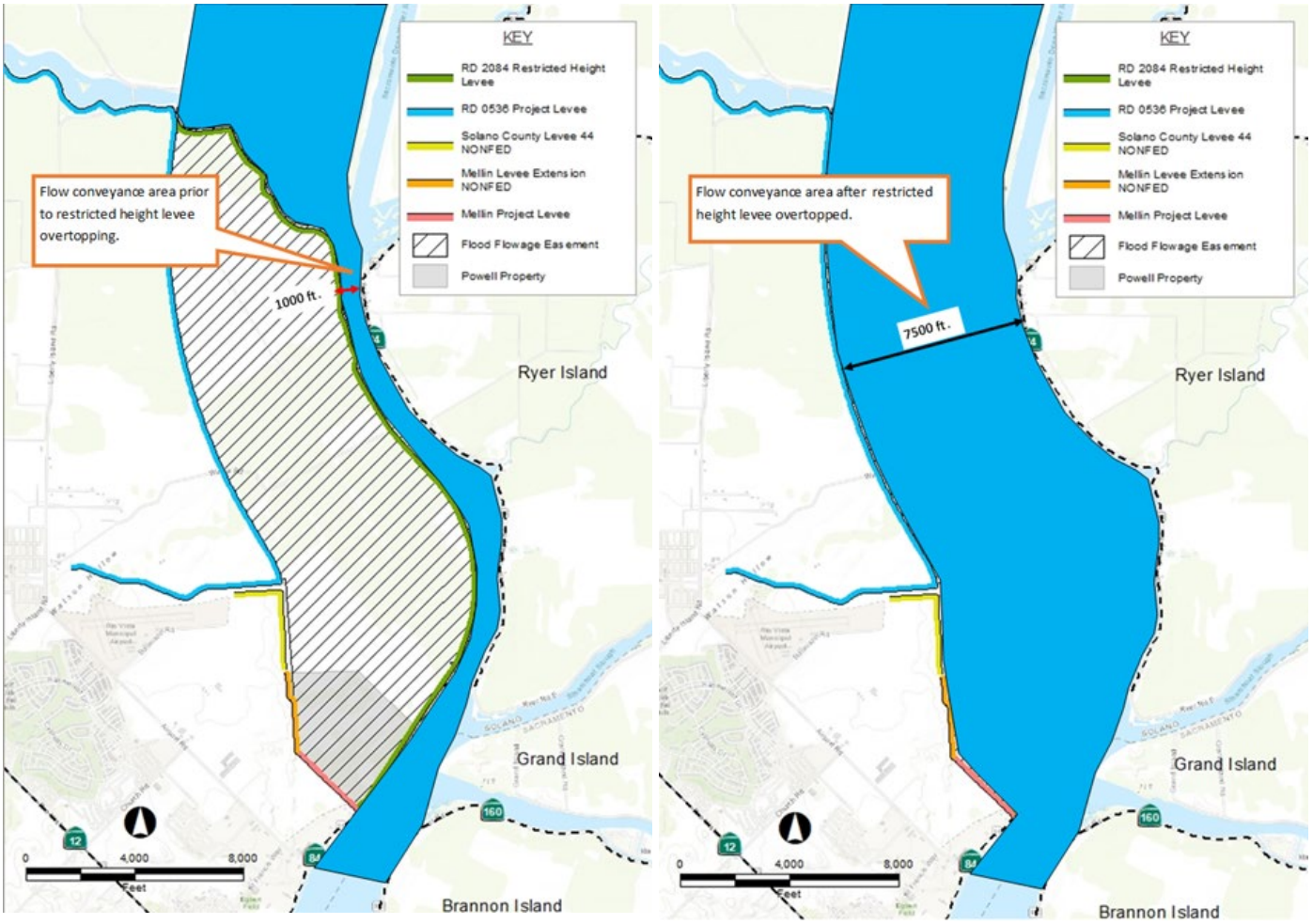


Figure 11. Yolo Bypass Flow Conveyance Area

Following the construction of Oroville Dam (in 1968) and New Bullards Dam (in 1970) the restricted height levee has been overtopped twice – in February 1986 and January 1997. Flood waters overtopping the restricted height levee caused the levee to breach and degrade at the north end of LET and enter the tract; then, at the south end when LET fills with flood water, the flood water overtops the restricted height levee and spills back into Cache Slough. Figure 12 shows the locations of levee breaches from the February 1986 and January 1997 flood.

The levee performance of the restricted height levee in the hydraulic model simulations will affect water surface elevations upstream and downstream of Little Egbert Tract.

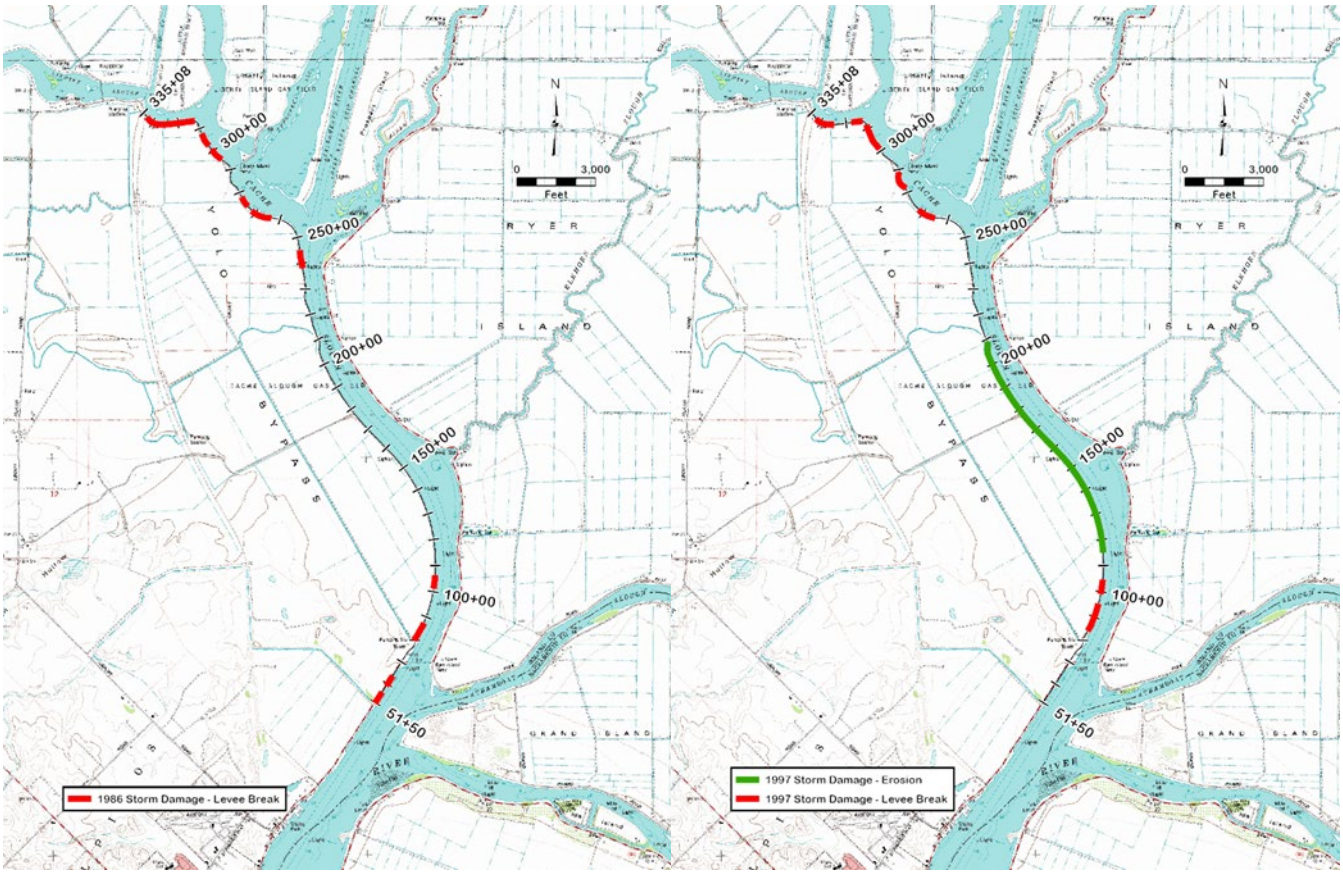


Figure 12. Restricted Height Levee Historic Breach Locations

Future Without Project Condition Simulations

For the FWOP simulation, two different levee performance assumptions were assumed. The two FWOP simulations are described below:

1. (FWOP1) - The RD 2084 restricted height Cache Slough levee is assumed to breach when overtopped, like what occurred during the 1997 flood event.
2. (FWOP2) - The restricted height levee is degraded to landside levee toe elevation along the entire length of the restricted height levee.

The four alternatives will be compared relative to each of the two FWOP simulations to measure hydraulic benefits/impacts.

Alternatives Simulations

In the alternative simulations, the restricted height levee (outside of where it is degraded for the inlet and outlet berm) will be strengthened and buttressed by a habitat berm. Due to this strengthening, the RD 2084 restricted height levee is assumed to act as a weir (i.e., overtop without failure) in the model simulations for all alternatives.

Hydraulic Model Simulations

The two FWOP conditions and four alternatives were simulated with the following flood events:

1. The 10-Year flood event Sacramento River at Verona Centering
2. The 200-Year flood event Sacramento River at Verona Centering

The 10-Year flood event was selected as the flood event did not overtop the RD 2084 restricted height Cache Slough levee under the FWOP.

The peak flows at the upstream end of the hydraulic model are tabulated Table 4:

Table 4. Peak Flow (cfs)

Flood Frequency (Annual Exceedance Probability)	Yolo Bypass below I-80	Sacramento River at Freeport
10-Year	295,400	93,400
200-Year	557,000	105,600

The hydrologic inputs to the LET model were obtained from a larger Sacramento River Flood Control Project (SRFCP) HEC-RAS model of the FWOP condition, developed by MBK in support of the Central Valley Flood Protection Board Yolo Bypass/Cache Slough Programmatic 408 Hydraulic Analysis.

The downstream boundaries for the hydraulic model are at three locations: 1) Sacramento River at Collinsville, 2) Three Mile Slough at San Joaquin River, and 3) Georgianna Slough at Mokelumne River. A stage hydrograph for the 10-Year and 200-Year CVHS pattern and scaling were developed by DWR (DWR, 2018). The peak stage at each of the locations are tabulated in Table 5. These downstream boundary conditions do not include any sea-level rise projection.

Table 5. Peak Stage (ft-NAVD88) at Downstream Boundary Condition

Flood Frequency (Annual Exceedance Probability)	Sacramento River at Collinsville	Three Mile Slough at San Joaquin River	Georgianna Slough at Mokelumne River
10-Year	8.6	8.7	8.8
200-Year	9.5	9.8	10.1

Summary of Results

Following is a summary of the hydraulic performance at some key locations:

10-Year Flood Performance in Comparison with FWOP1:

- Yolo Bypass at Lisbon (Index Point (IP) 8) – No significant reductions in stage for all alternatives.
- Yolo Bypass at Liberty Island (IP6) – Reductions in stage varies from 0.4 ft. to 0.6 ft.; with no significant difference between all four alternatives.
- Yolo Bypass near Upper Cache Slough (IP5) – Reductions in stage varies from 0.6 ft. to 1.1 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. NAVD88 having the greatest reduction in stage at this location.
- Yolo Bypass at Lindsey Slough (IP 4) – Reductions in stage varies from 0.8 ft. to 1.4 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. NAVD88 having the greatest reduction in stage at this location.
- Cache Slough above Ryer Island Ferry (IP 3) – Increases in stage varies from 0.7 ft. to 1.1 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. NAVD88 having the greatest increase in stage at this location.
- Sacramento River at Rio Vista (IP1)– No significant increases in stage for all alternatives.

200-Year Flood Performance in Comparison with FWOP1:

- Yolo Bypass at Lisbon – No significant reductions in stage for all alternatives.
- Yolo Bypass at Liberty Island – Increases in stage varies from 0.1 ft. to 0.2 ft.; with no significant difference between all four alternatives.
- Yolo Bypass near Upper Cache Slough – Increases in stage varies from 0.1 ft. to 0.3 ft., with no significant difference between all four alternatives.
- Yolo Bypass at Lindsey Slough – Increase in stage varies from 0.2 ft. to 0.5 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. NAVD88 having the smallest increase in stage at this location.
- Cache Slough above Ryer Island Ferry – Increases in stage varies from 0.4 ft. to 0.5 ft., with no significant difference between all four alternatives.
- Sacramento River at Rio Vista – No significant increases in stage for all alternatives.

Figure 13 is map showing a summary of the hydraulic performance for the 10-Year and 200-Year flood event.

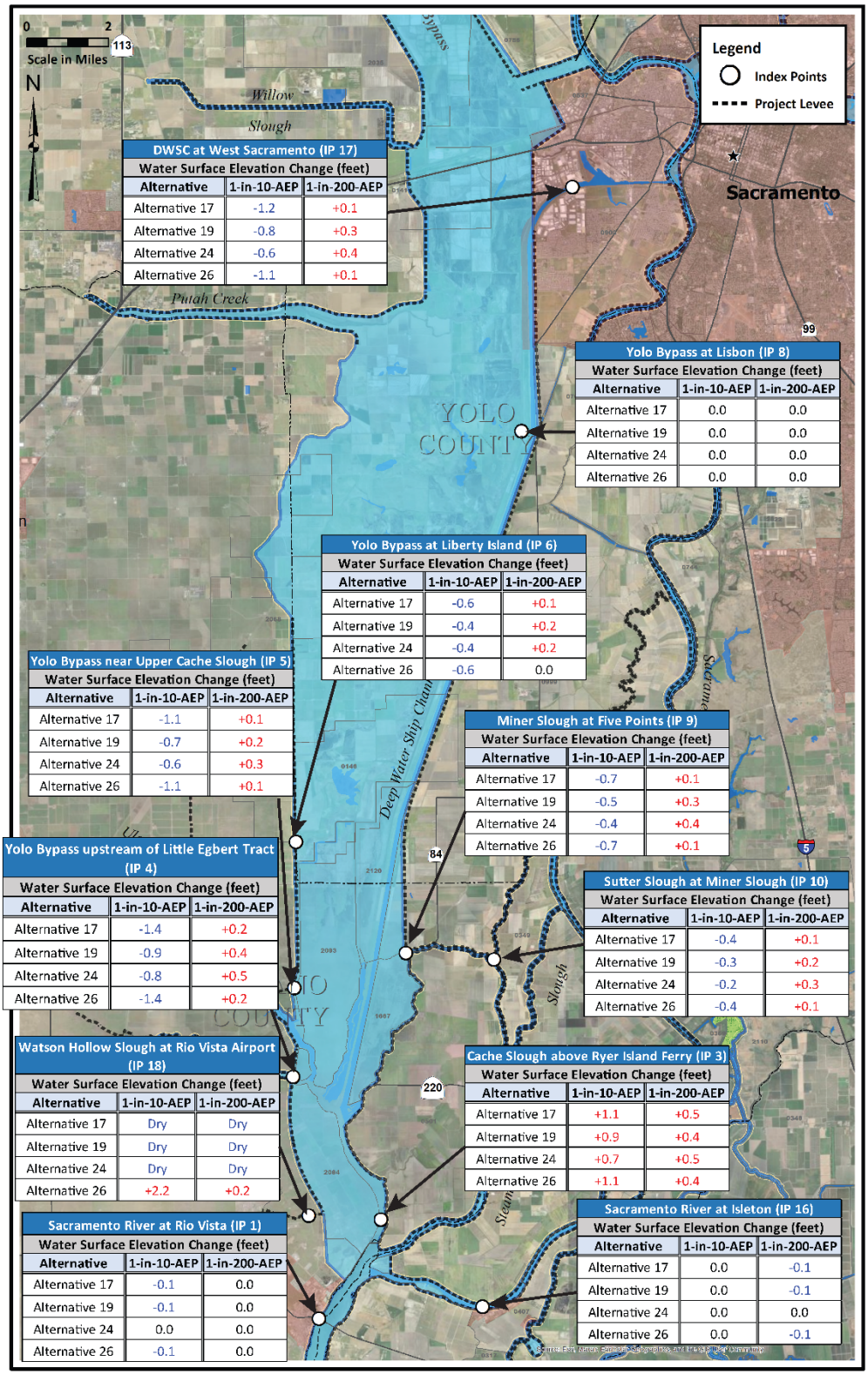


Figure 13. Impacts of Alternatives at Index Points Compared against FWOP1 (with RHL Breaches)

10-Year Flood Performance in Comparison with FWOP2:

- Yolo Bypass at Lisbon – No significant reductions in stage for all alternatives.
- Yolo Bypass at Liberty Island – Increases in stage varies from 0.1 ft. to 0.4 ft.; with no significant difference between all four alternatives.
- Yolo Bypass near Upper Cache Slough – Increases in stage varies from 0.3 ft. to 0.7 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. having the smallest increase in stage at this location.
- Yolo Bypass at Lindsey Slough – Increase in stage varies from 0.5 ft. to 1.1 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. having the smallest increase in stage at this location.
- Cache Slough above Ryer Island Ferry – Increases in stage of 0.2 for Alternative 17 and 26 and reductions in stage between 0 and 0.2 for Alternative 19 and 24.
- Sacramento River at Rio Vista – No significant increases in stage for all alternatives.

200-Year Flood Performance in Comparison with FWOP2:

- Yolo Bypass at Lisbon – No significant reductions in stage for all alternatives.
- Yolo Bypass at Liberty Island – Increases in stage varies from 0.3 ft. to 0.4 ft.; with no significant difference between all four alternatives.
- Yolo Bypass near Upper Cache Slough – Increases in stage varies from 0.4 ft. to 0.7 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. NAVD88 having the smallest increase in stage at this location.
- Yolo Bypass at Lindsey Slough – Increase in stage varies from 0.7 ft. to 1.0 ft., with Alternative 17 and 26 which have an inlet berm at elevation -4.0 ft. NAVD88 having the smallest increase in stage at this location.
- Cache Slough above Ryer Island Ferry – Increases in stage of 0.3 for all four alternatives.
- Sacramento River at Rio Vista – No significant increases in stage for all alternatives.

Figure 14 shows a summary of the hydraulic performance for the 10-Year and 200-Year flood events.

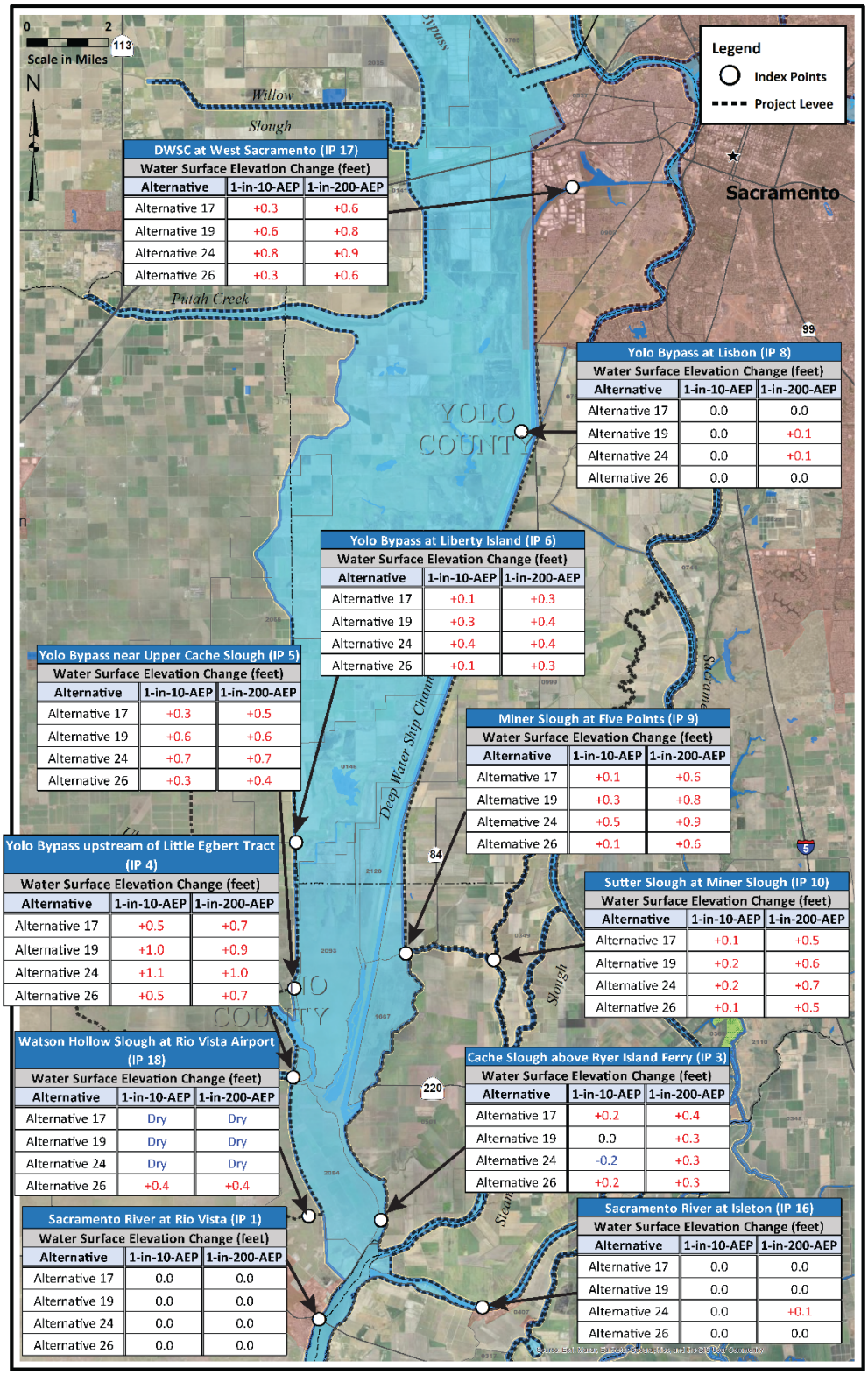


Figure 14. Impacts of Alternatives at Index Points Compared against FWOP2 (with RHL Degraded)

Full Results

The computed change in maximum water surface elevation at eighteen index points throughout the system are provided Table 6,7,8 and 9 for each of the two FWOP conditions and for the 10-Year and 200-Year flood events The difference in maximum water surface elevation was calculated by subtracting the FWOP water surface elevation from the alternative water surface elevation and represents the impact of the alternative on the maximum water surface elevation. The location of the eighteen index points is shown in Figure 15.

Maps showing spatial difference in the change in maximum water surface elevation when compared to the two FWOP conditions are shown in Figure 16 and Figure 18 for the 10-Year flood event, and Figure 17 and Figure 19 for the 200-Year flood event. Areas shown in yellow and red color schemes represent areas where there is an increase in water surface elevation due to the alternative and areas in greens and blue are where there is a decrease in water surface elevation due to the alternative.

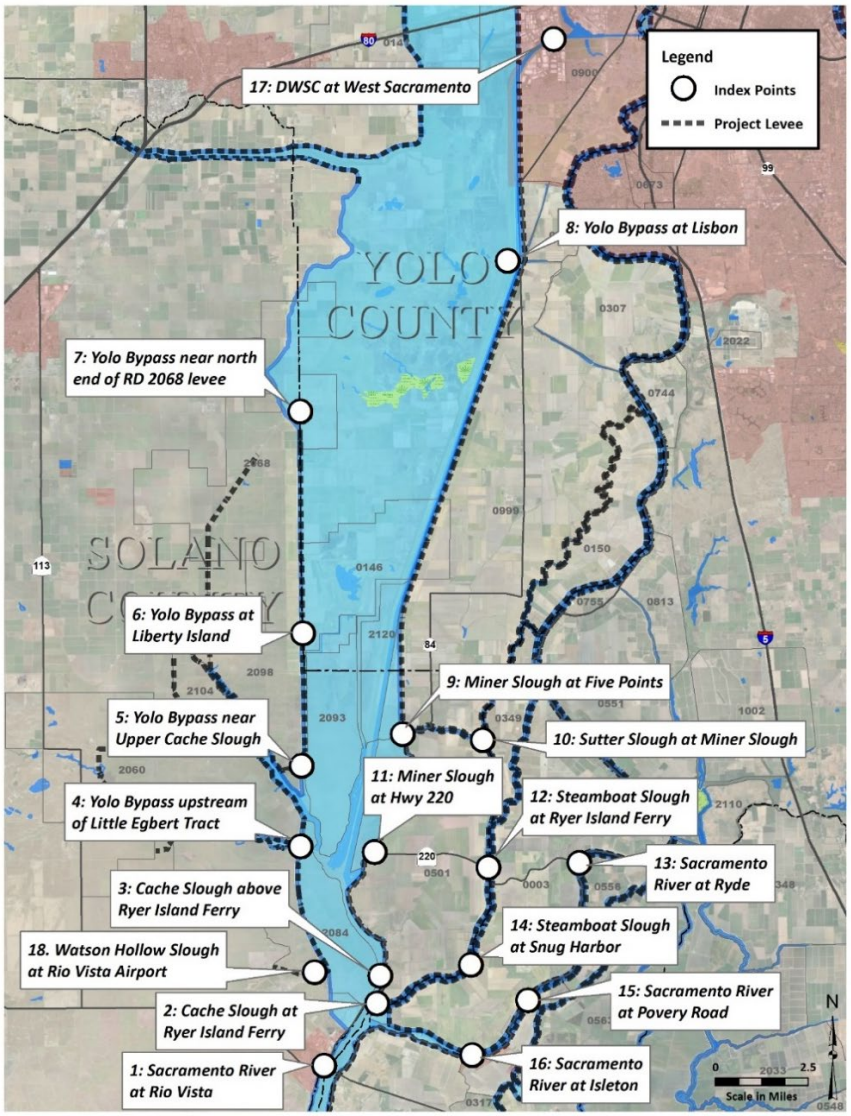


Figure 15. Evaluation Index Points

Table 6. Change in Max. Water Surface Elevation at Index Points, 10-Year Flood. FWOP1 (with Breaches)

Location	Change in Maximum Water Surface Elevation (feet)			
	Alt. 17 minus Future Without Project	Alt. 19 minus Future Without Project	Alt. 24 minus Future Without Project	Alt. 26 minus Future Without Project
1. Sacramento River at Rio Vista	-0.1	-0.1	0.0	-0.1
2. Cache Slough at Ryer Island Ferry	0.0	0.0	0.0	0.0
3. Cache Slough above Ryer Island Ferry	1.1	0.9	0.7	1.1
4. Yolo Bypass upstream of Little Egbert Tract	-1.4	-0.9	-0.8	-1.4
5. Yolo Bypass near Upper Cache Slough	-1.1	-0.7	-0.6	-1.1
6. Yolo Bypass at Liberty Island	-0.6	-0.4	-0.4	-0.6
7. Yolo Bypass near north end of RD 2068 levee	-0.1	0.0	0.0	-0.1
8. Yolo Bypass at Lisbon	0.0	0.0	0.0	0.0
9. Miner Slough at Five Points	-0.7	-0.5	-0.4	-0.7
10. Sutter Slough at Miner Slough	-0.4	-0.3	-0.2	-0.4
11. Miner Slough at Hwy 220	-0.9	-0.6	-0.5	-0.9
12. Steamboat Slough at Ryer Island Ferry	-0.1	-0.1	0.0	-0.1
13. Sacramento River at Ryde	0.0	0.0	0.0	0.0
14. Steamboat Slough at Snug Harbor	0.0	0.0	0.0	0.0
15. Sacramento River at Poverty Road	0.0	0.0	0.0	0.0
16. Sacramento River at Isleton	0.0	0.0	0.0	0.0
17. DWSC at West Sacramento	-1.2	-0.8	-0.6	-1.1
18. Watson Hollow Slough at Rio Vista Airport	Dry	Dry	Dry	2.2

Table 7. Change in Max. Water Surface Elevation at Index Points, 200-Year Flood. FWOP1 (with Breaches)

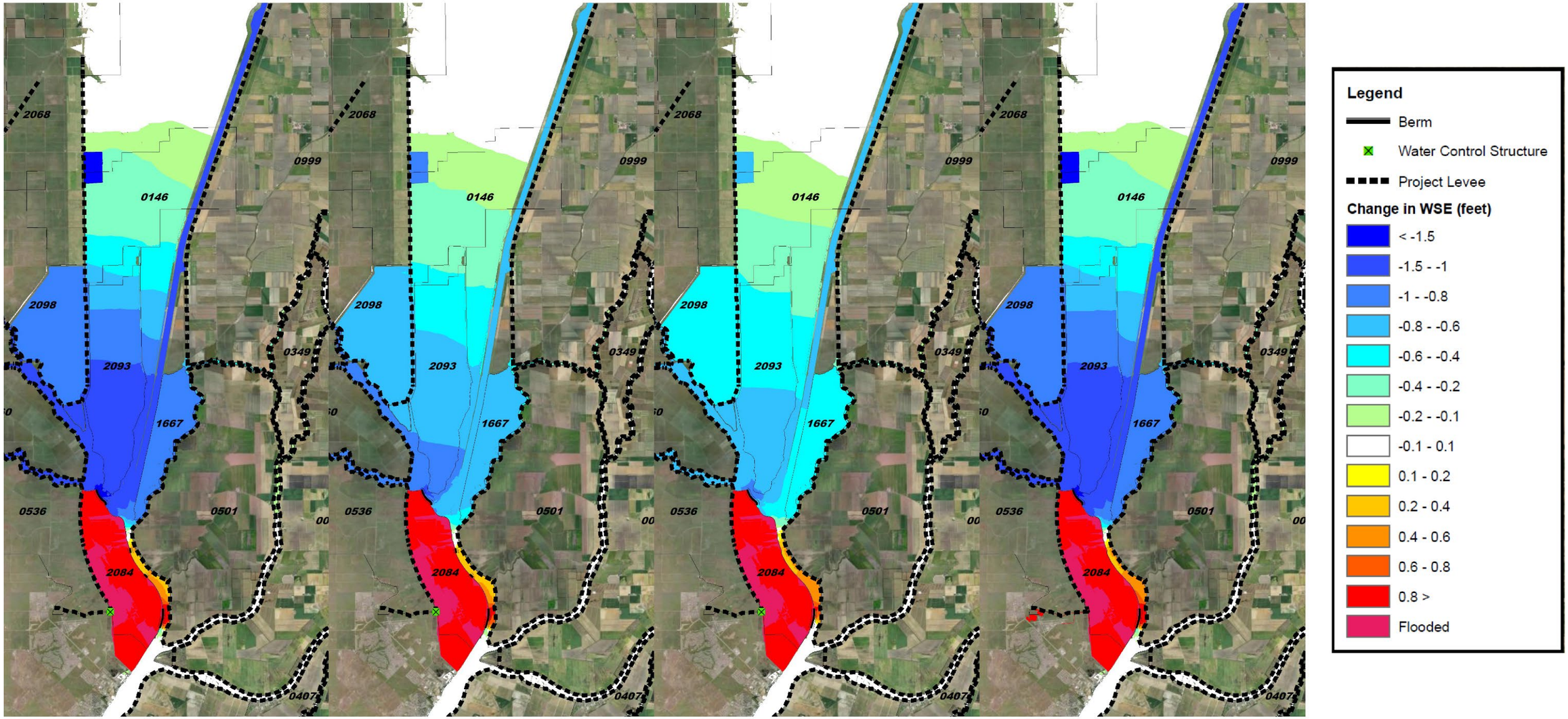
Location	Change in Maximum Water Surface Elevation (feet)			
	Alt. 17 minus Future Without Project	Alt. 19 minus Future Without Project	Alt. 24 minus Future Without Project	Alt. 26 minus Future Without Project
1. Sacramento River at Rio Vista	0.0	0.0	0.0	0.0
2. Cache Slough at Ryer Island Ferry	-0.1	-0.1	0.0	-0.1
3. Cache Slough above Ryer Island Ferry	0.5	0.4	0.4	0.4
4. Yolo Bypass upstream of Little Egbert Tract	0.2	0.4	0.5	0.2
5. Yolo Bypass near Upper Cache Slough	0.1	0.2	0.3	0.1
6. Yolo Bypass at Liberty Island	0.1	0.1	0.2	0.0
7. Yolo Bypass near north end of RD 2068 levee	0.0	0.0	0.1	0.0
8. Yolo Bypass at Lisbon	0.0	0.0	0.0	0.0
9. Miner Slough at Five Points	0.1	0.3	0.4	0.1
10. Sutter Slough at Miner Slough	0.1	0.2	0.3	0.1
11. Miner Slough at Hwy 220	0.1	0.3	0.4	0.1
12. Steamboat Slough at Ryer Island Ferry	0.0	0.0	0.1	0.0
13. Sacramento River at Ryde	0.0	0.0	0.0	0.0
14. Steamboat Slough at Snug Harbor	0.0	0.0	0.1	0.0
15. Sacramento River at Poverty Road	-0.1	0.0	0.0	-0.1
16. Sacramento River at Isleton	-0.1	-0.1	0.0	-0.1
17. DWSC at West Sacramento	0.1	0.3	0.4	0.1
18. Watson Hollow Slough at Rio Vista Airport	Dry	Dry	Dry	0.2

Table 8. Change in Max. Water Surface Elevation at Index Points, 10-Year Flood. FWOP2 (with RHL Degraded)

Location	Change in Maximum Water Surface Elevation (feet)			
	Alt. 17 minus Future Without Project	Alt. 19 minus Future Without Project	Alt. 24 minus Future Without Project	Alt. 26 minus Future Without Project
1. Sacramento River at Rio Vista	0.0	0.0	0.0	0.0
2. Cache Slough at Ryer Island Ferry	0.0	0.0	0.0	0.0
3. Cache Slough above Ryer Island Ferry	0.2	0.0	-0.2	0.2
4. Yolo Bypass upstream of Little Egbert Tract	0.5	1.0	1.1	0.5
5. Yolo Bypass near Upper Cache Slough	0.3	0.6	0.7	0.3
6. Yolo Bypass at Liberty Island	0.1	0.3	0.4	0.1
7. Yolo Bypass near north end of RD 2068 levee	0.0	0.0	0.0	0.0
8. Yolo Bypass at Lisbon	0.0	0.0	0.0	0.0
9. Miner Slough at Five Points	0.1	0.3	0.5	0.1
10. Sutter Slough at Miner Slough	0.1	0.2	0.2	0.1
11. Miner Slough at Hwy 220	0.2	0.4	0.6	0.2
12. Steamboat Slough at Ryer Island Ferry	0.0	0.0	0.1	0.0
13. Sacramento River at Ryde	0.0	0.0	0.0	0.0
14. Steamboat Slough at Snug Harbor	0.0	0.0	0.0	0.0
15. Sacramento River at Poverty Road	0.0	0.0	0.0	0.0
16. Sacramento River at Isleton	0.0	0.0	0.0	0.0
17. DWSC at West Sacramento	0.3	0.6	0.8	0.3
18. Watson Hollow Slough at Rio Vista Airport	Dry	Dry	Dry	0.4

Table 9. Change in Max. Water Surface Elevation at Index Points, 200-Year Flood. FWOP2 (with RHL Degraded)

Location	Change in Maximum Water Surface Elevation (feet)			
	Alt. 17 minus Future Without Project	**Alt. 19 minus Future Without Project**	**Alt. 24 minus Future Without Project**	**Alt. 26 minus Future Without Project**
1. Sacramento River at Rio Vista	0.0	0.0	0.0	0.0
2. Cache Slough at Ryer Island Ferry	0.0	0.0	0.1	0.0
3. Cache Slough above Ryer Island Ferry	0.3	0.3	0.3	0.3
4. Yolo Bypass upstream of Little Egbert Tract	0.7	0.9	1.0	0.7
5. Yolo Bypass near Upper Cache Slough	0.4	0.6	0.7	0.4
6. Yolo Bypass at Liberty Island	0.3	0.4	0.4	0.3
7. Yolo Bypass near north end of RD 2068 levee	0.1	0.1	0.1	0.1
8. Yolo Bypass at Lisbon	0.0	0.1	0.1	0.0
9. Miner Slough at Five Points	0.6	0.8	0.9	0.6
10. Sutter Slough at Miner Slough	0.5	0.6	0.7	0.5
11. Miner Slough at Hwy 220	0.6	0.8	0.8	0.6
12. Steamboat Slough at Ryer Island Ferry	0.2	0.2	0.3	0.2
13. Sacramento River at Ryde	0.1	0.1	0.1	0.1
14. Steamboat Slough at Snug Harbor	0.1	0.1	0.2	0.1
15. Sacramento River at Poverty Road	0.0	0.0	0.1	0.0
16. Sacramento River at Isleton	0.0	0.0	0.1	0.0
17. DWSC at West Sacramento	0.6	0.8	0.9	0.6
18. Watson Hollow Slough at Rio Vista Airport	Dry	Dry	Dry	0.4



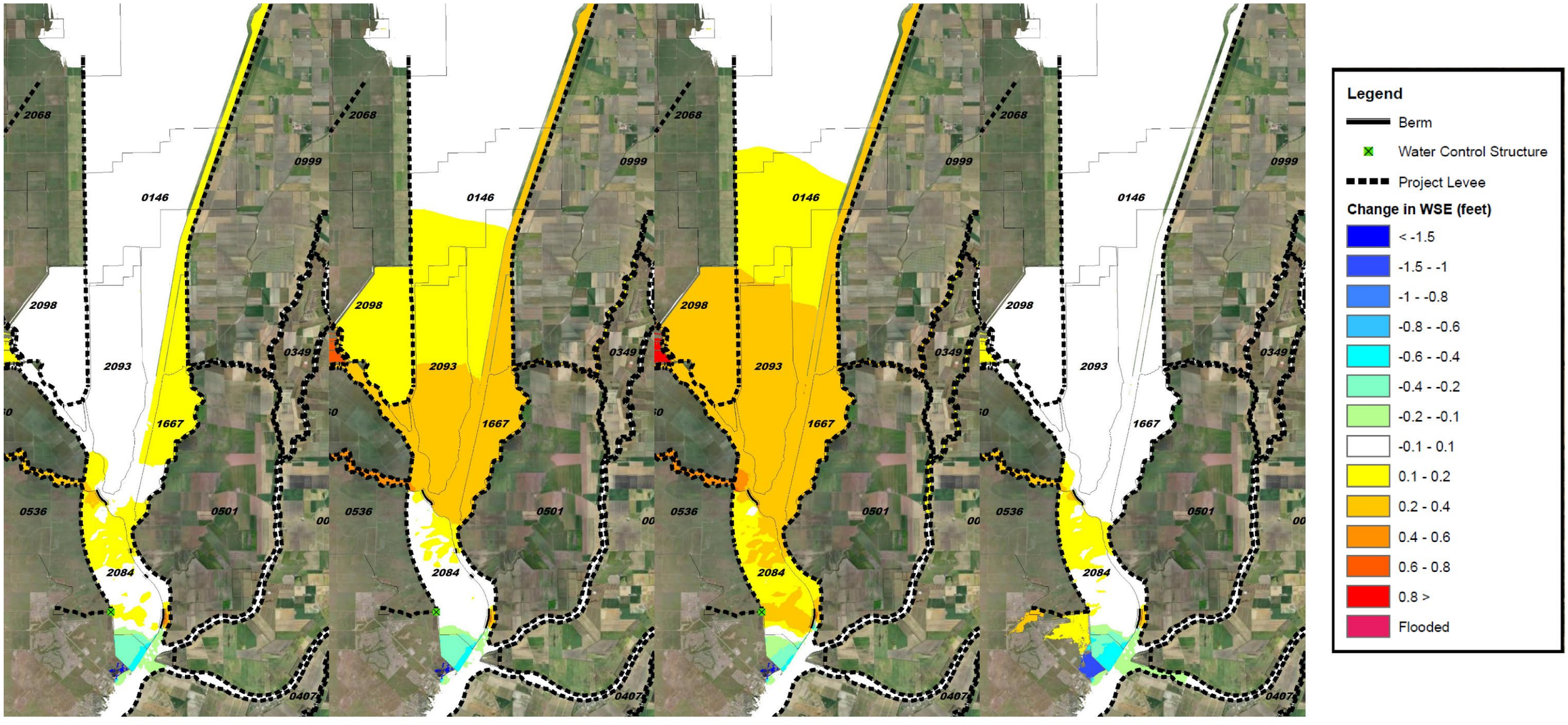
Alternative 17 minus FWOP (RHL Breaches)
WSE Difference – 10-Year

Alternative 19 minus FWOP (RHL Breaches)
WSE Difference – 10-Year

Alternative 24 minus FWOP (RHL Breaches)
WSE Difference – 10-Year

Alternative 26 minus FWOP (RHL Breaches)
WSE Difference – 10-Year

Figure 16. Change in Water Surface Elevations between Alternatives and FWOP1 (with Breaches), 10-Year Flood Event



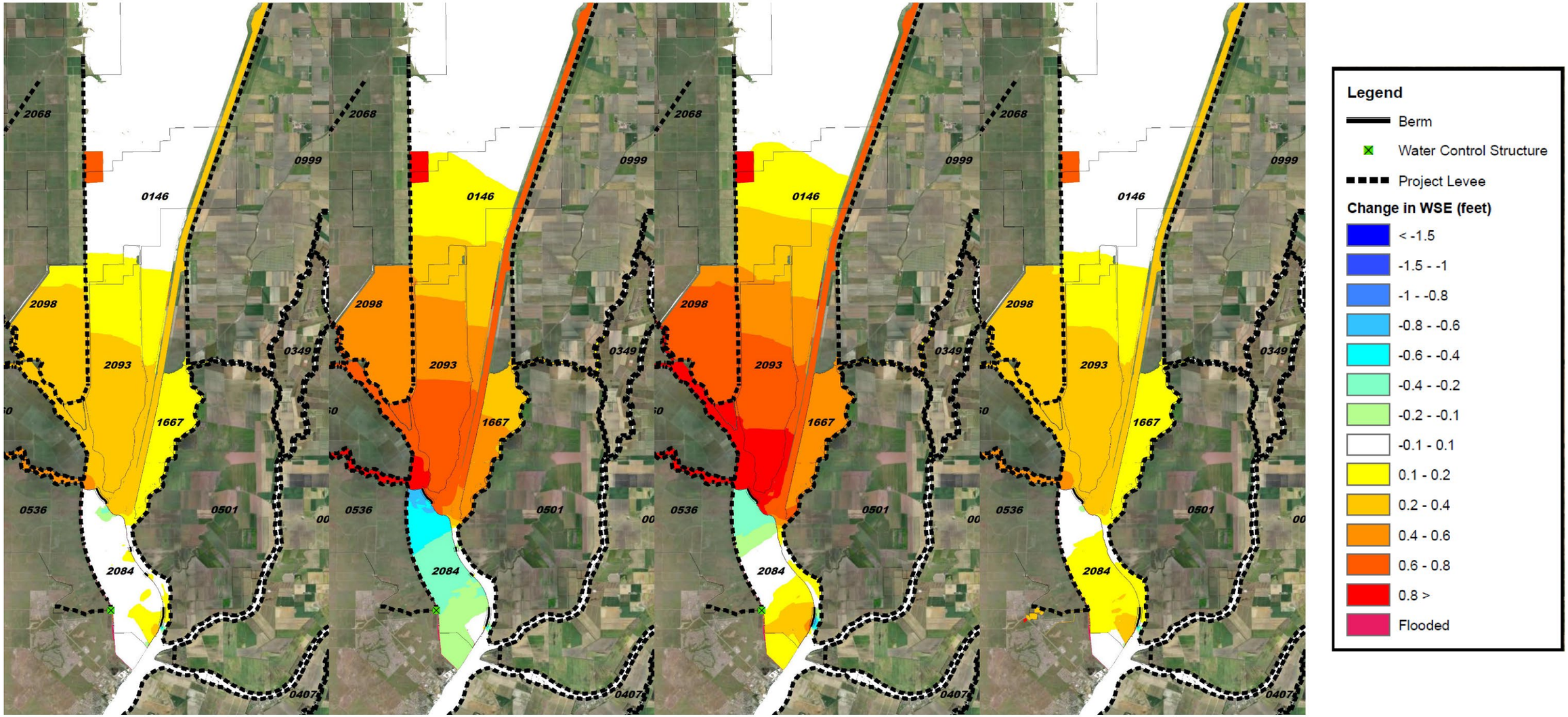
Alternative 17 minus FWOP (RHL Breaches)
WSE Difference – 200-Year

Alternative 19 minus FWOP (RHL Breaches)
WSE Difference – 200-Year

Alternative 24 minus FWOP (RHL Breaches)
WSE Difference – 200-Year

Alternative 26 minus FWOP (RHL Breaches)
WSE Difference – 200-Year

Figure 17. Change in Water Surface Elevations between Alternatives and FWOP1 (with Breaches), 200-Year Flood Event



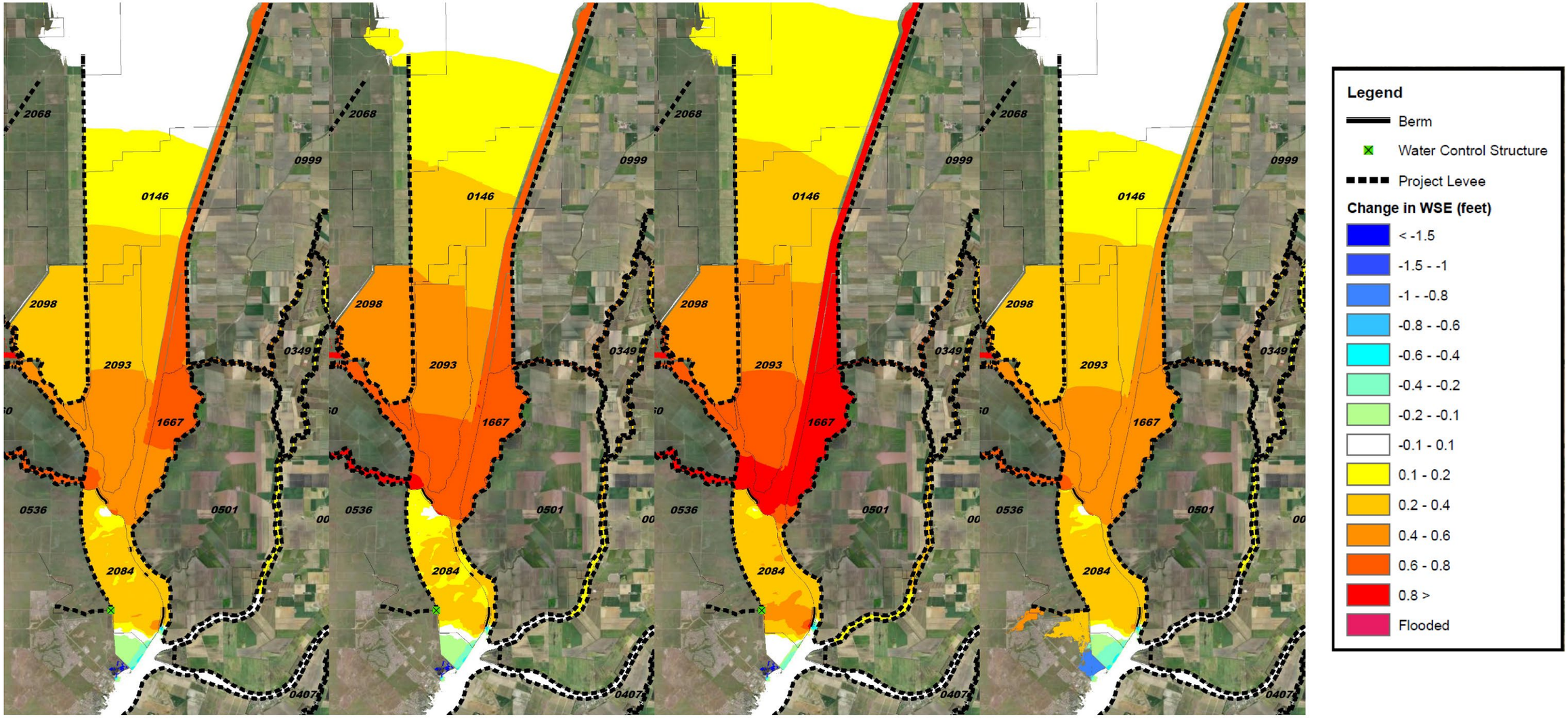
Alternative 17 minus FWOP (RHL Degraded)
WSE Difference – 10-Year

Alternative 19 minus FWOP (RHL Degraded)
WSE Difference – 10-Year

Alternative 24 minus FWOP (RHL Degraded)
WSE Difference – 10-Year

Alternative 26 minus FWOP (RHL Degraded)
WSE Difference – 10-Year

Figure 18. Change in Water Surface Elevations between Alternatives and FWOP2 (with RHL Degraded), 10-Year Flood Event



Alternative 17 minus FWOP (RHL Degraded) WSE Difference – 200-Year

Alternative 19 minus FWOP (RHL Degraded) WSE Difference – 200-Year

Alternative 24 minus FWOP (RHL Degraded) WSE Difference – 200-Year

Alternative 26 FWOP (RHL Degraded) WSE Difference – 200-Year

Figure 19. Change in Water Surface Elevations between Alternatives and FWOP2 (with RHL Degraded), 200-Year Flood Event

Discussion of Alternative Analysis

Berm Elevation and Frequency of Flow Conveyance

Figure 20 is an exceedance plot of water surface elevation at the north end of LET based on estimates of stage using 37 years of record (1983 to 2020) from the Yolo Bypass at Lisbon gage (B91560). This plot could be used to estimate the frequency the inlet berm would be overtopped for various elevations. The elevation at the restricted height levee at the north end LET is approximately 15 ft.; this elevation has a probability of exceeding in any year of approximately 8% (Figure 20). Lowering the restricted height levee would increase the frequency by which the Yolo Bypass flows through LET and utilize the 7500-foot conveyance flow area. Alternatives 17 and 26 have an inlet berm elevation of -4.0 ft.; at this elevation LET would convey flood waters in 100% of the years, an increase of 92% percent. For Alternatives 19 and 24, the inlet berm elevation is set at 7.5 ft., the probability of LET conveying flood flows is 67%, an increase of 59% over existing condition.

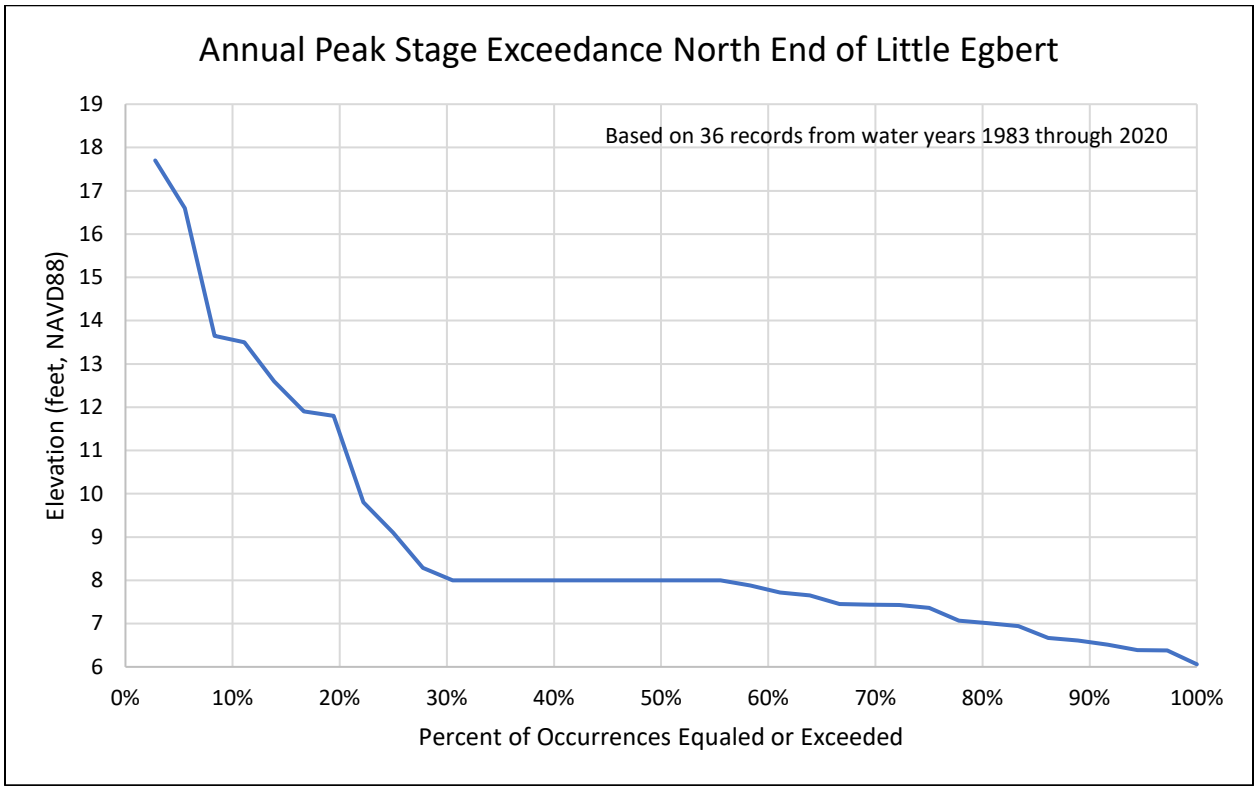


Figure 20. Probability of Exceedance at North End of LET

Hydraulic Performance Affected by Restricted Height Levee Performance Assumption

The magnitude of Yolo Bypass flows entering LET and utilizing the 7500 ft. flow conveyance is governed by the length and elevation of the inlet berm. Larger inlet berm areas will allow more flood waters to convey through LET; thereby reducing water surface elevations upstream of LET.

The increase in water surface elevation upstream of LET for the 200-Year flood event is attributed to the change in inlet berm area between the alternatives and each of the FWOP restricted height levee

performance assumption. Figure 21 is a plot of the profile of the restricted height levee for the FWOP1, FWOP2, and all four alternatives. The area of the inlet berm was calculated for FWOP1 and all alternatives and tabulated in Figure 21.

For the FWOP1 simulations, the breaches are based on breaches that occurred during the January 1997 flood. The location of the breach, length, and depth are based on visual estimates from a damage assessment field review following the flood event. Figure 21 shows the three levee breaches simulated in the FWOP1 model simulation, which has a total flow area of 42,000 square feet (sf).

For the FWOP2 simulations, the restricted height levee was assumed to degrade down to approximately the landside levee toe elevation approximately -2 to -4 ft. The flow area was not calculated as spatially over the of length restricted height levee, the location where water may enter or exits LET changes with flow conditions. Nonetheless, Figure 21 shows that a degraded restricted height levee has significantly greater flow area than any of the alternatives.

With Alternative 17 and 26, the inlet berm flow area is approximately 45,000 sf. This area is approximately the same as the FWOP1 breach area of 42,000 sf. Given that the flow areas are approximately the same, it would be expected that the water surface elevations upstream of LET for the 200-Year flood event would be approximately the same under the alternative and FWOP1 condition. Figure 17 and Table 7 show there is very little change in the 200-Year maximum water surface elevations in the Yolo Bypass upstream of LET.

The inlet berm flow area for Alternative 19 and 24 is approximately 17,000 sf. This is a reduction of approximately 60% in flow area from the FWOP1 condition. A reduction of inlet berm flow area would allow less flow to enter LET versus the FWOP1 condition. For the 200-Year flood, Alternatives 19 and 24, show increases in water surface elevation on the order of 0.3 ft. upstream of LET and propagate to the Deep-Water Ship Channel at West Sacramento (IP17) and Miner Slough (IP9 and 10), see Table 7.

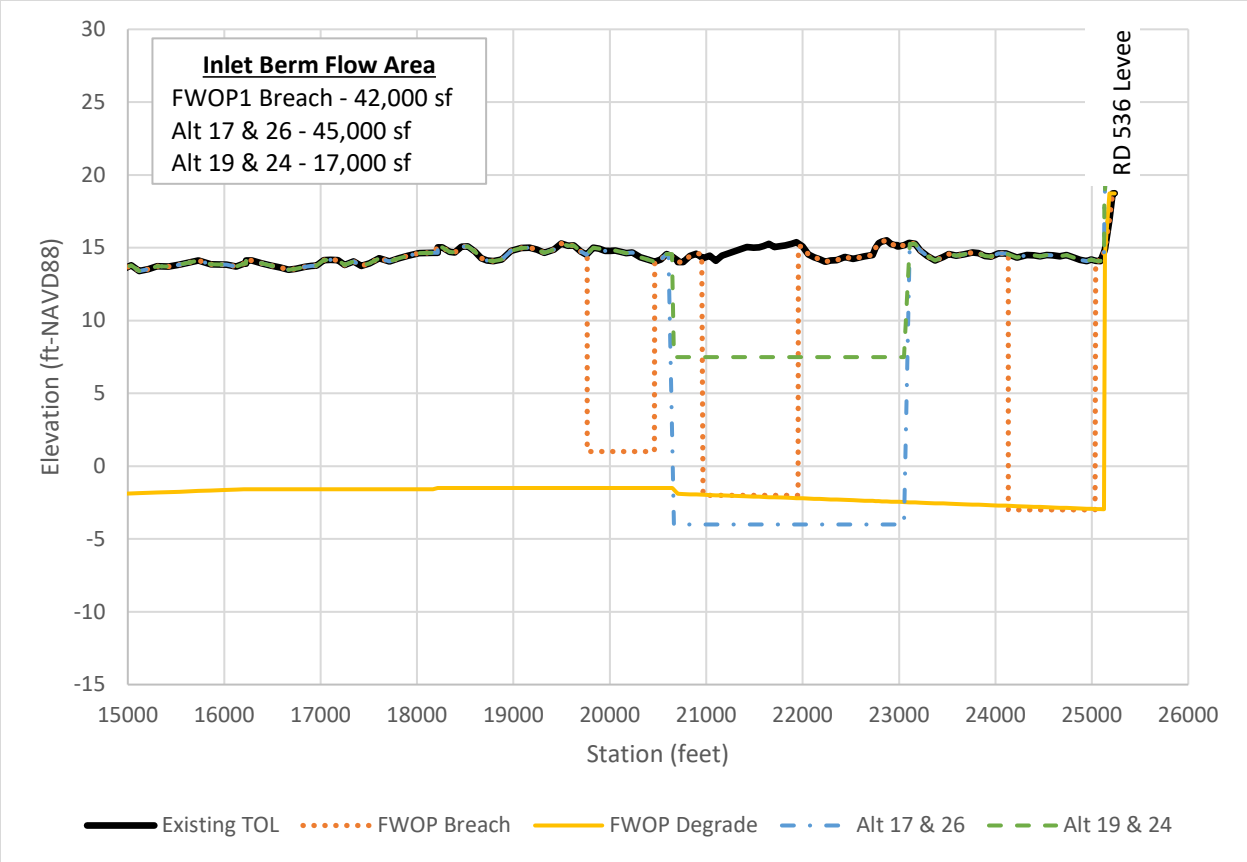


Figure 21. Inlet Berm Profile

As flood waters enter LET and begin to fill and convey through LET, the flood waters will re-join Cache Slough/Sacramento River. The height of the restricted height levee and the Highway 84 embankment are hydraulic controls governing how much flow re-enters. Hydraulically, flood waters seek its lowest energy, which on LET is the lowest elevation of the tract which is approximately 1500 ft. upstream of the Ryer Island Ferry. In January 1997, this is the location where the restricted height levee overtopped and breached, allowing flood waters from LET to re-join back into Cache Slough. Flood waters from LET reentering at Cache Slough will slow down velocities in Cache Slough thereby having the potential to increase water surface elevation. The index point at Cache Slough above Ryer Island Ferry (IP3) is an indicator of the effects of the outlet berm.

The increase in water surface elevation along Cache Slough for both the 10-Year and 200-Year flood event is attributed to the change in breach area for the FWOP1, and alternative simulations. Figure 22 shows the profile of the outlet weir for the FWOP1, FWOP2, and four alternatives with the respective conveyance area.

For the 10-Year flood event, the increase in maximum water surface elevation at IP3 is 1.1,0.9,0.7 and 1.1 ft. for Alt. 17,19,24 and 26, respectively. For the 10-Year simulation under the FWOP1 condition, since the restricted height levee did not overtop, there was no flow from LET re-entering Cache Slough from LET. With the alternatives, the flow area increases from zero to 52,000 sf, 51,000 sf, 16,000 sf and 47,000 sf (See Figure 22) for Alternative 17,19,24 and 26, respectively. Alternative 24 has the smallest

increase in outlet berm area due to a compound elevation configuration, therefore, has the least increase in stage (0.7 ft) at the IP3 for the 10-Year flood.

For the 200-Year flood event, the increase at IP3 is 0.5,0.4,0.4 and 0.4 for Alt. 17,19,24 and 26, respectively. The impacts at this index point are not significantly different as overtopping of the restricted height levee and Highway 84 embankment occurs, allowing for a much greater total flow area in comparison to the outlet berm.

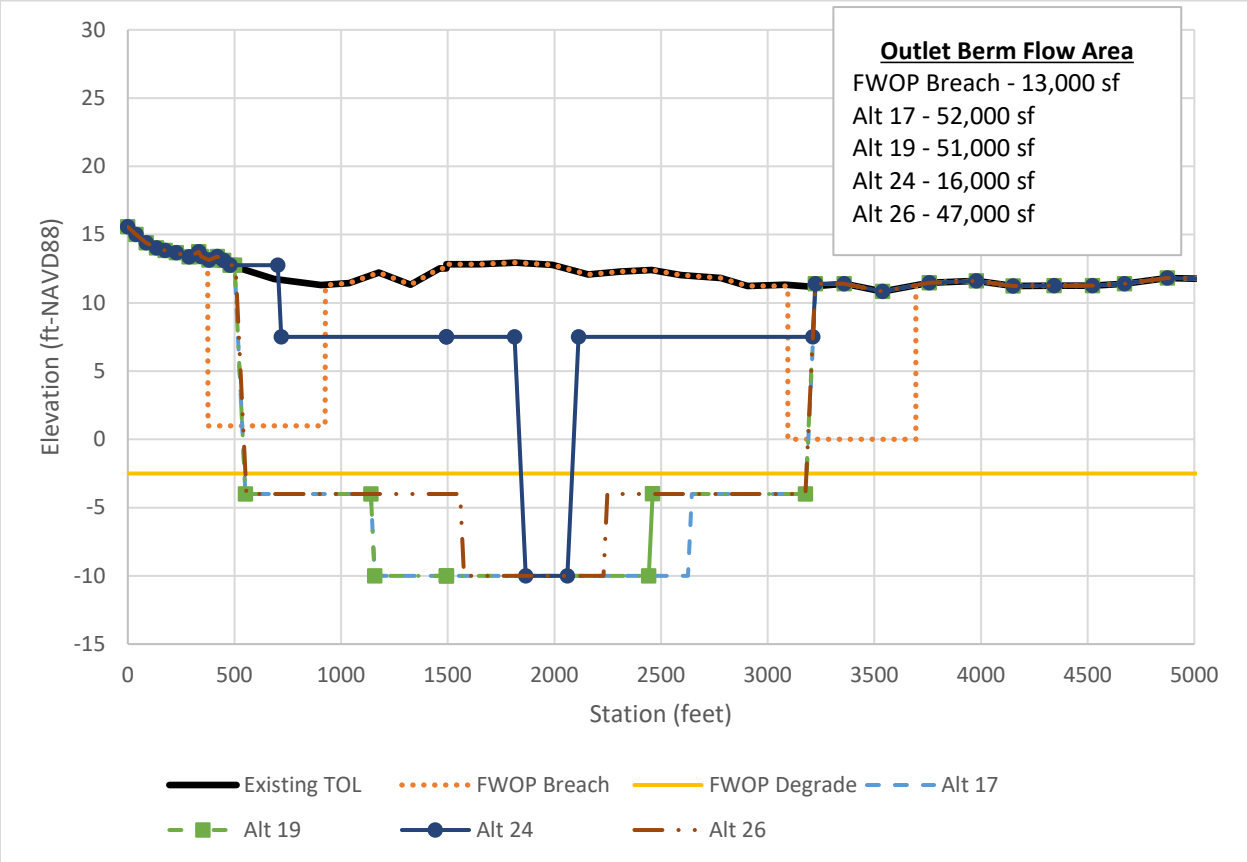


Figure 22. Outlet Berm Profile

FWOP2 Impacts

As shown in Table 8 and Table 9, with the FWOP2 levee performance assumption, the hydraulic effects of all alternatives upstream of LET are significant for both the 10-Year and 200-Year flood events. The reduction in flow area between the alternatives and FWOP2 significantly reduces the amount of flood flows entering LET.

The FWOP2 model simulation assumes that the restricted height levee is fully degraded to its landside levee toe elevation along approximately 4 miles. As shown in Figure 21 and Figure 22, this degrade would allow for significant flow through and exiting LET. Essentially, allowing flood flows of the Yolo Bypass to flow through LET unobstructed. Degrade of the restricted height levee is one bookend on the long-term performance of the levee under a future without project condition.

The performance of other restricted height levees in the Yolo Bypass is an indication of how extreme this assumption is. On RD 2093 – Liberty Island, just north of LET, the restricted height levee was overtopped and breached during the January 1997 flood. The island was not reclaimed after the flood and thus the restricted height levees have been unmaintained for over 25 years. Visual observation of recent aerial photos shows that portions of the levee remains and that they have not fully degraded to its entirety.

Floodplains

For the FWOP condition, the 200-Year floodplain along Watson Hollow Slough, Solano County Levee 44, Mellin Levee, and Sacramento River is shown in Figure 23. Lands behind the levee are flooded as a result of outflanking, overtopping and gaps in the levee.

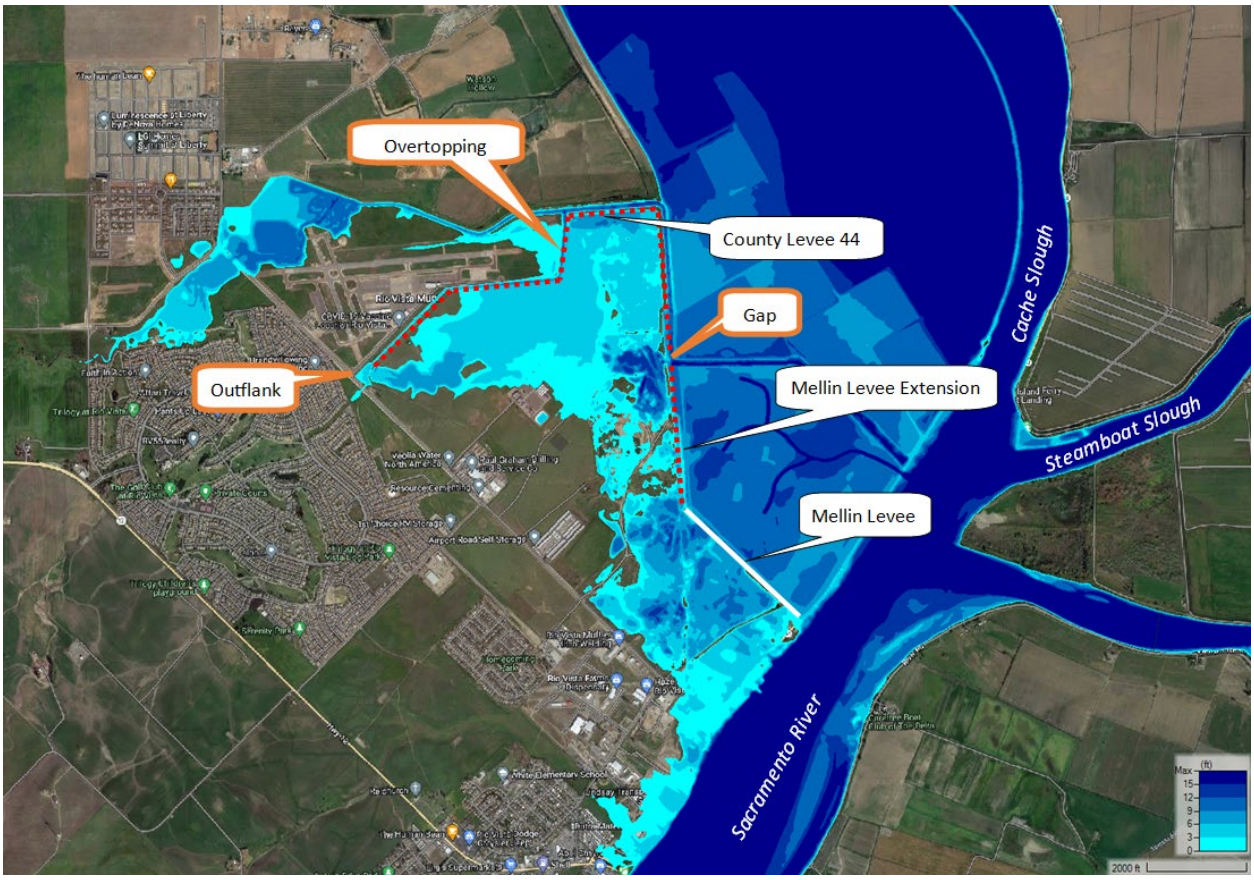


Figure 23. 200-Year Floodplain - FWOP

With the levee improvements on Solano County Levee 44, Mellin Levee Extension, Mellin Levee, and the water control structure at Watson Hollow Slough proposed in Alternatives 17, 19, and 24; the floodplain behind the levees is eliminated for the 200-Year floodplain (Figure 24). However, there would remain a residual floodplain along the Sacramento River within the City of Rio Vista as there is not a flood control feature under existing conditions or any of LEMBP alternatives.

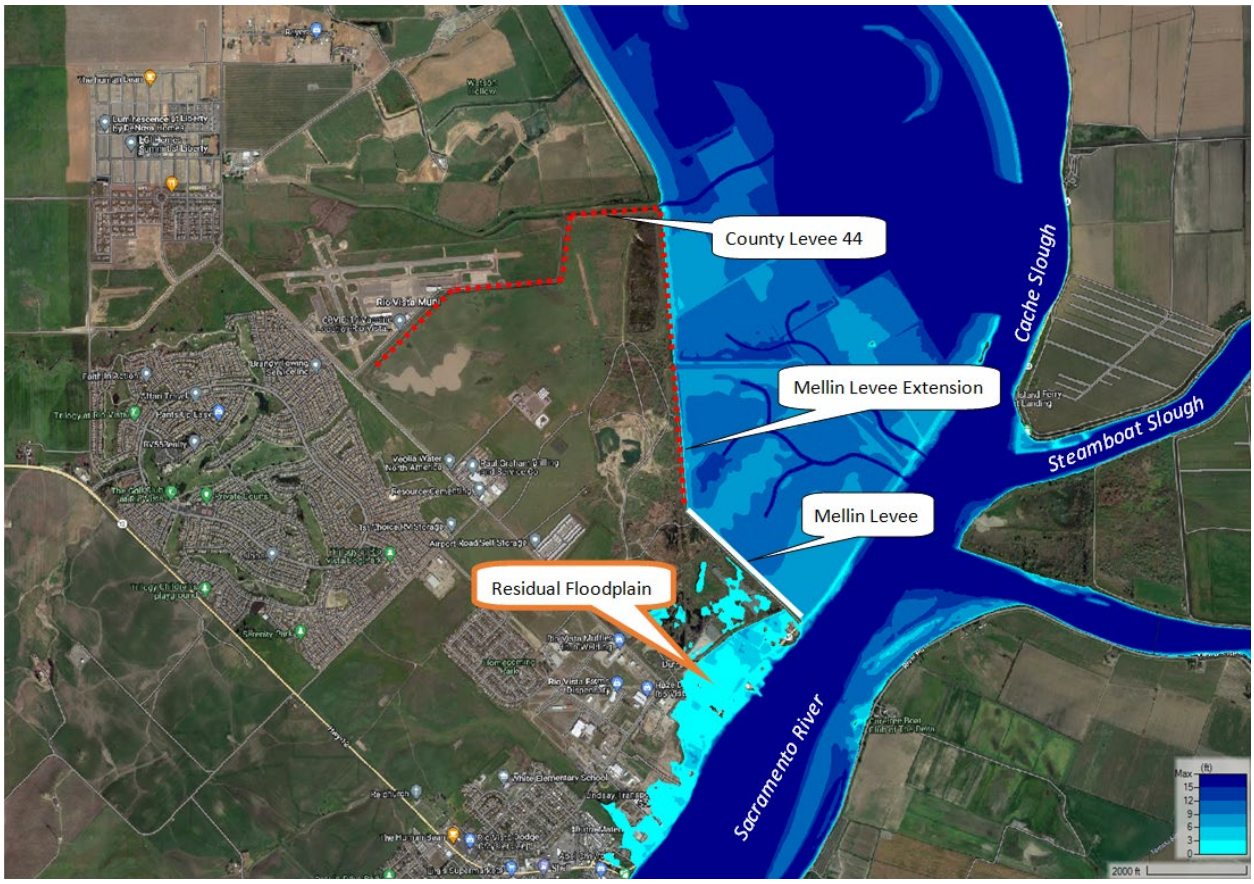


Figure 24. 200-Year Residual Floodplain for Alternative 17,19, and 24

Water Control Structure

Alternative 17, 19, and 24 include a water control structure at Watson Hollow Slough. It was assumed to operate during extreme flood events when high flows in the Yolo Bypass could backwater into Watson Hollow Slough and pond water against the levees along Watson Hollow Slough. In the hydraulic model simulation for Alternative 17, 19, and 24; it was assumed for both the 10 and 200-Year flood events that the water control structure would be closed. IP 18 in Table 6 through Table 9 show that Watson Hollow Slough would be dry thereby reducing water surface elevations along 1.5 miles of the RD 536 Watson Hollow Slough project levee.

Alternative 26 does not include a water control structure at Watson Hollow Slough similar to the FWOP conditions. For Alternative 26 under the 10-Year flood event, there is an increase of 2.2 ft. in water surface elevation in Watson Hollow Slough as the alternative has an inlet and outlet berm at elevation -4 ft. allowing water to backwater into Watson Hollow Slough versus FWOP1. For the 200-Year flood event, flood waters that entered Watson Hollow Slough, overtops the east-west segment of Solano County Levee 44 and outflanks it thereby flooding lands behind the levee, Mellin Levee Extension and Mellin Levee (Figure 25)

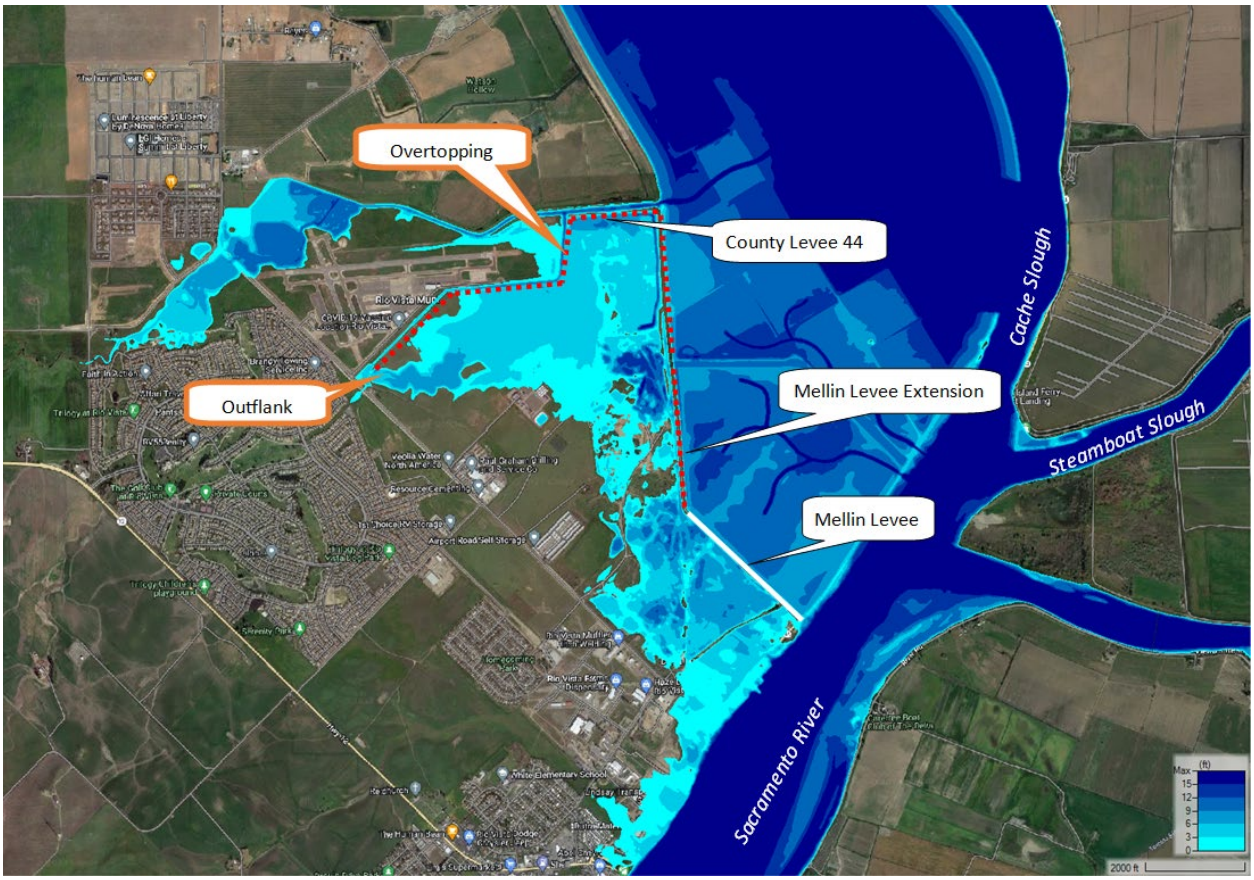


Figure 25. Alternative 26 - 200-Year Floodplain

Conclusions

Based on the hydraulic analysis conducted, several general conclusions can be drawn:

1. Inlet Berm Elevation: Setting the inlet berm elevation at 7.5 ft. or elevation -4.0 will yield similar hydraulic effects upstream of the Yolo Bypass at Liberty Island. However, there can be a significant difference in hydraulic effects for Cache-Haas Slough, Lindsey Slough Deep-Water Ship Channel, and Miner Slough.

2. Outlet Berm Elevation: The maximum water surface elevation difference between an outlet berm elevation of 7.5 ft. and -4.0 ft. is approximately 0.1. Modifying the length and elevation of the outlet berm will not significantly alleviate increases in water surface elevation along Cache Slough upstream of the outlet berm.

3. Stage Reductions: Setting the inlet berm at 7.5 ft. would result in more frequent stage reductions upstream of the Lower Elkhorn Tule (LET) ranging from 8% to 67% probability in a given year. Similarly, an inlet berm set at -4 ft. would provide stage reductions more frequently, ranging from 8% to 100% probability in a given year.

4. Flood Hydraulic Performance: The flood hydraulic performance of all alternatives does not extend beyond the Sacramento River at Rio Vista and the Yolo Bypass at Lisbon on the upstream end.

5. Watson Hollow Slough Water Control Structure: Implementing a water control structure at Watson Hollow Slough would prevent floodwaters from ponding against 1.5 miles of RD 536 Watson Hollow Slough levee.

6. Protection Measures: To safeguard the lands behind Solano County Levee 44, Mellin Levee Extension, and Mellin Levee, levee raising, and rehabilitation measures are necessary in conjunction with a water control structure at Watson Hollow Slough.

Next Steps

- Consider moving the inlet berm to the west to facilitate flows to enter LET and align closely with location of historic breach locations on the restricted height levee and to reduce water surface elevations along the levees of RD 536 and RD 2060 on Lindsey Slough (Figure 26).

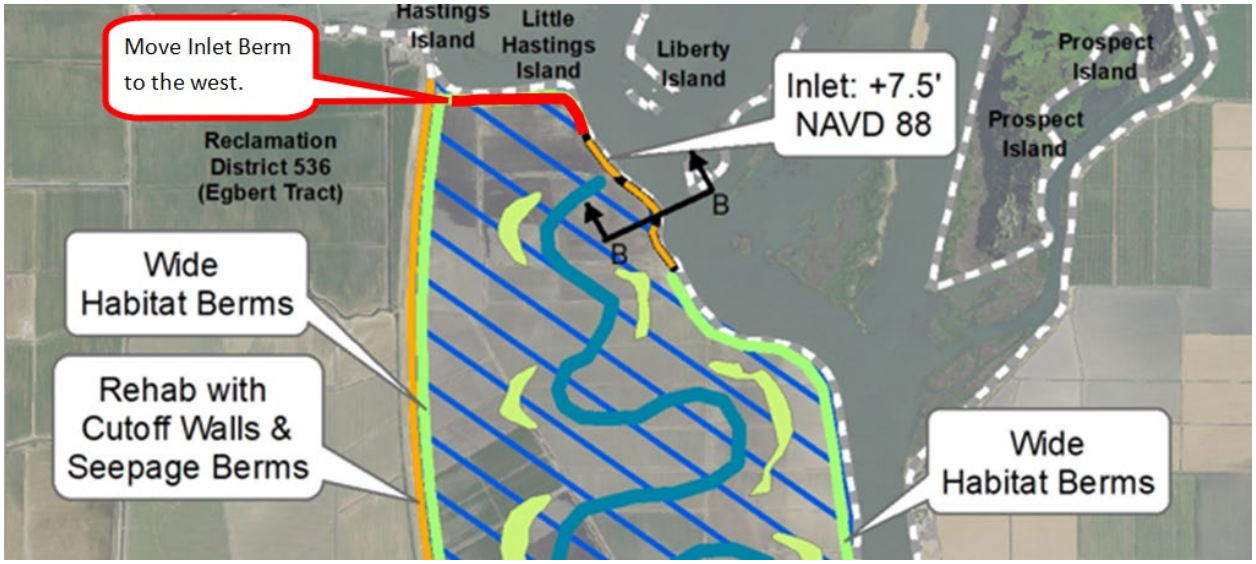


Figure 26. Refined Inlet Berm Location

- During the California Environmental Quality Act (CEQA) and design phase of the project; should an alternative with an inlet berm 7.5 elevation be carried forward, investigate a longer inlet berm length greater than 2300 to increase inlet berm flow conveyance area and further reduce water surface elevations upstream of LET and along the Deep-Water Ship Channel, and Miner Slough for flood events greater the 10-Year flood.

- During the CEQA and design phase, project features should be evaluated using current hydrologic estimates and checked with projected climate change and sea level rise for resiliency.

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(DWR, 2018). *Development of Stage-Frequency Curves in the Sacramento – San Joaquin Delta for Climate Change and Sea Level Rise.* A Report for California's Fourth Climate Change Assessment. [Prepared by Romain Malendy]. August 2018.

(MBK, 2023). *Calibration and Verification of Little Egbert Tract 1D/2D System HEC-RAS Model.* MBK Engineers. June 30, 2023.

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