Cache Slough Mitigation Bank

Solano County, California

Hydrologic and Hydraulic Impact Analysis

Supporting documentation for:

California Environmental Quality Act (CEQA)

Prepared for:

Westervelt ECOLOGICAL SERVICES

Prepared by:

MBK ENGINEERS

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PE Certification

This report has been prepared by or under the supervision of the following Registered Engineer. The Registered Civil Engineer attests to the technical information contained herein and has judged the qualifications of any technical specialists providing engineering data upon which recommendations, conclusions, and decisions are based.

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List of Abbreviations and Acronyms

Abbreviation/Acronym	Defined Term
1-D	One Dimensional
2-D	Two Dimensional
AEP	Annual Exceedance Probability
CFS	Cubic Feet per Second
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPB	Central Valley Flood Protection Board
CVHS	Central Valley Hydrology Study
DEM	Digital Elevation Model
DWSC	Deep Water Shipping Channel
FPS	Feet per Second
HIA	Hydraulic Impact Analysis
LET	Little Egbert Tract
MBK	MBK Engineers
NAVD 88	North American Vertical Datum of 1988
Project	Cache Slough Mitigation Bank Project
RD	Reclamation District
SRFCP	Sacramento River Flood Control Project
TO34	Task Order No. 34
ULOP	Urban Level-of-Protection
USACE	U.S. Army Corps of Engineers
WCS	Water Crossing Structure
WHS	Watson Hollow Slough
WSE	Water Surface Elevation

1. Purpose

Westervelt Ecological Services (Westervelt) proposes to restore tidal freshwater marsh and floodplain riparian habitat along Cache Slough and the Sacramento River in Solano County. The Cache Slough Mitigation Bank Project (Project) is located along the western bank of Cache Slough/Sacramento River just north of the City of Rio Vista and the Mellin Levee (**Figure 2**). The Project study area is bounded by State Route 84 (SR 84) to the southeast, the Mellin Levee to the southwest, the Mellin Levee extension to the west, and the southern embankments of Watson Hollow Slough to the north and northeast. SR 84 along the southeasterly property line of the Project is also Solano County Levee 28. The Project reconnects the site with Cache Slough/Sacramento River through a new water crossing structure (WCS) on State Route 84. MBK Engineers (MBK) has prepared a hydraulic impact analysis (HIA) of the proposed Project to support the California Environmental Quality Act (CEQA) analysis. The purpose of this report is to document the HIA.

2. Project Description

The proposed Project consists of restoring and protecting approximately 330 acres of tidal freshwater marsh and floodplain riparian habitat (**Figure 3** and **Figure 4**). The Project study area is owned by Westervelt Ecological Services, LLC (WES) and is located at the south end of the Yolo Bypass adjacent to Cache Slough and the Sacramento River at State Route 84. The restoration plan includes the following features:

- Construct a tidal opening to Cache Slough and the Sacramento River under SR 84 to achieve full tidal influence.
- Excavate tidal channels to increase tidal influence, provide habitat for fish, and transport nutrients to support the local aquatic food web.
- Re-contour the existing pastures to create topographic complexity and to promote diverse plant and habitat assemblages, including perennial emergent marsh, shallow subtidal wetlands, riparian scrub, and riparian woodlands.
- Conduct marsh and riparian plantings to promote development of shaded riverine aquatic habitat.
- Construct habitat berms and upland buffers to minimize tidal impacts on adjacent levees.

2.1 Mitigation Bank

Several restoration communities are proposed for the Project study area. Channel excavation will convert approximately 24 acres to open water. Excavated material from the channels will be used to create a habitat berm around the perimeter of the Project study area and to create planting mounds along the channels. Outside of the open water channels, the Project study area will be revegetated with three vegetation types: Emergent Marsh, Grassland, and Riparian Scrub Shrub. The total area for each habitat type is listed in **Table 1**.

Table 1. Project Habitat Restoration Areas

Vegetation Type	Total Area (acres)
Emergent Marsh	206.7
Grassland	21.5
Open Water	24.0
Riparian Shrubs	78.0

2.2 Habitat Grading

Sub-tidal and tidal channels will be excavated throughout the Project study area. The channels are proposed at thalweg elevations ranging between -5 feet and -2 feet North American Vertical Datum of 1988 (NAVD 88). The grading will start at the tidal opening under SR 84 and extend through the Project study area. The channels are intended to allow water to spread throughout the Project study area under tidal conditions. Habitat mounds are included in the proposed grading to provide upland transition habitat. These habitat mounds are proposed elevations ranging between 5 feet and 11 feet. In addition to the proposed habitat mounds, a perimeter habitat berm is proposed to be constructed along the western and northern perimeter of the Project study area. This berm would be constructed with elevations along the top of the berm ranging from 9.5 feet to 10.5 feet at finished grade and is intended to contain tidal waters on the Project study area, keeping the Mellin levee and other flood control features dry under regular tidal conditions. **Figure 4** shows the extent of the grading features on the Project study area.

2.3 Water Crossing Structure

A Water Crossing Structure (WCS) with a natural bottom opening will be constructed at State Route 84 to provide connectivity between the Project study area and Cache Slough/Sacramento River. The bottom width of the opening will span 30 feet with an invert elevation at -2 feet NAVD 88 and side slopes of 1 (vertical) to 2 (horizontal) until the slopes meet the deck of the water crossing structure. The SR 84 road crossing section will have a width of 44 feet and will have 3-foot-tall concrete barriers (type 836A). The low chord of the opening will be at elevation 8 feet NAVD 88. A cross section of the tidal opening is included in **Figure 5**.

3. Hydraulic Model

Two hydraulic models of the lower Sacramento River flood control system were developed for this study using HEC-RAS version 6.4.1. A flood hydraulic model was used to simulate and evaluate impacts of the project for the flood condition simulations, and a tidal model was used to simulate and evaluate impacts of the Project under tidal and lower flow conditions. HEC-RAS is capable of simulating one-dimensional (1D) and two-dimensional (2D) unsteady flow calculations through a full network of open channels. The Cache Slough Mitigation Bank HEC-RAS flood model (flood model) simulates the Sacramento River from Freeport to Suisun Bay; the distributaries of the Sacramento River, downstream of Freeport; and the Yolo Bypass, downstream of I-80 (**Figure 6**). The Cache Slough Mitigation Bank HEC-RAS tidal model (tidal model) simulates a similar extent; however, it simulates the Yolo Bypass downstream of Lisbon (**Figure 7**).

The Cache Slough Mitigation Bank HEC-RAS models are reduced versions of the Central Valley Floodplain Evaluation and Delineation (CFVED) Task Order No.34 (TO34) Lower Sacramento River HEC-RAS model, MBK version 2020-04 (MBK, 2021). The TO34 model was reduced to the Project study area and refinements were made to capture localized hydraulics near the Project study area. The model was calibrated to the 2017 flood and verified with the 1997 and 2006 floods (MBK, 2023). Calibration and verification of the tidal model was completed as part of this effort and is documented separately (MBK, 2024a). All elevations in the hydraulic model are referenced to the vertical datum North American Vertical Datum of 1988 (NAVD88).

4. Hydraulic Analysis

4.1 Scenarios

Several hydrologic scenarios which include tidal, flood, and rainfall hydrologic conditions were configured and evaluated to determine the potential effects of the Project. **Table 2** summarizes the scenarios. The purpose of each scenario is described as follows:

- Tidal conditions were simulated to evaluate the potential effects to agricultural operations such as pump intakes and siphons in the region, which depend on tidal stages to operate. Tidal conditions were also simulated to evaluate the Project effects to the navigability of the Sacramento Deep Water Shipping Channel (DWSC) and its navigation lane which is managed by the United States Army Corps of Engineers (USACE), San Francisco District (**Figure 1**).
- The hydraulic impact analysis of the Sacramento River Flood Control Project (SRFCP) 1957 design flow was completed by MBK as part of the Central Valley Flood Protection Board (CVFPB) encroachment permit application which is documented separately from this memorandum (MBK, 2024b).
- The 100-year flood conditions are evaluated to address regulatory floodplains managed by FEMA and Solano County floodplain ordinances.
- The 200-year flood conditions are evaluated to address regulatory requirements related to the Urban Levee-of-Protection (ULOP).
- A 100-year, 24-hour rainfall event was simulated to evaluate the potential effects of the Project on drainage in the Watson Hollow Slough basin. Particularly, effects were measured at drainage infrastructure for the City of Rio Vista and the City of Rio Vista Airport. Effects to neighboring parcels near Watson Hollow Slough were also evaluated during this condition.

Table 2. Scenario Matrix

Hydrologic Condition		Address
Yolo Bypass	**Watson Hollow Slough**	
Tidal	No Flow	Potential effects to agriculture; DWSC shipping lane operations; Regional habitat restoration projects
1957 Design Flow	No Flow	Potential effects on regulated floodways and ULOP
100-year	No Flow	
200-year	No Flow	
2-year	100-Year, 24-hour	Potential effects to drainage from the City of Rio Vista and Airport

4.2 Methodology

The methodology to determine hydraulic impacts is to configure and evaluate hydraulic model simulations of each scenario with- and without-Project conditions during the various hydrologic conditions. The simulation results of the with-Project conditions will be compared to the simulation results of the without-Project conditions to determine evaluate impacts of the Project. Both changes in water surface elevations and changes in flow velocities will be used to evaluate impacts of the Project.

4.3 Levee Performance Assumption

Levees and embankments in the hydraulic model will overtop and hold-up against major floods. In realistic conditions, natural earth and non-engineered levees have a high probability of failing when overtopped which is a likelihood for the RD 2084 restricted height levee. The RD 2084 restricted height levee (**Figure 1**) provides flood control to lands within the RD 2084 from flooding on Cache Slough. However, under flood flow conditions, the RD 2084 restricted height levee is intended to breach to facilitate increased conveyance of flood flows through the Yolo Bypass. Historically, this levee was breached in the floods of 1986 and 1997. To allow the model to represent a real and historical performance of the restricted height levee, the levee was assumed to fail when overtopped for flood simulations at the locations and approximate dimensions the levee historically breached in 1997. This condition would maximize the flooding footprint on regional SRFCP flood control levees, the Project study area, and capture effects of flood hydraulics of the entire Yolo Bypass under with-Project conditions.

4.4 Without-Project Condition

The Project study area is currently agricultural lands that are managed as irrigated pasture and waterfowl habitat. State Route 84 and Solano County Levee 28, located to the southeast of the site separates the Project study area from Cache Slough/Sacramento River during frequent floods under without-Project conditions. The existing site currently does not have a direct hydraulic connection to Cache Slough/Sacramento River under non-flood conditions. Field drains are currently aligned in a southwest to northeasterly direction and drain directly into Watson Hollow Slough (WHS) through culverts. Watson Hollow Slough ties into Cache Slough through four 60-inch culverts below State

Route 84. Related regional projects that are authorized or under construction as of 2024 are included in the hydraulic model. These projects include:

- Sacramento Weir Expansion and Sacramento Bypass Expansion (USACE, 2021)
- Lower Elkhorn Basin Levee Setback Project (DWR, 2020a)
- Fremont Weir Adult Fish Passage Modification (DWR, 2017)
- Lower Yolo Ranch Tidal Restoration Project (cbec, 2020)
- Yolo Flyway Farms Tidal Restoration Project (cbec, 2020)
- Lookout Slough Tidal Restoration Project (Wood Rodgers, 2020)
- Prospect Island Restoration Project (DWR, 2020b)
- Yolo Bypass Wildlife Area Habitat and Drainage Improvement Project (cbec, 2017)

4.4.1 Flood Model

The without-Project conditions hydraulic model was developed from the 2017 flood event calibration model. All projects upstream of the Yolo Bypass at I-80 (Sacramento Weir and Bypass Expansion, Lower Elkhorn Basin Levee Setback Project, and the Fremont Weir Adult Fish Passage) are included as flows into the without-Project conditions hydraulic model while the remaining projects are added to the without-Project conditions hydraulic model geometry by adjusting the Digital Elevation Model (DEM), Manning's roughness coefficients, and model components to represent the implementation of these projects within the model domain. All other Manning's roughness coefficients and other areas of the model remain the same from the calibration geometry. **Figure 8** shows the Manning's roughness coefficients for the without-Project condition in the Project vicinity for the flood model.

4.4.2 Tidal Model

The without-Project condition hydraulic model was developed from the tidal event calibration model. The model without-Project geometry includes the projects within the model domain. These projects were added to the without-Project conditions hydraulic model geometry from the tidal model by adjusting the Digital Elevation Model (DEM), Manning's roughness coefficients, and model components to represent the implementation of these projects within the model domain. All other Manning's roughness coefficients and other areas of the model, remain the same from the calibration geometry. **Figure 8** shows the Manning's roughness coefficients for the without-Project condition in the Project vicinity.

4.5 With-Project Condition

The with-Project conditions for the flood and tidal models were developed from the without-Project conditions models. The with-Project conditions reflect the proposed vegetation and design elevations of the Project study area along with the water crossing structure at State Route 84 as described in Section 2. The proposed vegetation communities were simulated by modifying the Manning's roughness coefficients in the respective areas of the model domain. **Table 3** lists the Manning's roughness coefficients of the Project condition vegetation for the 2D flow area (**Figure 9**).

Table 3. With-Project Condition – Manning's Roughness Coefficients for the 2D Flow Area

Land Use/Veg/Habitat	Manning's Roughness Coefficient
Emergent Marsh	0.045
Grassland	0.04
Open Water	0.025
Riparian Shrubs	0.085

4.6 Hydrology

The with- and without-Project hydraulic models were simulated for various hydrology representing a wide range of events and conditions (**Table 2**) to evaluate impacts of the Project.

4.6.1 Flood Hydrology

The with- and without- Project condition flood hydraulic model geometries were simulated for various flood conditions to evaluate potential impacts from the Project. The Cache Slough Mitigation Bank HEC-RAS Flood model simulated the 100-year and 200-year flood events in unsteady flow conditions. The USACE developed the 100-year and 200-year flood hydrology using methodology from the Central Valley Hydrology Study (CVHS). 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. The hydrology used for the 100-year and 200-year flood events were based on a CVHS event selection performed by USACE (USACE, 2020). The event selection determined flood events for two locations, or centerings, at the Sacramento River at Verona, and the American River at Fair Oaks and Sacramento River at the latitude of Sacramento. For this analysis, MBK simulated the flood events centered at the American River at Fair Oaks and Sacramento River at latitude of Sacramento, which is represented by a 1986 flood pattern. The CVHS scale factors for the events simulated are shown in **Table 4**. Inflow boundary hydrographs were obtained from a larger Sacramento River Flood Control Project HEC-RAS system model of the without-Project conditions (YBCS, 2023).

The downstream boundaries of the model utilize stage hydrographs developed as part of the CVHS (USACE, 2020). **Figure 10** and **Figure 11** plot the upstream flow hydrographs for the 100-year and 200-year flood condition simulations, respectively. The peak flows at the upstream model boundaries for the flood events are tabulated in **Table 5**.

Table 4. CVHS Hydrologic Scale Factors for 1986 Pattern, American River at Fair Oaks and Sacramento River at Latitude of Sacramento Centering

Flood Event	Peak Flow (cfs)	
	System Scale	American River Scale
2-Year	25%	8%
100-Year	95%	100%
200-Year	110%	125%

Table 5. Upstream Boundary Condition Peak Flows

Flood Event	Peak Flow (cfs)	
	Sacramento River at Freeport	Yolo Bypass at I-80
100-Year	104,440	528,590
200-Year	106,590	561,710

4.6.2 Tidal Hydrology

The with- and without-Project condition hydraulic models were simulated under various flow regimes under tidal conditions to evaluate potential impacts from the Project.

1. A period between February 11, 2016 and February 19, 2016 was simulated to represent a typical winter period and a time when juvenile winter-run-sized Chinook Salmon are in the Yolo Bypass (Rosario et al., 2013). The period measures project effects against regional projects such as Lookout Slough Tidal Restoration Project and the Prospect Island Restoration Project. A peak stage of 7.0 feet was simulated on the Sacramento River at Rio Vista gage. During this period, the mean higher high water (MHHW) simulated was 6.2 feet, the mean high water surface elevation (MHW) was 5.75 feet, and the mean lower low water (MLLW) was 2.6 feet at the Sacramento River at Rio Vista gage. This range of tidal stages represents the MHHW, MHW, and MLLW calculated on the Sacramento River at Rio Vista for a 26-year period of record from 1995 to 2021 (MBK, 2023b).
2. A period between July 7, 2020 and July 15, 2020 was simulated to represent a typical summer irrigation period. A peak stage of 6.3 feet with a low stage of 2.1 feet were simulated on the Sacramento River at Rio vista gage. During this period, the MHHW simulated was 5.9 feet, the MHW was 5.5 feet, and the MLLW was 2.5 feet at the Sacramento River at Rio Vista gage. The California Water year of 2020 was classified as Dry.

The boundary conditions for the tidal model for this period were records obtained from USGS and DWR gages located at the model boundaries. The gages used for this record are detailed in section **Table 6**.

Table 6. Boundary Locations

Boundary Location	HEC-RAS Location	Gage Record
Sacramento River at Freeport	SAC R08 46.188	Flow Hydrograph from Observed Data USGS 11447650
Yolo Bypass at Lisbon	Yolo_Byp_Inflow	Flow Hydrograph from Observed Data DWR B91560Q
Sacramento River at Collinsville	SAC R01 0.844	Stage Hydrograph from Observed Data DWR B95020
Three Mile Slough at San Joaquin River	THR_R01_0.148	Stage Hydrograph from Observed Data DWR B95060
Georgiana Slough at Mokelumne River	GEO R01 0.037	Stage Hydrograph from Observed Data DWR B94100

4.6.3 Watson Hollow Slough Flood Hydrology

A 100-year, 24-hour rainfall event on the Watson Hollow Slough watershed was also simulated in the hydraulic model to evaluate potential impacts from the Project. The 100-year, 24-hour Watson Hollow Slough hydrology was developed as part of the Little Egbert Tract Multi-Benefit Project CEQA analysis (MBK, 2024c). The rainfall hydrology was included in the tidal model for this simulation. A CVHS 2-year (**Table 4**) coincident event was simulated on the Yolo Bypass to provide tailwater conditions on the Yolo Bypass (**Figure 12**). The 100-year rainfall hydrographs used for the upstream model boundaries on Watson Hollow Slough are shown in **Figure 13**.

4.7 Results

For each scenario described in Section 4.1, changes in water surface elevations or velocities were determined to evaluate impacts of the Project to address flood, tidal, and drainage related concerns.

4.7.1 Flood Impacts

The with- and without-Project condition maximum water surface elevations were compared at index points to determine the changes in the maximum water surface elevations due to the Project. The 20 index point locations used to evaluate impacts are shown in **Figure 14**. Tabulations of the changes in water surface elevation at these index points for the 100-year and 200-year flood simulations are shown in **Table 7** and **Table 8** respectively. A summary of findings from the flood impacts analysis is as follows:

- The increases in maximum water surface elevations observed at these index points across the 100- and 200-year simulations are at most +0.03 feet.
- A spatial representation of the changes in maximum water surface elevations for the 100-year flood event near the Project vicinity is shown in **Figure 15**. Localized increase in maximum water surface elevations are at most +0.3 feet, which occurs immediately downstream of the opening of the proposed water crossing structure at State Route 84. Increases in maximum water surface elevation of +0.12 feet occur within the property and along the northern perimeter berm of Watson Hollow Slough.

Table 7. Maximum Water Surface Elevations at Index Points for 1/100 AEP Flood

Location (see Figure *14*)	Computed Maximum Water Surface Elevations (feet, NAVD88)		Change in Maximum Water Surface Elevation (feet)
	Without-Project	With-Project	With-Project minus Without-Project
1. Sacramento River at Rio Vista	12.44	12.44	0.00
2. Cache Slough at Ryer Island Ferry	15.04	15.02	-0.02
3. Cache Slough above Ryer Island Ferry	15.97	15.98	+0.01
4. Yolo Bypass upstream of Little Egbert Tract	18.25	18.27	+0.02
5. Yolo Bypass near Upper Cache Slough	19.29	19.31	+0.02
6. Yolo Bypass at Liberty Island	21.45	21.46	+0.01
7. Yolo Bypass near north end of RD 2068 levee	26.55	26.56	+0.01
8. Yolo Bypass at Lisbon	28.38	28.38	0.00
9. Miner Slough at Five Points	18.50	18.53	+0.03
10. Sutter Slough at Miner Slough	18.72	18.73	+0.01
11. Miner Slough at Hwy 220	18.35	18.38	+0.03
12. Steamboat Slough at Ryer Island Ferry	17.01	17.01	0.00
13. Sacramento River at Ryde	17.07	17.05	-0.02
14. Steamboat Slough at Snug Harbor	15.97	15.97	0.00
15. Sacramento River at Poverty Road	15.53	15.49	-0.04
16. Sacramento River at Isleton	14.94	14.90	-0.04
17. DWSC at West Sacramento	18.53	18.56	+0.03
18. Watson Hollow Slough at Rio Vista Airport	16.28	16.31	+0.03
19. Prospect Island Tidal Habitat Restoration Project	18.49	18.51	+0.02
20. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	20.32	20.33	+0.01

Table 8. Maximum Water Surface Elevations at Index Points for 1/200 AEP Flood

Location (see Figure *14*)	Computed Maximum Water Surface Elevations (feet, NAVD88)		Change in Maximum Water Surface Elevation (feet)
	Without-Project	With-Project	With-Project minus Without-Project
1. Sacramento River at Rio Vista	13.19	13.19	0.00
2. Cache Slough at Ryer Island Ferry	16.23	16.22	-0.01
3. Cache Slough above Ryer Island Ferry	17.19	17.21	+0.02
4. Yolo Bypass upstream of Little Egbert Tract	19.28	19.30	+0.02
5. Yolo Bypass near Upper Cache Slough	20.23	20.25	+0.02
6. Yolo Bypass at Liberty Island	22.39	22.41	+0.02
7. Yolo Bypass near north end of RD 2068 levee	27.33	27.34	+0.01
8. Yolo Bypass at Lisbon	29.11	29.11	0.00
9. Miner Slough at Five Points	19.67	19.70	+0.03
10. Sutter Slough at Miner Slough	19.80	19.81	+0.01
11. Miner Slough at Hwy 220	19.46	19.48	+0.02
12. Steamboat Slough at Ryer Island Ferry	18.06	18.06	0.00
13. Sacramento River at Ryde	17.92	17.90	-0.02
14. Steamboat Slough at Snug Harbor	17.10	17.09	-0.01
15. Sacramento River at Poverty Road	16.50	16.46	-0.04
16. Sacramento River at Isleton	15.97	15.92	-0.05
17. DWSC at West Sacramento	19.72	19.75	+0.03
18. Watson Hollow Slough at Rio Vista Airport	17.20	17.23	+0.03
19. Prospect Island Tidal Habitat Restoration Project	19.66	19.69	+0.03
20. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	21.28	21.29	+0.01

4.7.2 Tidal Impacts

4.7.2.1 Winter Season

Water surface elevation hydrographs were compared at index points near the project vicinity to evaluate potential impacts of the Project during winter tidal conditions. A period in February 2016 was selected for this analysis. The index point locations evaluated for tidal conditions are shown in **Figure 16**. Water surface elevation hydrographs for the seven index point locations are shown in **Figure 17** through **Figure *22***. For each of the index points, the simulated daily higher-highs, highs, lows, and lower-lows were averaged for the with- and without-Project conditions for the period between February 11, 2016 and February 19, 2016 to determine a mean higher high water (MHHW) elevation, mean high water (MHW) elevation, mean low water (MLW) elevation, and a mean lower-low water (MLLW) elevation. These mean daily tidal fluctuations will be different than tidal datums, as those require a long period-of-record, typically a 19-year period, to calculate. The purpose of using these daily tidal averages is to evaluate potential effects of the Project within the hydraulic model simulation period. The mean higher high water surface elevations (MHHW) for the index points are tabulated in **Table 9**; the mean high water surface elevations (MHW) for the index points are tabulated in **Table 10**; the mean low water surface elevations (MLW) for the index points are tabulated in **Table 11**; the mean lower low water surface elevations (MLLW) for the index points are tabulated in **Table 12**. Changes in water surface elevations were measured at both the Prospect Island Tidal Habitat Restoration Project (Index Point 4) and the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Index Point 6). No significant effects were observed at either location, as shown in **Figure 17** through **Figure *22***, and **Table 9** through **Table 12**.

Table 9. Mean Higher High Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MHHW (feet)	With-Project MHHW (feet)	Change in MHHW (feet)
1. Sacramento River at Rio Vista	6.2	6.19	-0.01
2. Watson Hollow Slough Siphon	6.19	6.19	0.0
3. Cache Slough at Steamboat Slough	6.2	6.2	0.0
4. Prospect Island Tidal Habitat Restoration Project	5.82	5.82	0.0
5. Lindsey Slough at Yolo Bypass	6.2	6.2	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	6.11	6.11	0.0
7. Cache Slough Mitigation Bank	Dry	6.14	--

[1]Mean Higher High Water is the average of the daily higher high water from February 11, 2016, through February 19, 2016.

Table 10. Mean High Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MHW (feet)	With-Project MHW (feet)	Change in MHW (feet)
1. Sacramento River at Rio Vista	5.75	5.75	0.0
2. Watson Hollow Slough Siphon	5.75	5.75	0.0
3. Cache Slough at Steamboat Slough	5.76	5.76	0.0
4. Prospect Island Tidal Habitat Restoration Project	5.45	5.45	0.0
5. Lindsey Slough at Yolo Bypass	5.78	5.78	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	5.7	5.7	0.0
7. Cache Slough Mitigation Bank	Dry	5.71	--

[1]Mean High Water is the average of the daily high water from February 11, 2016, through February 19, 2016.

Table 11. Mean Low Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MLW (feet)	With-Project MLW (feet)	Change in MLW (feet)
1. Sacramento River at Rio Vista	2.98	2.98	0.0
2. Watson Hollow Slough Siphon	3.01	3.01	0.0
3. Cache Slough at Steamboat Slough	3.02	3.02	0.0
4. Prospect Island Tidal Habitat Restoration Project	4.25	4.25	0.0
5. Lindsey Slough at Yolo Bypass	3.06	3.06	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	3.66	3.66	0.0
7. Cache Slough Mitigation Bank	Dry	3.01	--

[1]Mean Low Water is the average of the daily low water from February 11, 2016, through February 19, 2016.

Table 12. Mean Lower-Low Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MLLW (feet)	With-Project MLLW (feet)	Change in MLLW (feet)
1. Sacramento River at Rio Vista	2.59	2.59	0.0
2. Watson Hollow Slough Siphon	2.63	2.63	0.0
3. Cache Slough at Steamboat Slough	2.64	2.65	+0.01
4. Prospect Island Tidal Habitat Restoration Project	4.15	4.15	0.0
5. Lindsey Slough at Yolo Bypass	2.7	2.7	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	3.53	3.53	0.0
7. Cache Slough Mitigation Bank	Dry	2.62	--

[1]Mean Lower Low Water is the average of the daily lower low water from February 11, 2016, through February 19, 2016.

4.7.2.2 Agricultural Operation Impacts

Similar to Section 4.7.2.1, water surface elevation hydrographs were compared at index points near the project vicinity to evaluate potential Project impacts during a summer irrigation period in July of 2020. For each of the index points, the simulated daily higher-highs, highs, lows, and lower-lows were averaged for the with- and without-Project conditions for the period between July 7, 2020, and July 15, 2020, to determine a mean higher high water (MHHW) elevation, mean high water (MHW) elevation, mean low water (MLW) elevation, and a mean lower-low water (MLLW) elevation. The mean higher high water surface elevations (MHHW) for the index points are tabulated in **Table 13**; the mean high water surface elevations (MHW) for the index points are tabulated in **Table 14**; the mean low water surface elevations (MLW) for the index points are tabulated in **Table 15** the mean lower low water surface elevations (MLLW) for the index points are tabulated in **Table 16**. No significant effects were observed at the measured index points near the project vicinity as shown in **Figure 23** through **Figure 28**, and **Table 13** through **Table 16**.

Table 13. Mean Higher High Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MHHW (feet)	With-Project MHHW (feet)	Change in MHHW (feet)
1. Sacramento River at Rio Vista	5.94	5.94	0.0
2. Watson Hollow Slough Siphon	5.94	5.94	0.0
3. Cache Slough at Steamboat Slough	5.95	5.95	0.0
4. Prospect Island Tidal Habitat Restoration Project	5.63	5.63	0.0
5. Lindsey Slough at Yolo Bypass	5.99	5.99	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	5.92	5.92	0.0
7. Cache Slough Mitigation Bank	Dry	5.92	--

[1]Mean Higher High Water is the average of the daily higher-high water from July 7, 2020, through July 15, 2020.

Table 14. Mean High Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MHW (feet)	With-Project MHW (feet)	Change in MHW (feet)
1. Sacramento River at Rio Vista	5.46	5.46	0.0
2. Watson Hollow Slough Siphon	5.47	5.47	0.0
3. Cache Slough at Steamboat Slough	5.48	5.48	0.0
4. Prospect Island Tidal Habitat Restoration Project	5.2	5.2	0.0
5. Lindsey Slough at Yolo Bypass	5.53	5.53	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	5.47	5.47	0.0
7. Cache Slough Mitigation Bank	Dry	5.46	--

[1]Mean High Water is the average of the daily high water from July 7, 2020, through July 15, 2020.

Table 15. Mean Low Water1 Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MLW (feet)	With-Project MLW (feet)	Change in MLW (feet)
1. Sacramento River at Rio Vista	3.09	3.09	0.0
2. Watson Hollow Slough Siphon	3.12	3.12	0.0
3. Cache Slough at Steamboat Slough	3.12	3.12	0.0
4. Prospect Island Tidal Habitat Restoration Project	4.04	4.04	0.0
5. Lindsey Slough at Yolo Bypass	3.11	3.11	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	3.65	3.65	0.0
7. Cache Slough Mitigation Bank	Dry	3.1	--

[1]Mean Low Water is the average of the daily low water from July 7, 2020, through July 15, 2020.

Table 16. Mean Lower Low Water[1] Surface Elevations Calculated at Index Points

Index Point (see Figure 16)	Without-Project MLLW (feet)	With-Project MLLW (feet)	Change in MLLW (feet)
1. Sacramento River at Rio Vista	2.46	2.46	0.0
2. Watson Hollow Slough Siphon	2.52	2.52	0.0
3. Cache Slough at Steamboat Slough	2.51	2.51	0.0
4. Prospect Island Tidal Habitat Restoration Project	3.79	3.79	0.0
5. Lindsey Slough at Yolo Bypass	2.5	2.5	0.0
6. Lookout Slough Tidal Habitat Restoration and Flood Improvement Project	3.45	3.45	0.0
7. Cache Slough Mitigation Bank	Dry	2.49	--

[1]Mean Lower-Low Water is the average of the daily lower-low water from July 7, 2020, through July 15, 2020.

4.7.2.3 Effects to Deep Water Shipping Channel Navigation Lane

Changes in flow velocities were also compared near and within the Sacramento Deep Water Shipping Channel navigation lane to evaluate potential effects to ships navigating through the designated lane. The delineation of the Shipping Channel Navigation Lane was obtained from the U.S. Army Corps of Engineers Geospatial National Channel Framework (USACE, 2017). During a tidal prism between approximately elevations 2 feet to 7 feet, the maximum change in flow velocity within the navigation lane that occurred during the tidal conditions simulations were at most +0.8 feet per second (fps) during an ebb tide (**Figure 29**) and +0.1 fps during a flood tide (**Figure 30**).

4.7.3 Effects to Watson Hollow Slough 100-Year Rainfall-Runoff Interior Drainage

Maximum water surface elevations and maximum flood extent were compared between with- and without-Project conditions for the 100-year rainfall-runoff event from Watson Hollow Slough. Stage hydrographs and maximum water surface elevations were compared at index points within the Watson Hollow Slough drainage system to evaluate potential impacts of the Project during a major rainfall event. The five index points evaluated for this analysis are shown in **Figure 31**. **Figure 32** through **Figure 36** show the stage hydrographs at the index points for the with-Project and without-Project simulations. Across all index points, the change in maximum water surface elevation is at most +0.07 feet and occurs at the Watson Hollow Slough at Little Egbert Tract index point (**Figure 32**). The maximum inundation extents for with- and without-Project conditions are shown in **Figure 37**. The extent of inundation increases under with-Project conditions to the north of Watson Hollow Slough and the west of the Solano County Levee 44.

5. Conclusion

Westervelt proposes to convert 330 acres of agricultural lands to tidal habitats along Cache Slough and Sacramento River in Solano County. This hydraulic analysis assesses the Project's potential effects on the State and Federal Flood control system, nearby infrastructure and operations, and existing tidal projects in the Yolo Bypass. The results of the hydraulic analysis indicate:

- The Project study area will be tidally connected to Cache Slough / Sacramento River on a daily basis. Under winter or summer tidal conditions, changes to daily tidal highs and lows are minimal (at most +/- 0.01 feet). Based on the findings from the changes in tidal stages:
    - Existing drainage pattern on- and off-site would not be substantially altered.
    - The with-Project conditions are not expected to affect water diversions that rely on stage to function such as siphons and pump intakes.
    - The with-Project conditions are not expected to divert water away from areas in the region that would have been providing groundwater recharge under existing conditions and therefore, the local groundwater table level is not expected to be depleted under with-Project conditions.
- Under both winter and summer tidal conditions, changes in velocity within the Deep Water Shipping Channel Navigation Lane are at most +0.8 fps during ebb tides (**Figure 29**) and at most +0.1 fps during flood tides (**Figure 30**). Changes in flow velocities are local to the proposed WCS opening and the Project study area is approximately 4 miles away from the mouth of the DWSC (**Figure 1**). Therefore, the potential for sediment deposition within the DWSC is not expected to be significant.
- During the SRFCP 1957 design flow, change in maximum water surface elevations are localized and are at most +0.1 feet and +0.3 feet. Water surface elevation increases of greater than +0.1 feet are not adjacent to any state or federal flood control features. Therefore, the Project is not expected to increase flood risk to neighboring properties or flood control infrastructures.

- During a 100-year flood event, changes in maximum water surface elevations measured at index points range from +0.03 feet to -0.04 feet; simulated changes in flow velocity is localized with a maximum change of approximately +10 fps occur primarily immediately downstream and below the proposed WCS. The Project design proposes rip-rap rocks as a form of erosion protection along areas of high velocities and therefore the increase in flow velocities are mitigated under the Project's erosion protection design (MBK, 2024d).

- During a 200-year flood event, changes in maximum water surface elevations measured at index points range from +0.03 feet to -0.05 feet.

- During a 100-year, 24-hour rainfall event on the Watson Hollow Slough Basin, the Project increases maximum stages within the Watson Hollow Slough basin at most +0.07 feet at the junction of Watson Hollow Slough and Little Egbert Tract (Index Point 1; **Figure 31**). The with-Project conditions simulation show increases in floodplain extent onto neighboring parcels to the north of Watson Hollow Slough, and west of the Solano County Levee 44 during a 100-year, 24-hour rainfall event on the Watson Hollow Slough basin (**Figure 37**). Under existing conditions, lands north of the Project study area potentially receives drainage water from a 100-year, 24-hour rainfall event from Watson Hollow Slough and field-level drainage infrastructure are not represented in the hydraulic model as they were likely not designed nor intended to drain a 100-year, 24-hour rainfall-runoff intensity—these are agricultural fields. The effects of increased floodplain extent are the result of accumulation of additional drainage that would normally be managed by pump stations on RD 2084 and crossing below agricultural roads; all of which are not modeled in the simulations. Therefore, the increase in floodplain extent is not expected to be significant.

6. References

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Figures

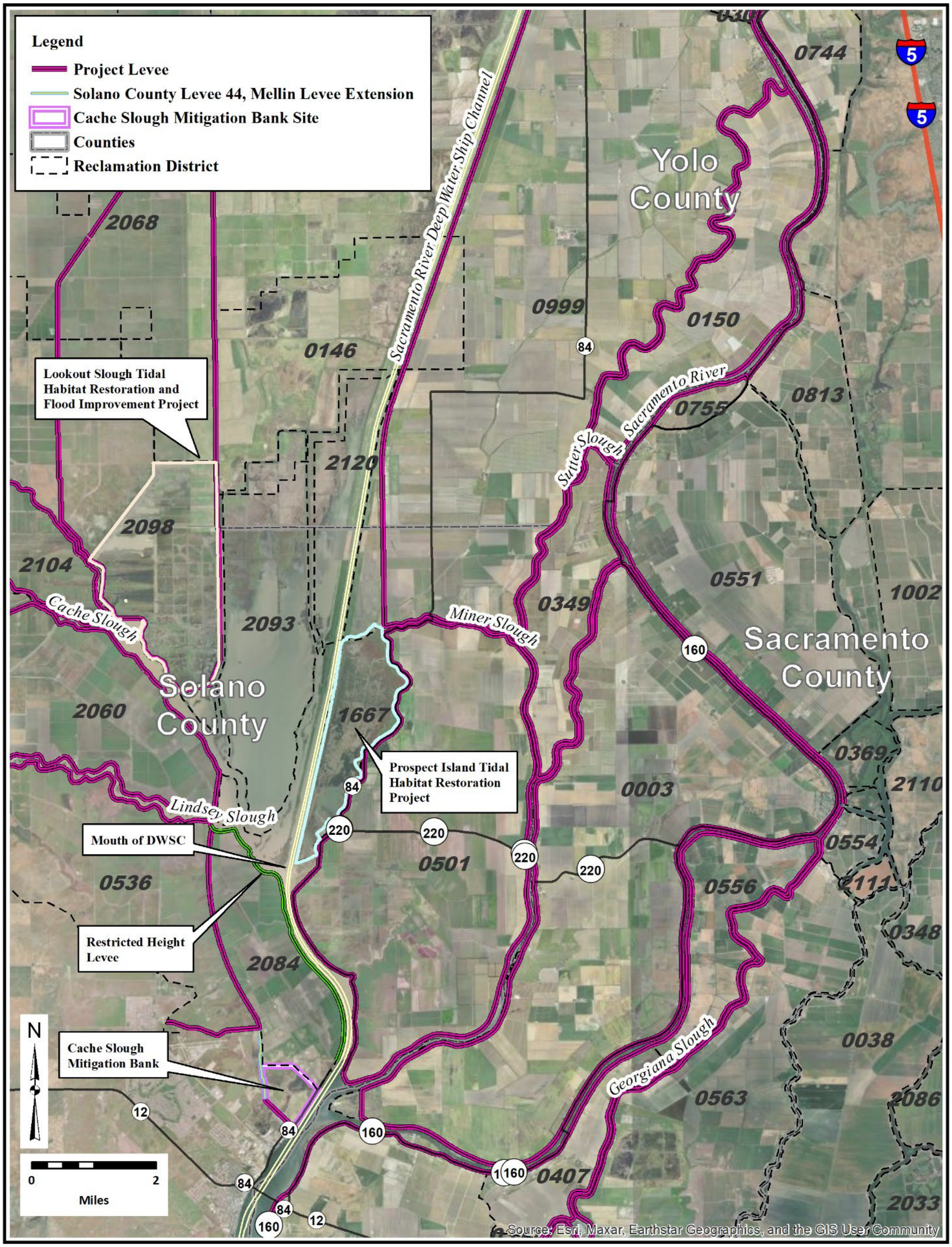

Figure 1. Vicinity Map - Large

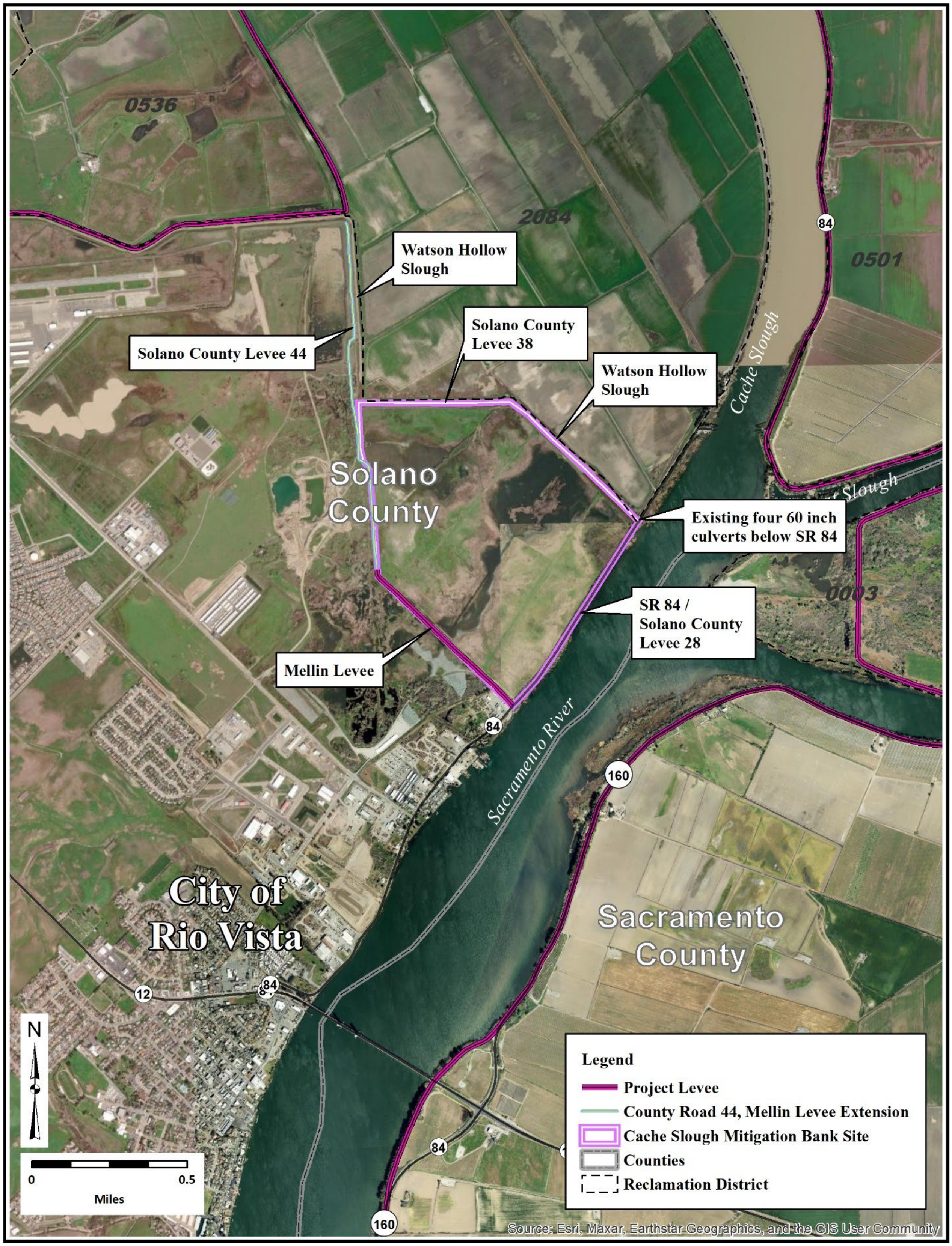

Figure 2. Vicinity Map - Small

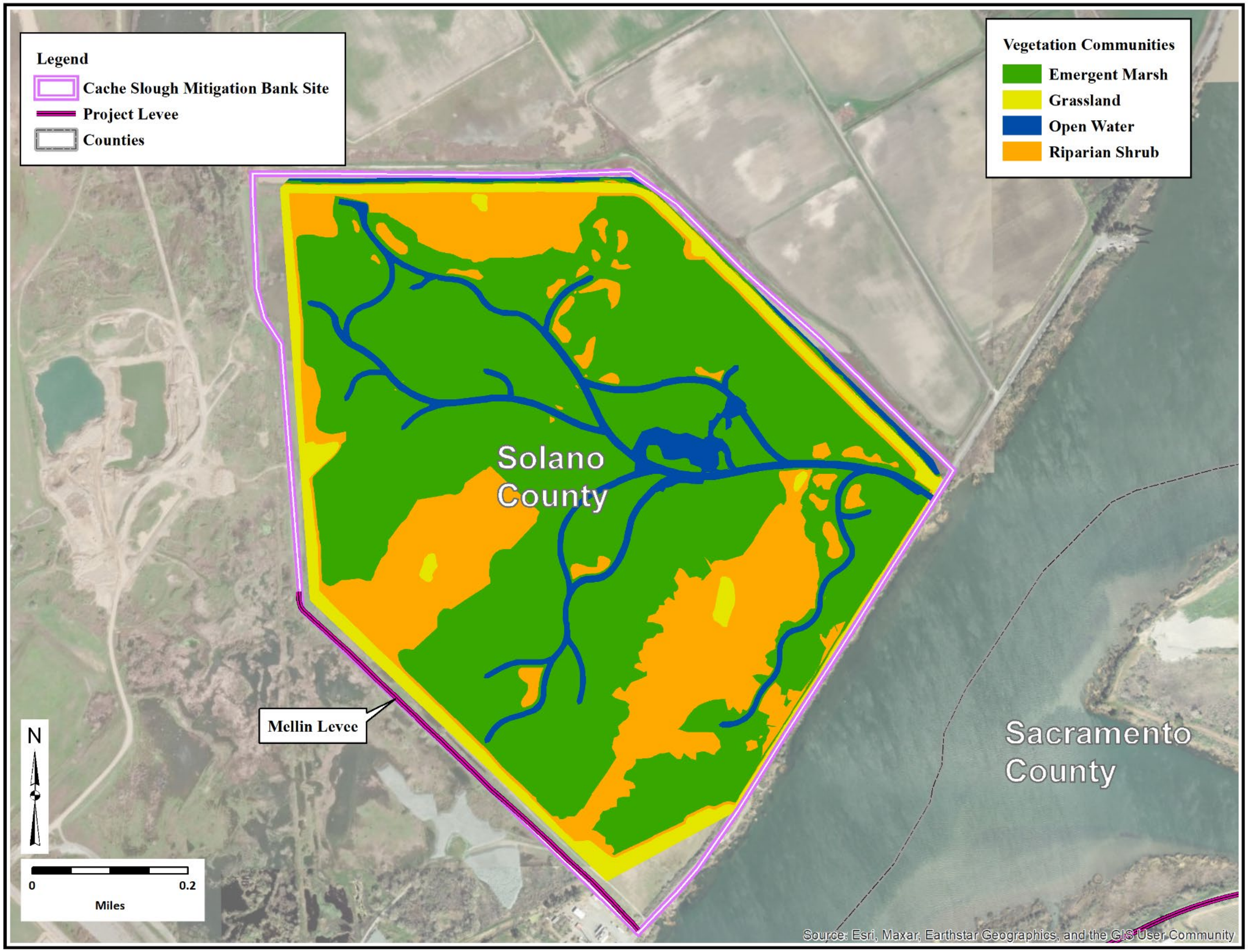

Figure 3. Restoration Plan – Vegetation Communities

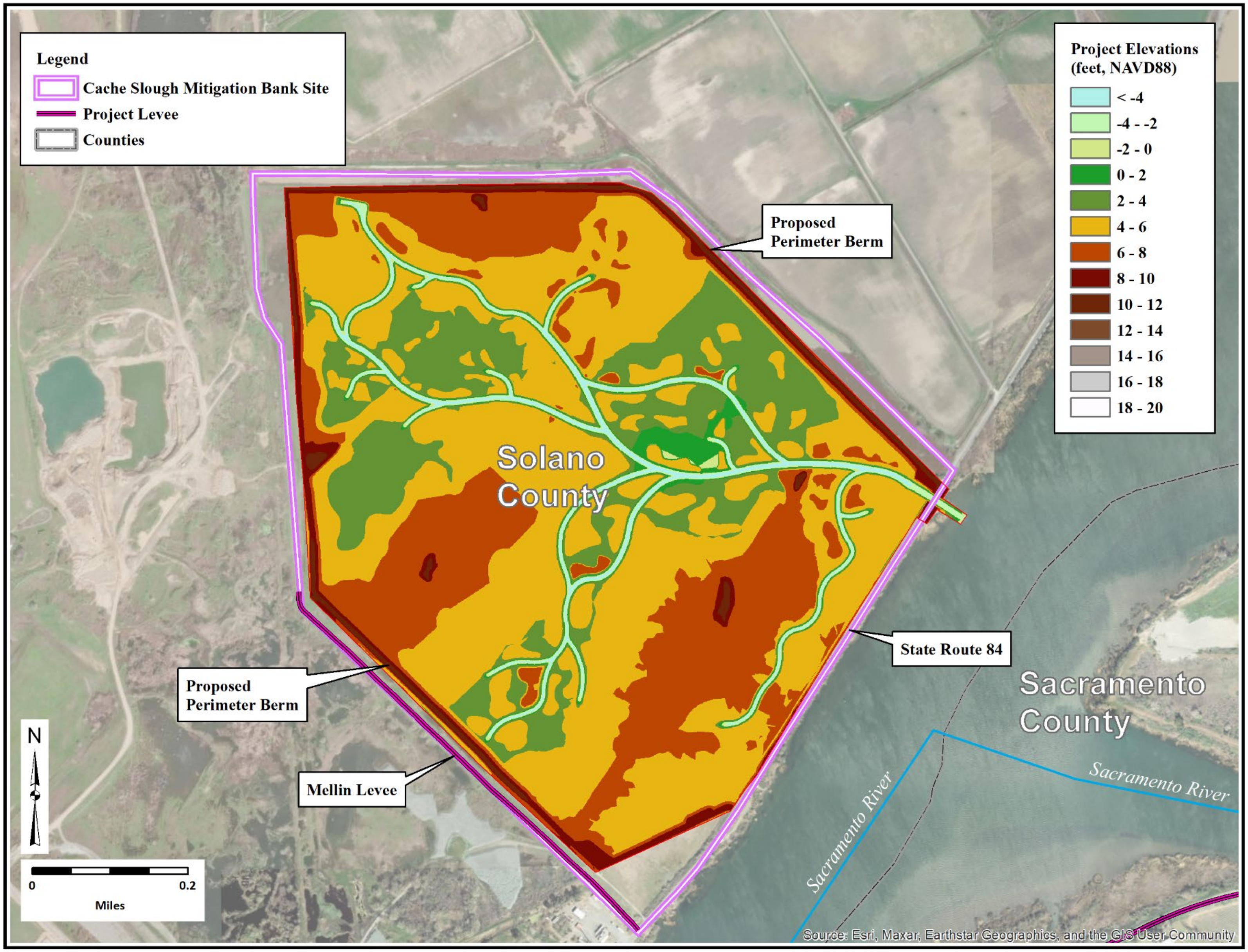

Figure 4. Restoration Plan - Grading

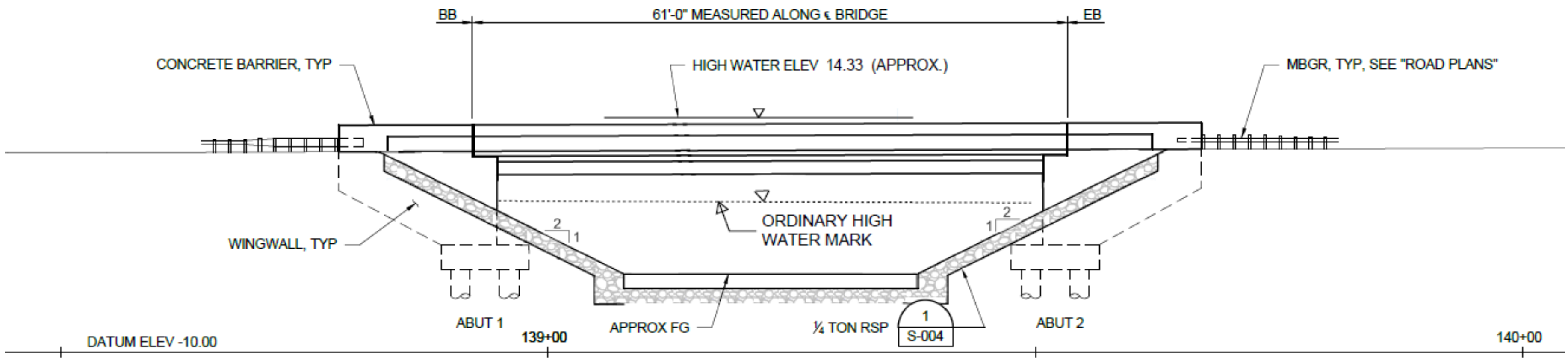

Figure 5. Proposed State Route 84 Water Control Structure

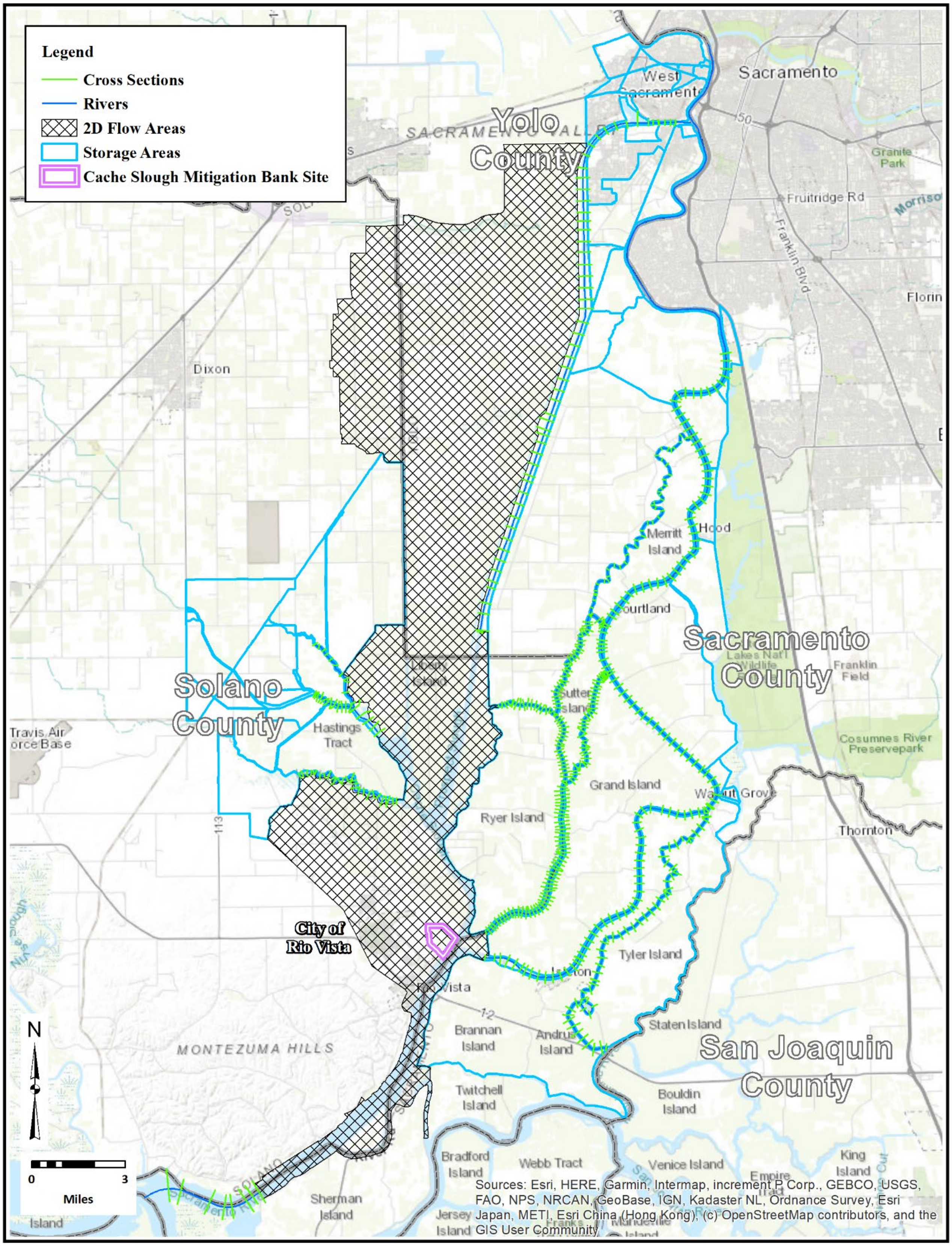

Figure 6. Flood Hydraulic Model Schematic

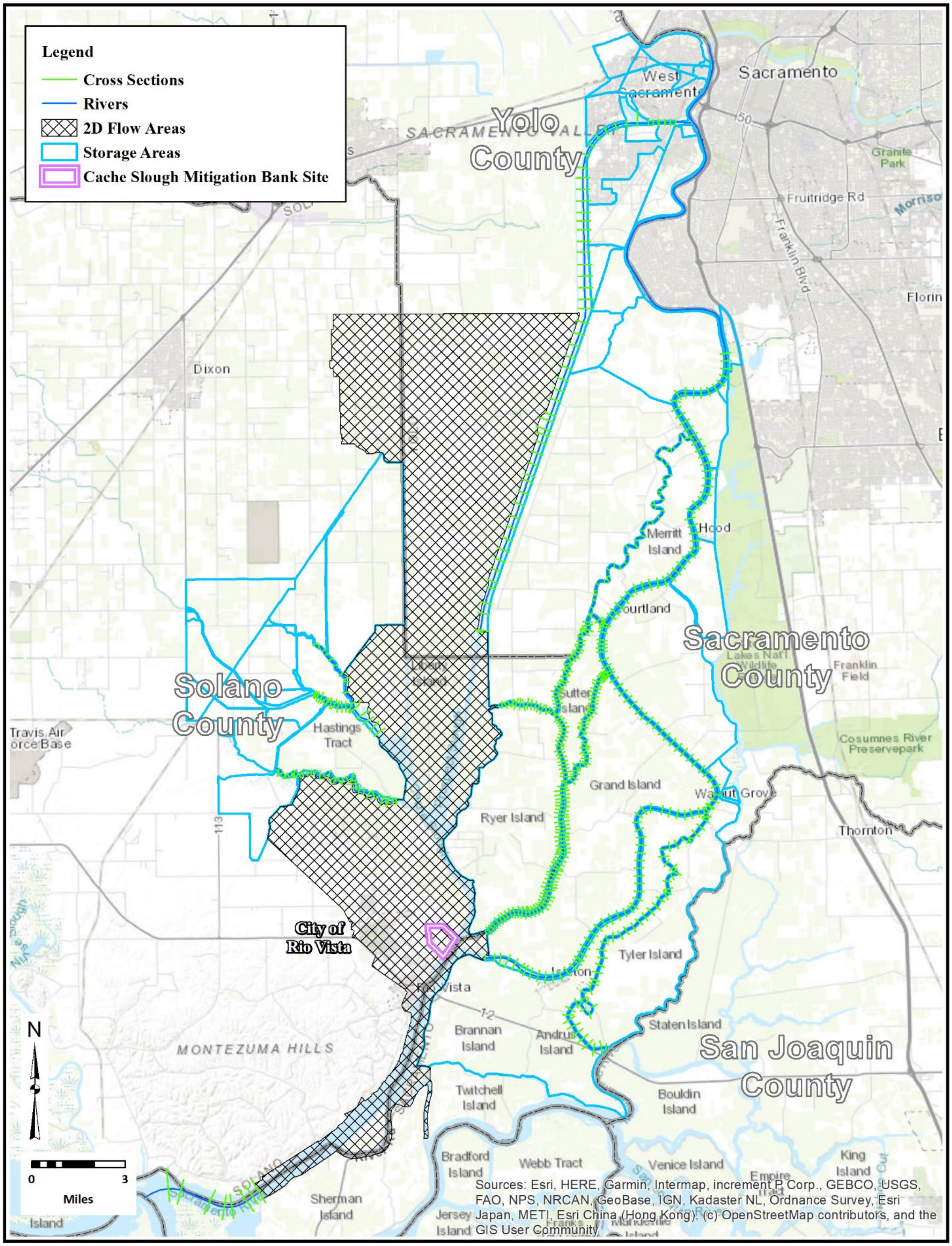

Figure 7. Tidal Hydraulic Model Schematic

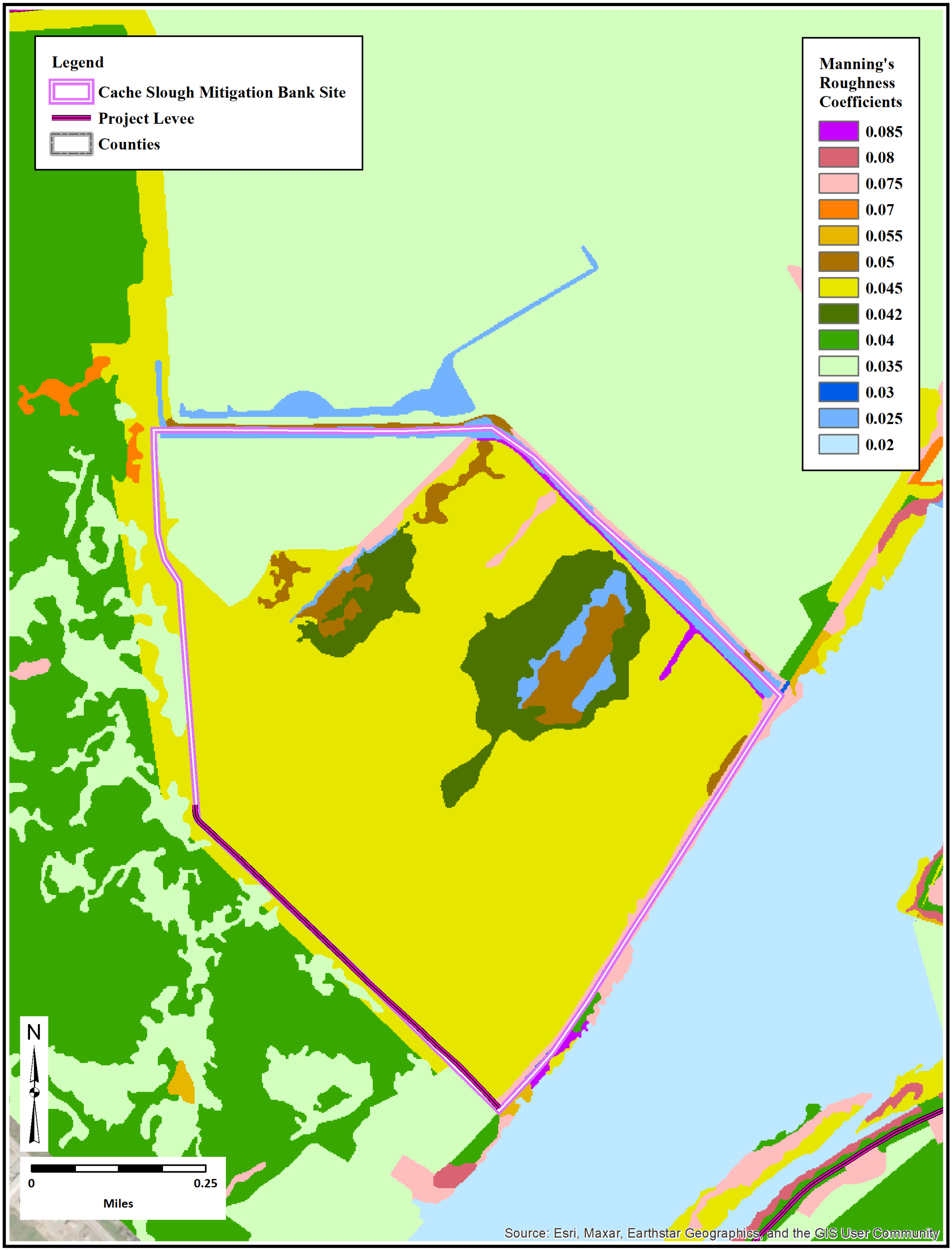

Figure 8. Without-Project Manning's Roughness Coefficients

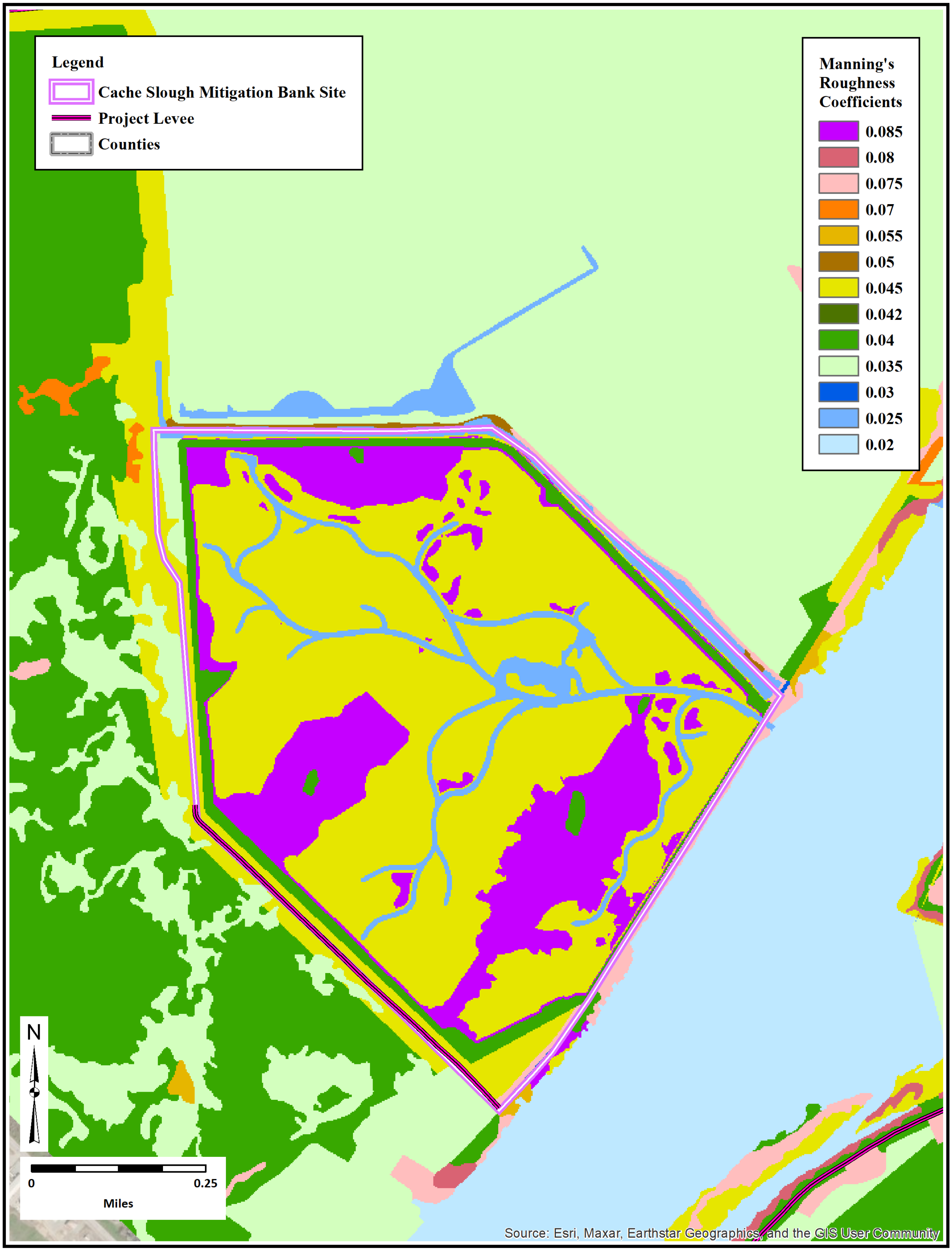

Figure 9. With-Project Manning's Roughness Coefficients

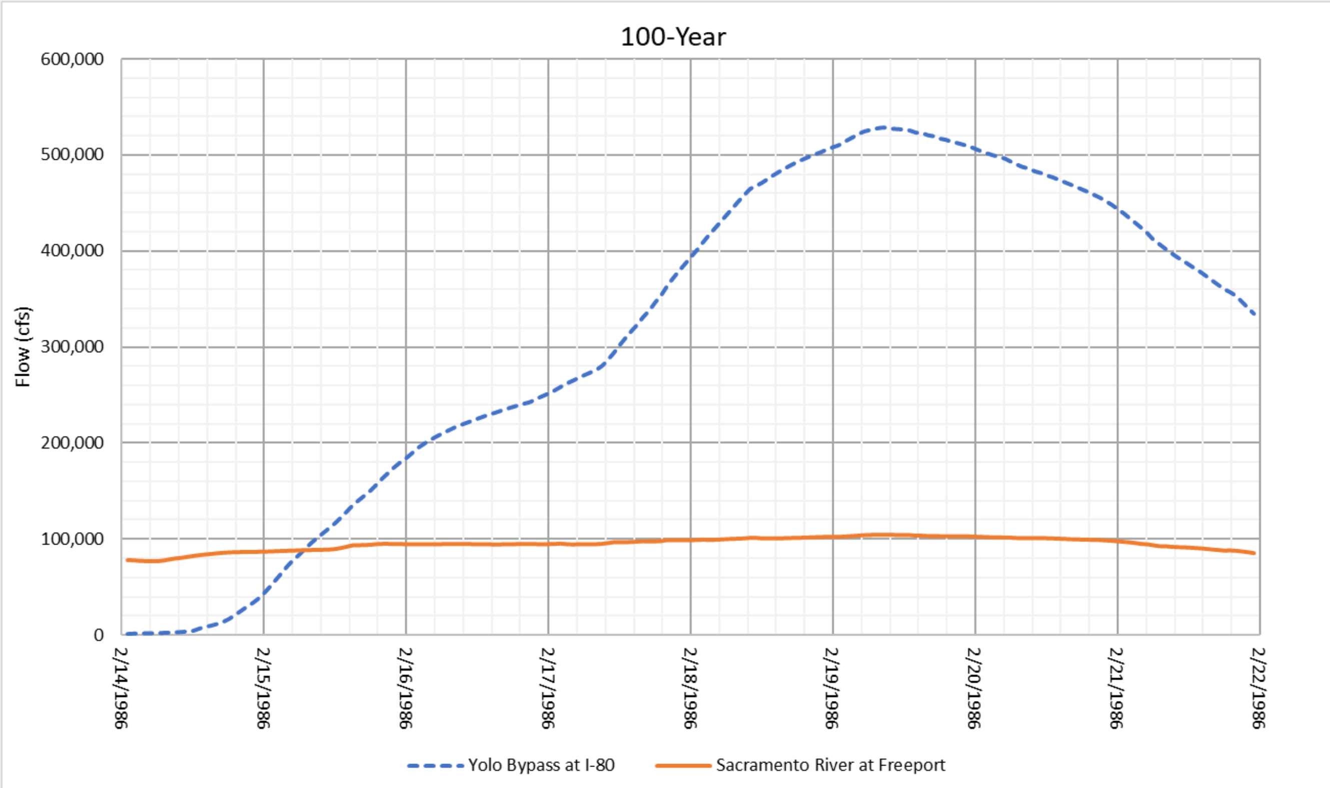

Figure 10. 100-Year Flow Hydrographs for Upstream Boundary Conditions

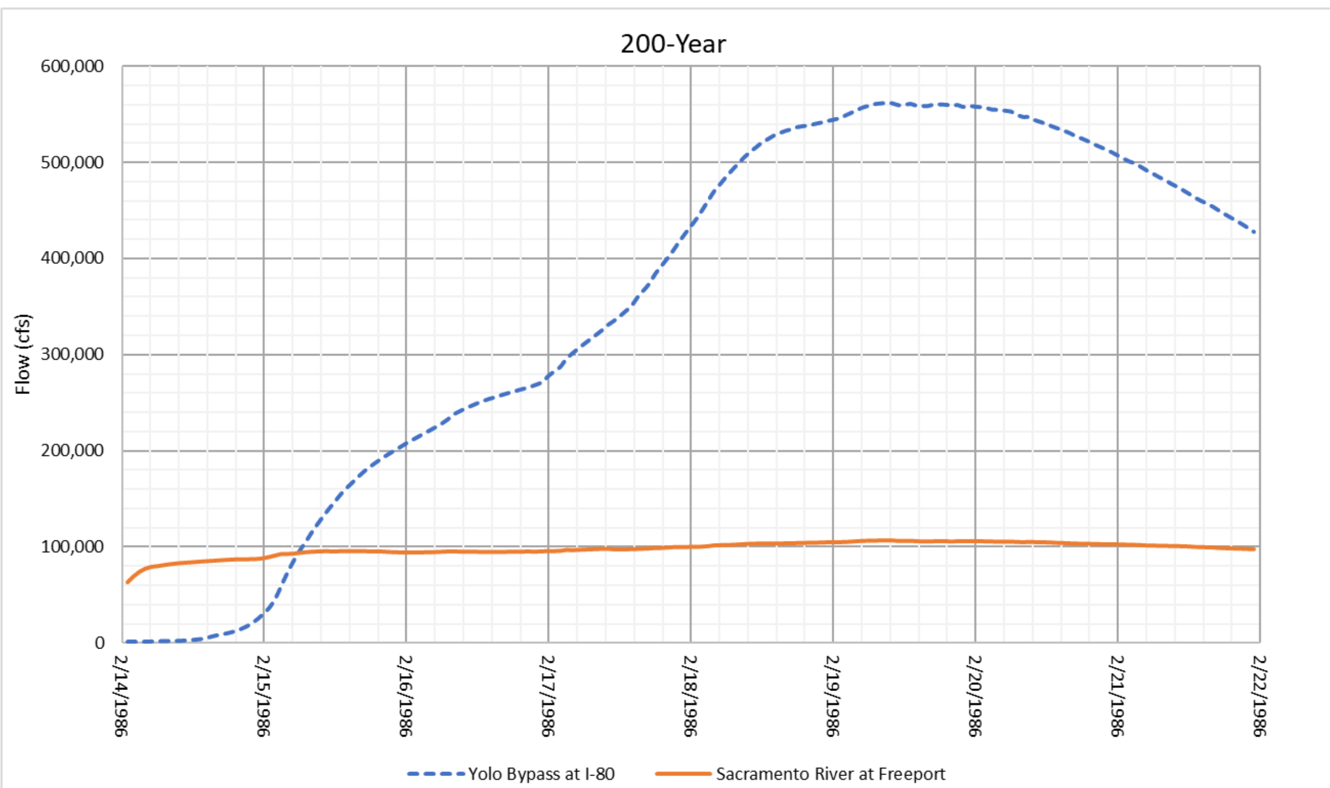

Figure 11. 200-Year Flow Hydrographs for Upstream Boundary Conditions

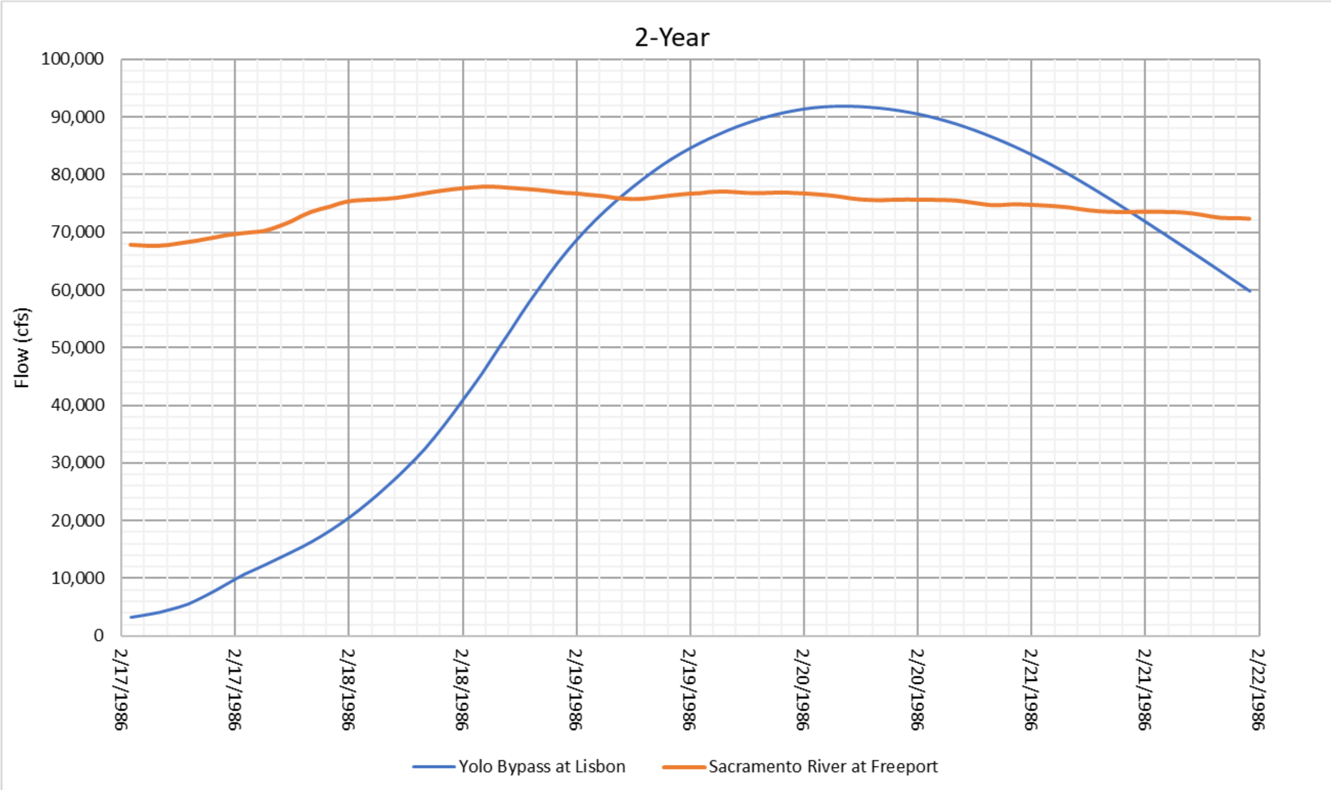

Figure 12. 2-Year Flow Hydrographs for Upstream Boundary Conditions

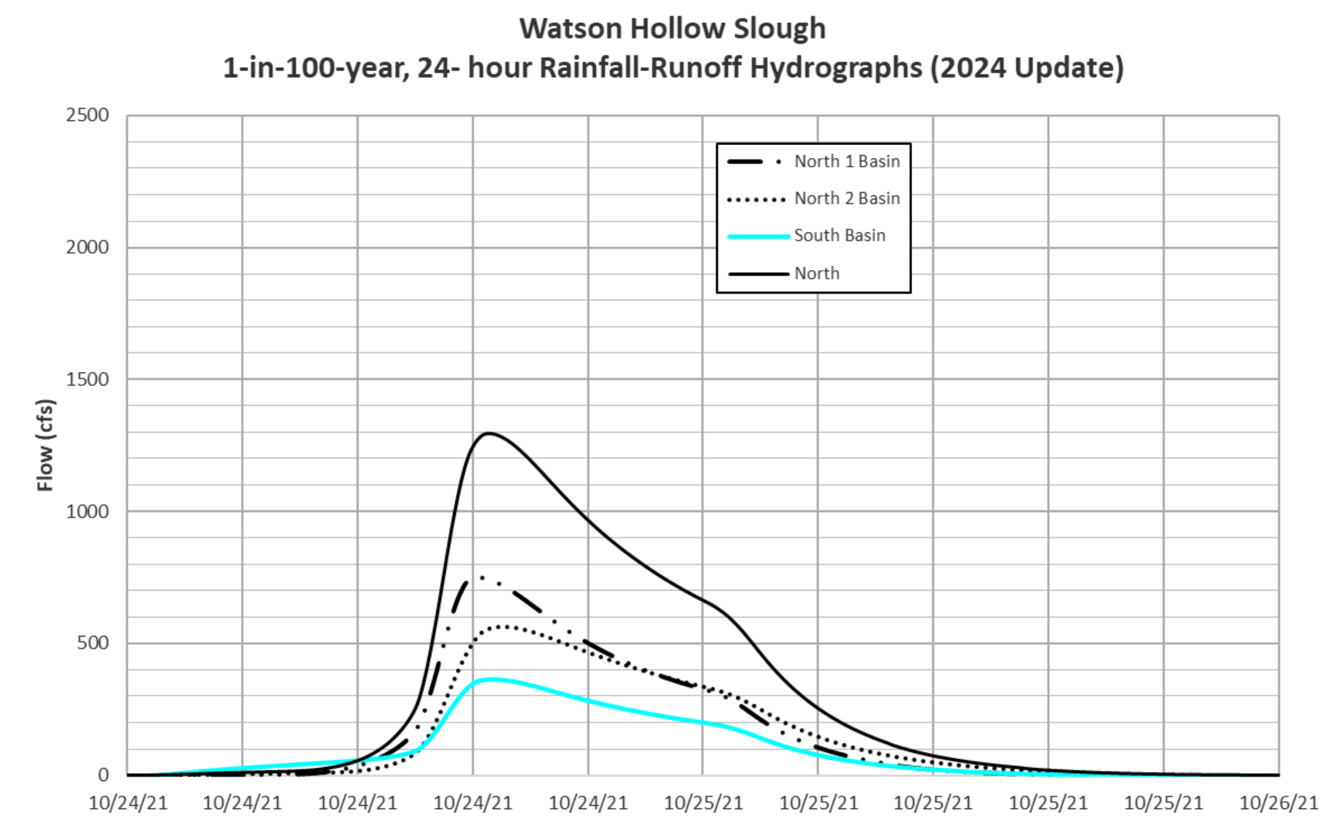

Figure 13. 100-Year Flow Hydrographs for Watson Hollow Slough Boundary Conditions

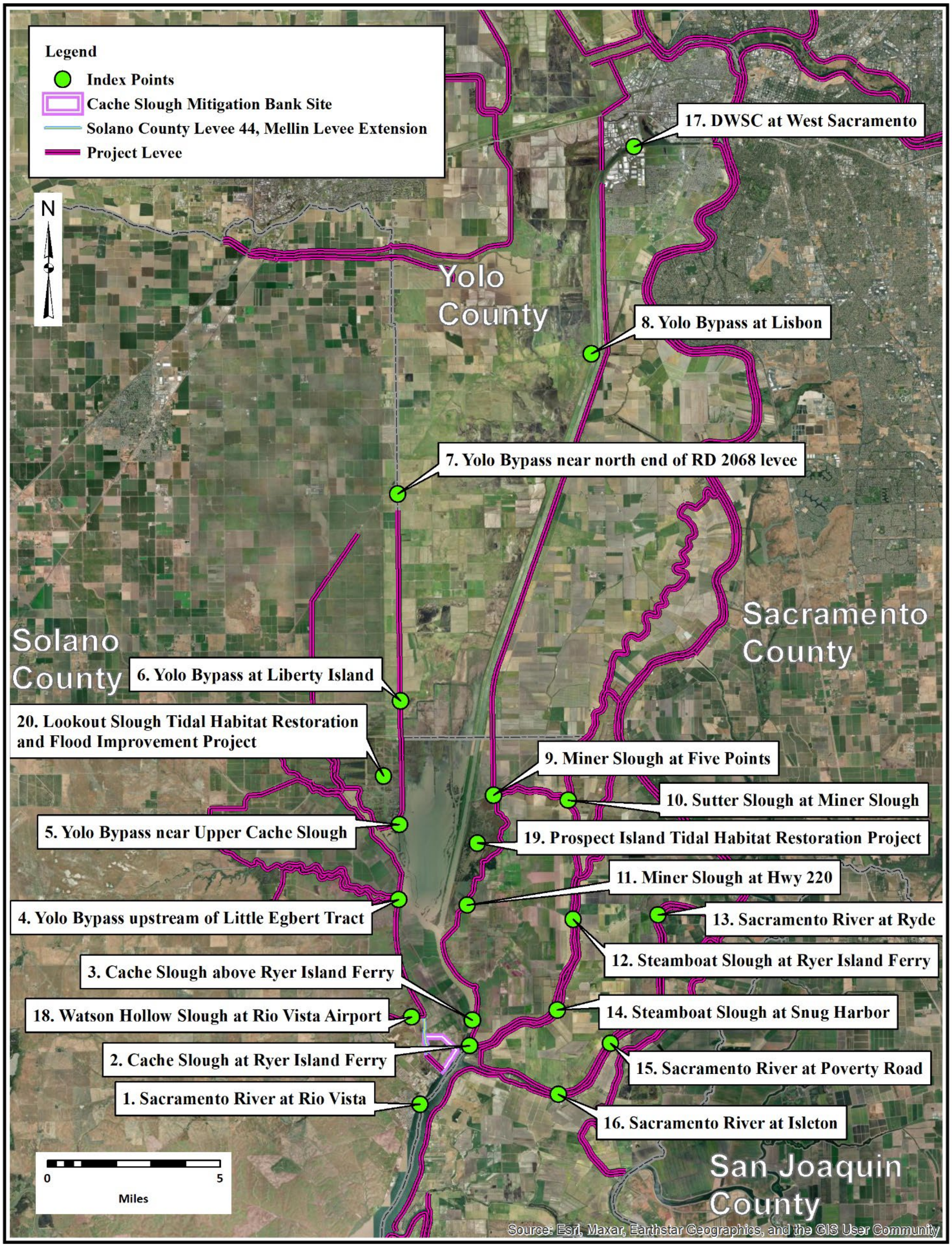

Figure 14. System Index Point Locations

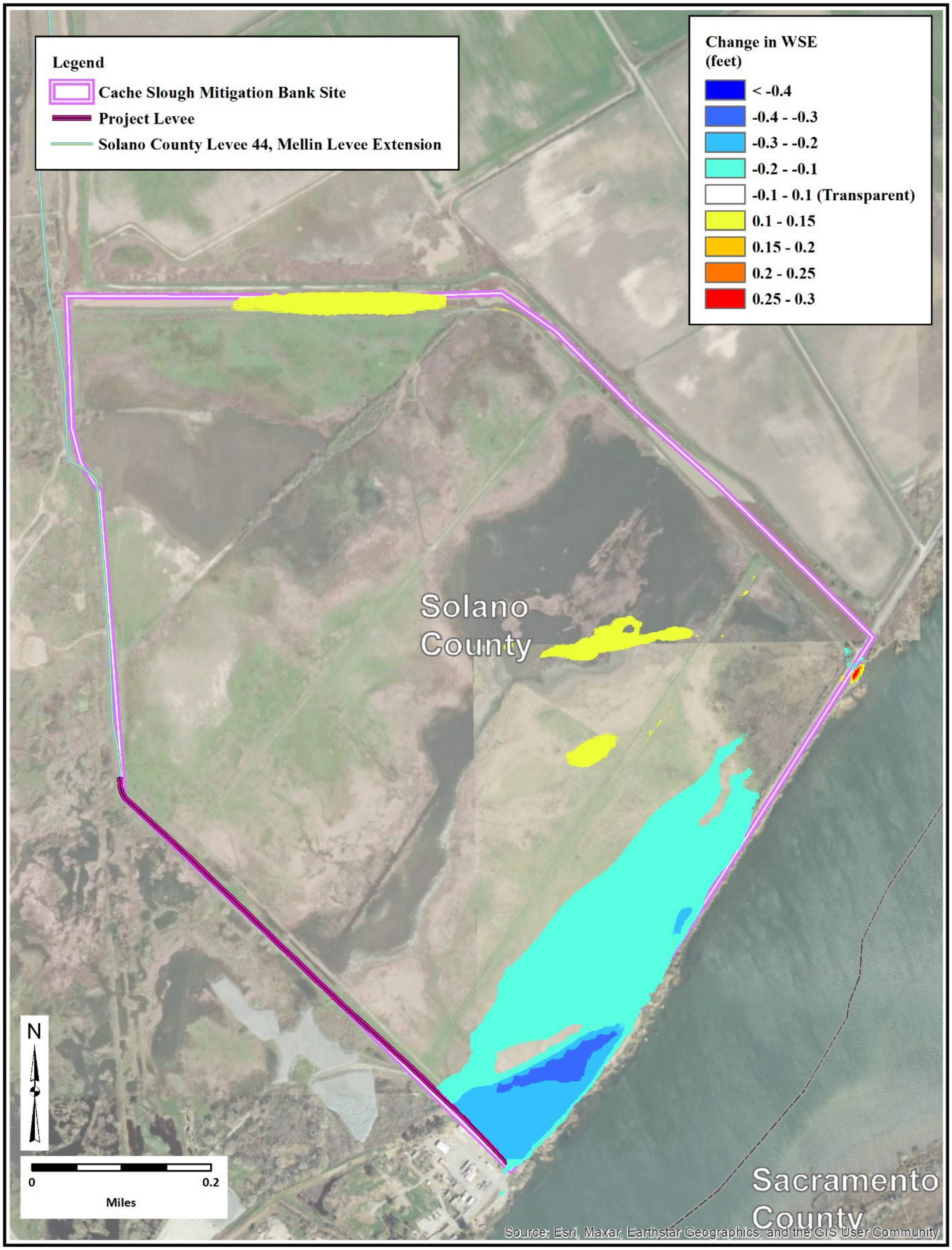

Figure 15. WSE Differences in Project Vicinity, 100-Year Flood Event

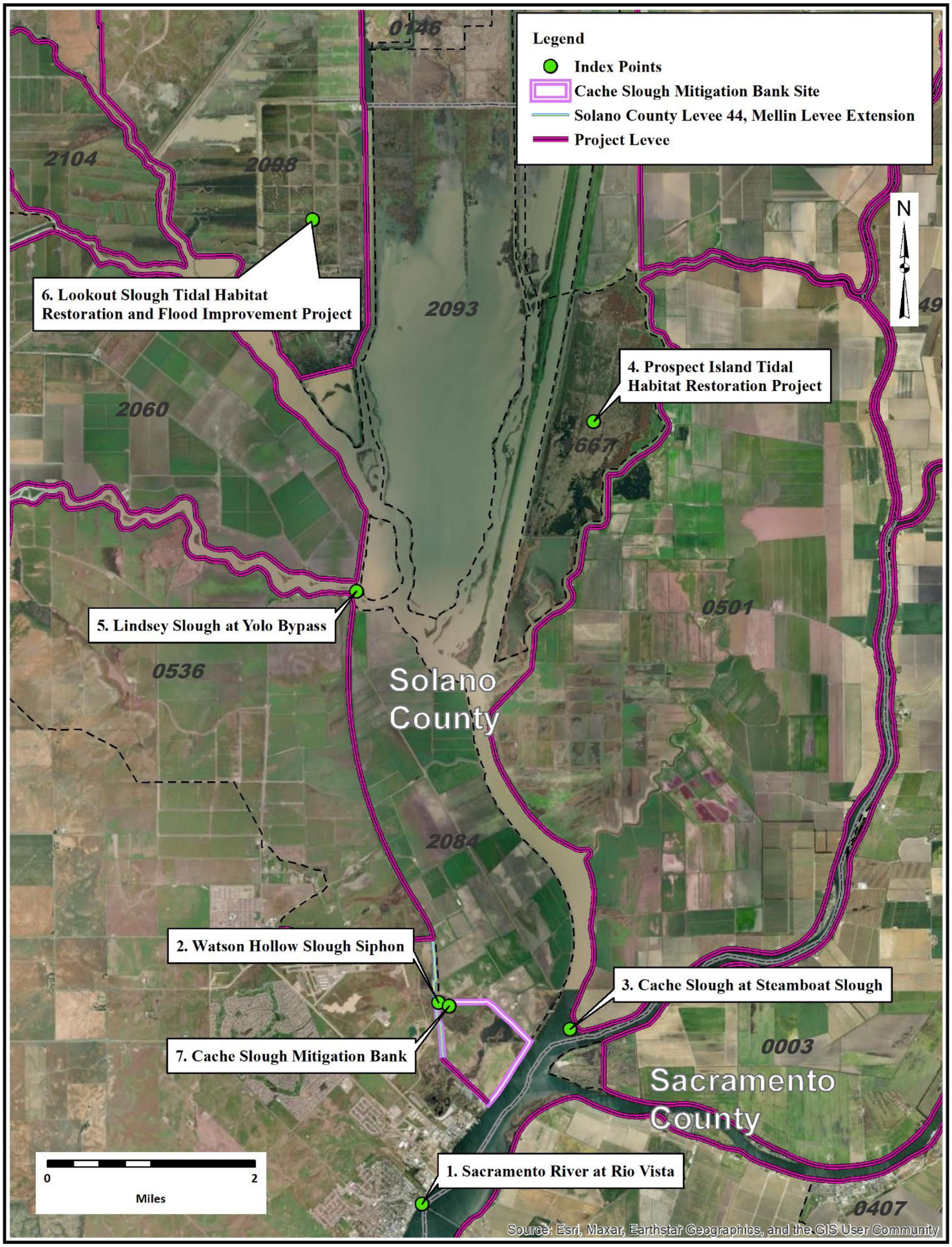

Figure 16. Tidal Index Point Locations

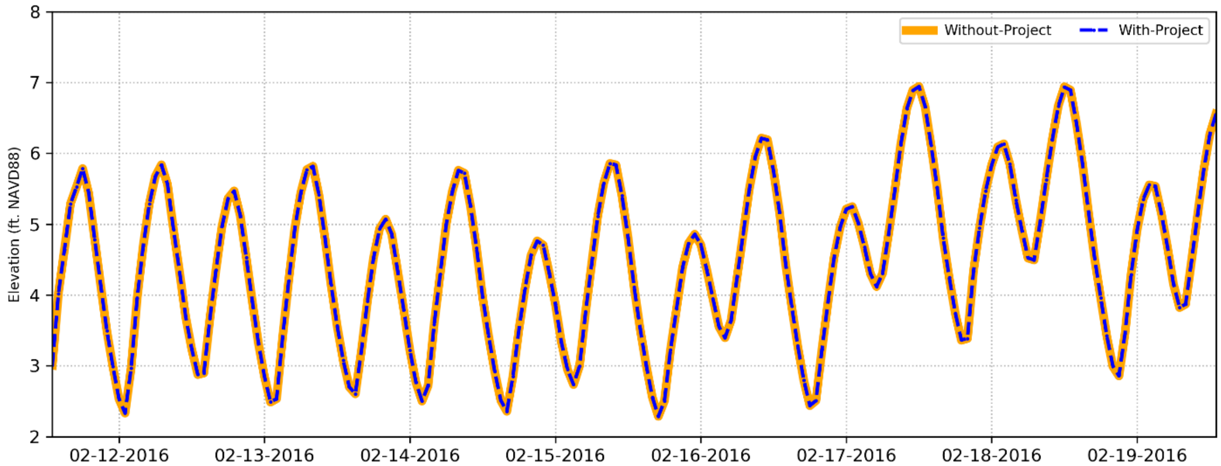

Figure 17. With- and Without-Project Tidal Stage Hydrograph, Sacramento River at Rio Vista, Winter Season

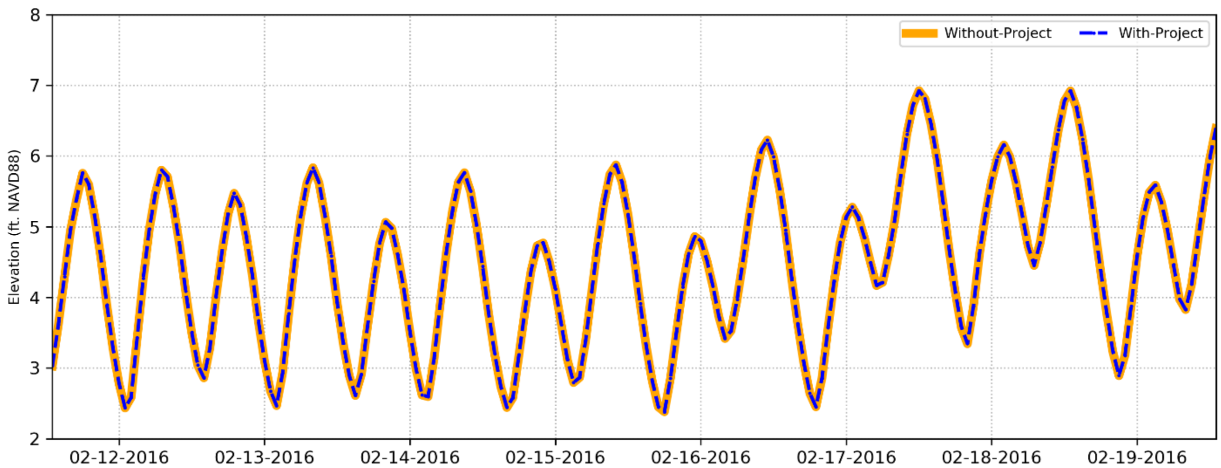

Figure 18. With- and Without-Project Tidal Stage Hydrograph, Watson Hollow Slough Siphon, Winter Season

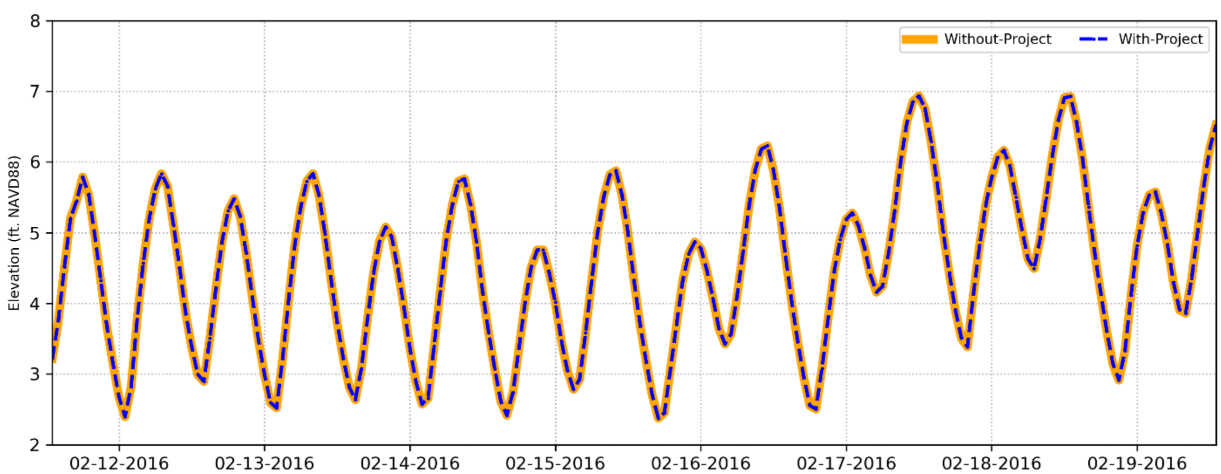

Figure 19. With- and Without-Project Tidal Stage Hydrograph, Cache Slough at Steamboat Slough, Winter Season

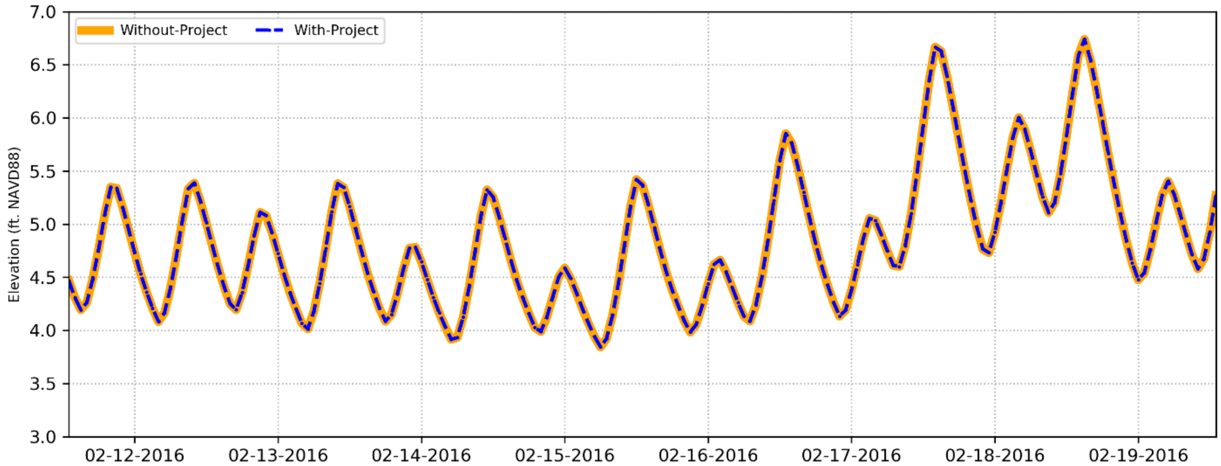

Figure 20. With- and Without-Project Tidal Stage Hydrograph, Prospect Island Tidal Habitat Restoration Project, Winter Season

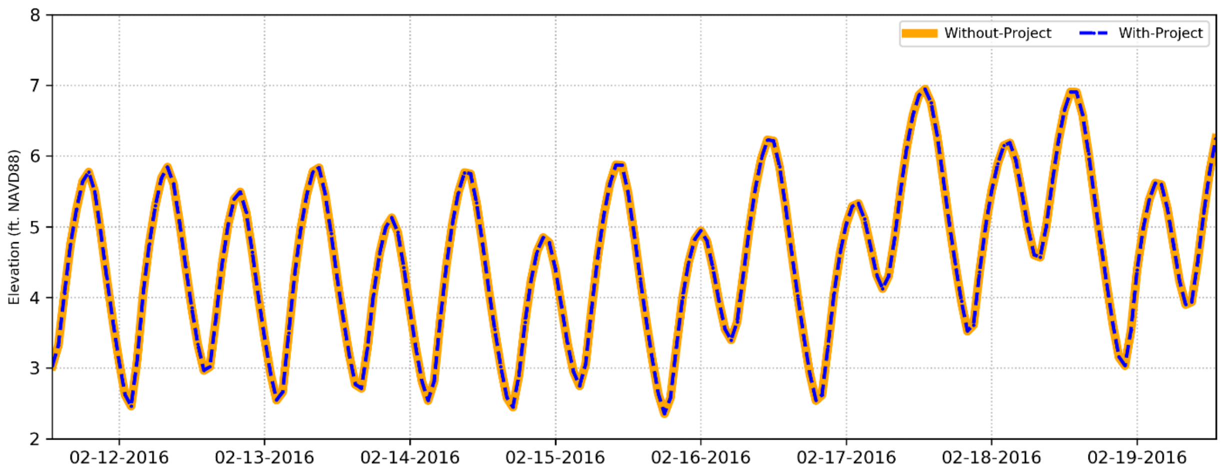

Figure 21. With- and Without-Project Tidal Stage Hydrograph, Lindsey Slough at Yolo Bypass, Winter Season

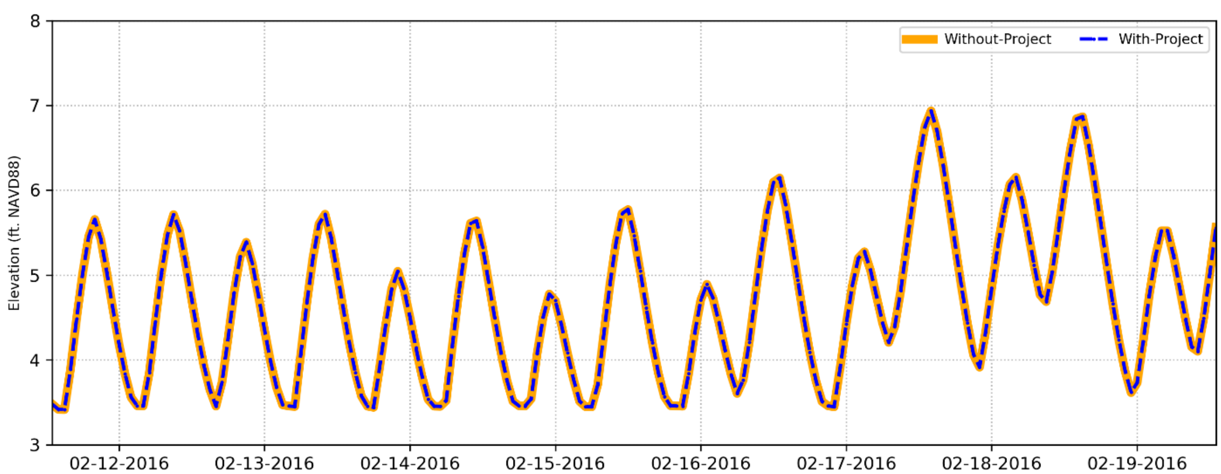

Figure 22. With- and Without-Project Tidal Stage Hydrograph, Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, Winter Season

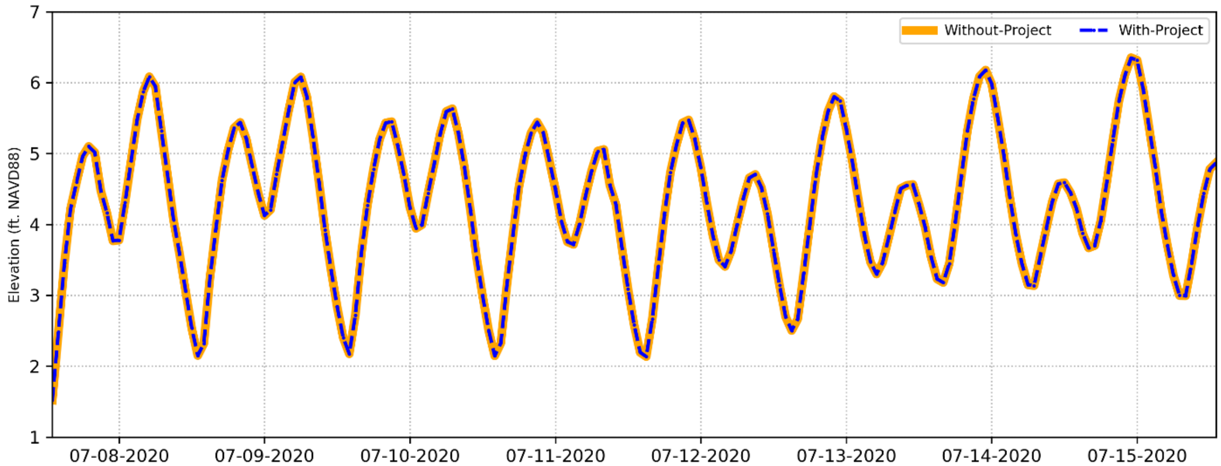

Figure 23. With- and Without-Project Tidal Stage Hydrograph, Sacramento River at Rio Vista, Agriculture Operation Season

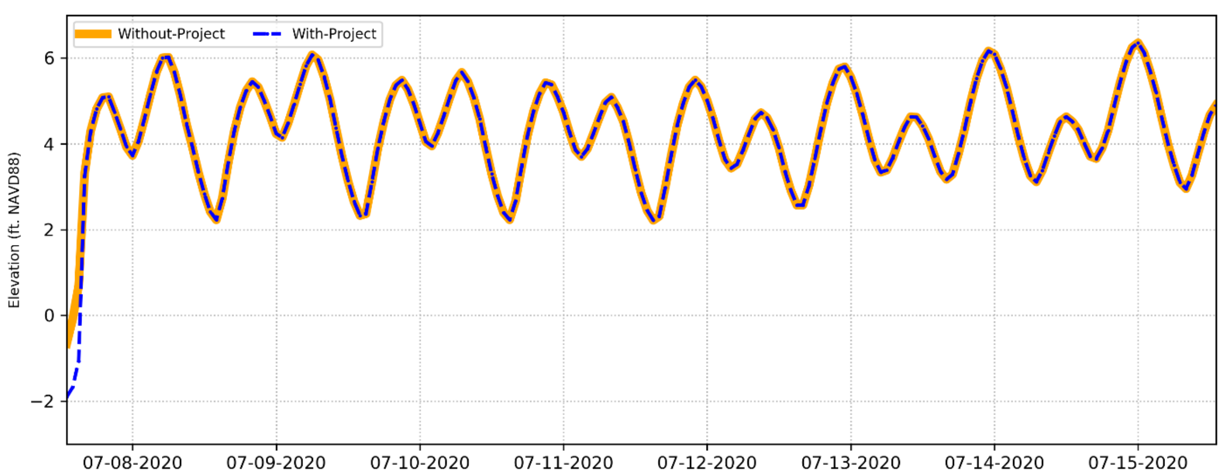

Figure 24. With- and Without-Project Tidal Stage Hydrograph, Watson Hollow Slough Siphon, Agriculture Operation Season

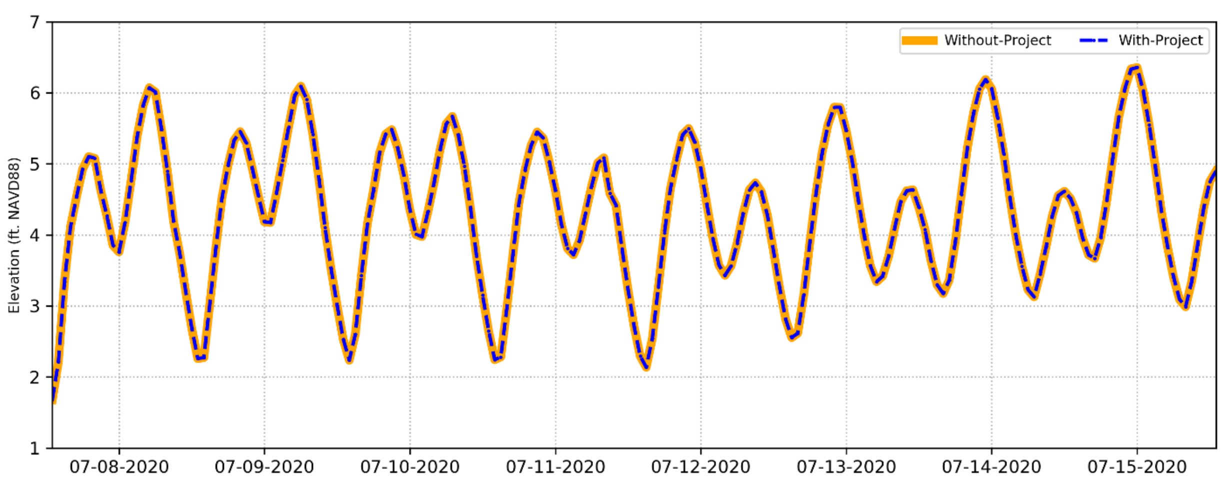

Figure 25. With- and Without-Project Tidal Stage Hydrograph, Cache Slough at Steamboat Slough, Agriculture Operation Season

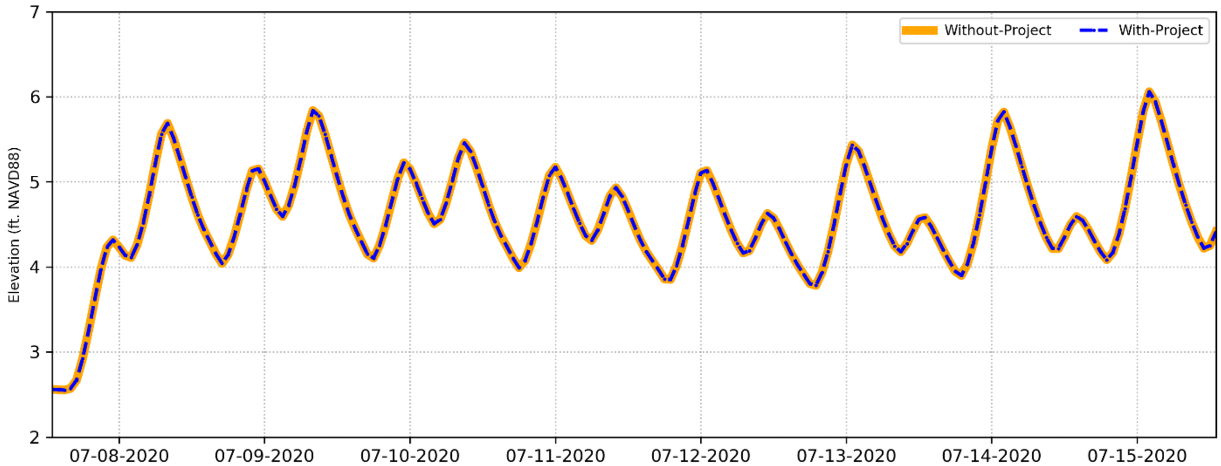

Figure 26. With- and Without-Project Tidal Stage Hydrograph, Prospect Island Tidal Habitat Restoration Project, Agriculture Operation Season

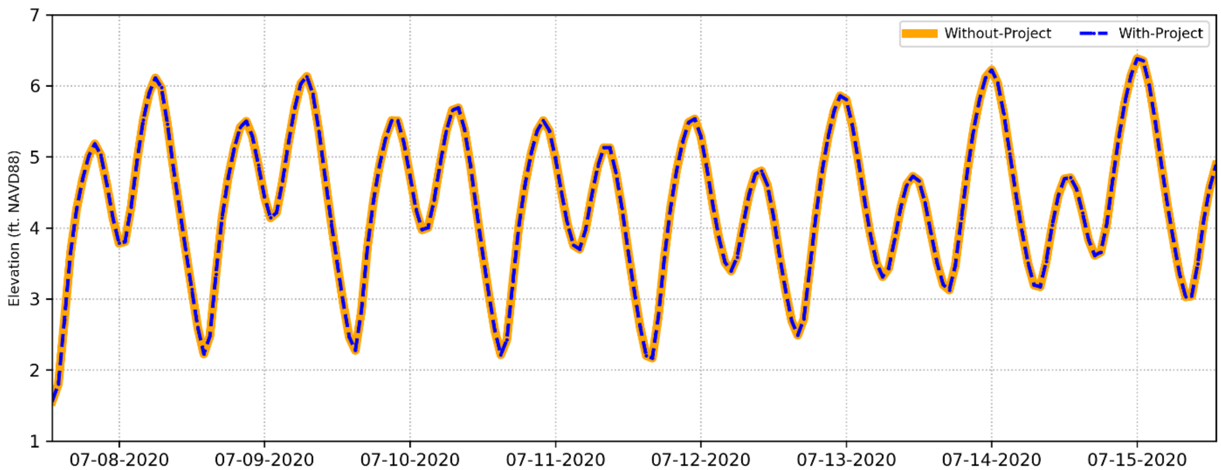

Figure 27. With- and Without-Project Tidal Stage Hydrograph, Lindsey Slough at Yolo Bypass, Agriculture Operation Season

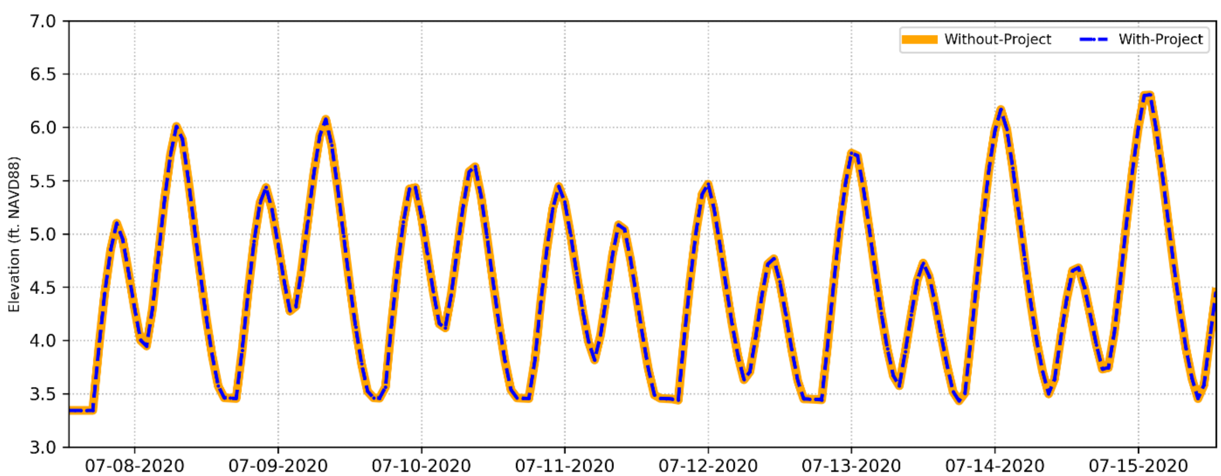

Figure 28. With- and Without-Project Tidal Stage Hydrograph, Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, Agriculture Operation Season

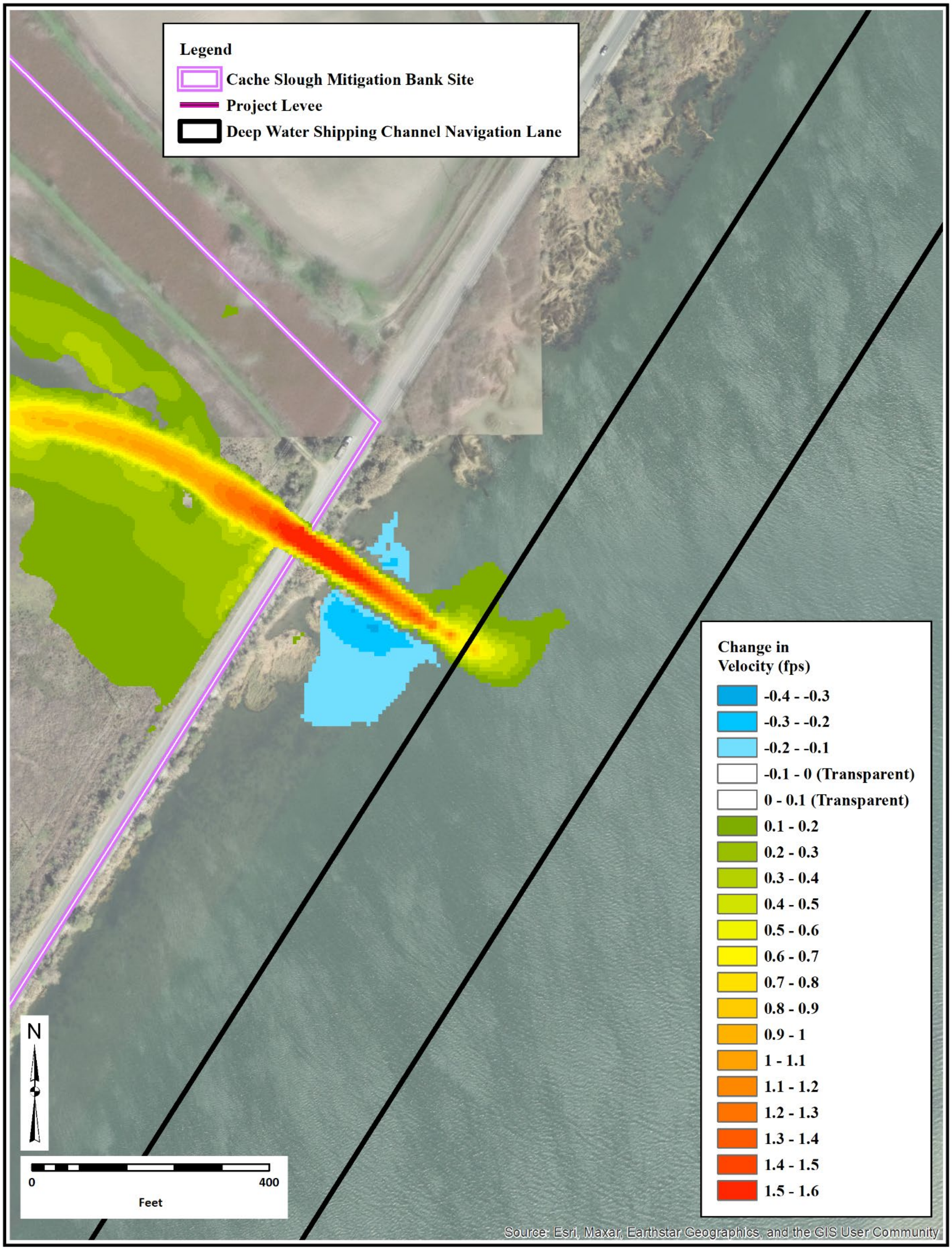

Figure 29. Changes to Velocities at DWSC Navigation Lane during an Ebb Tide (2/18/2016, 3:00)

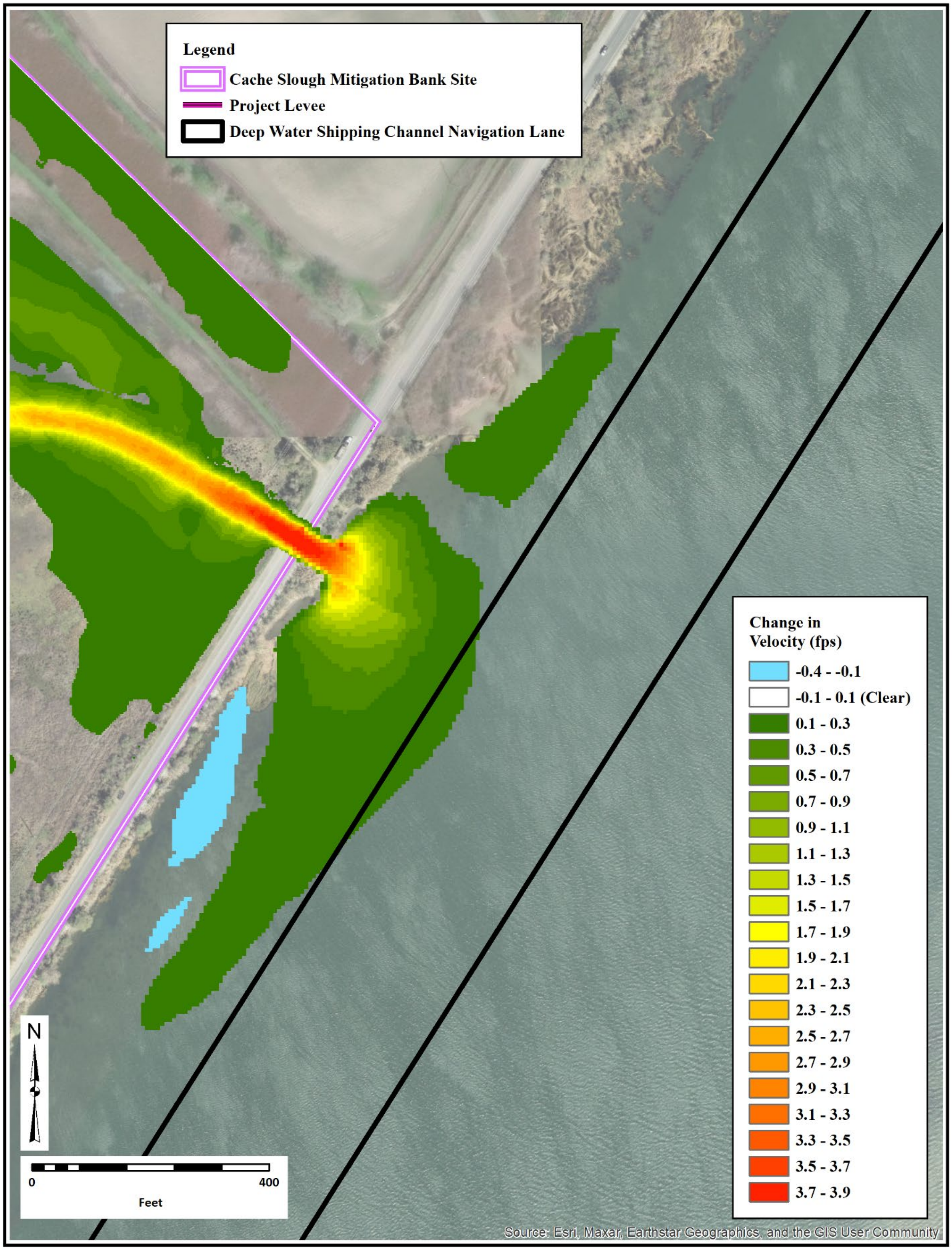

Figure 30. Changes to Velocities at DWSC Navigation Lane during a Flood Tide (2/18/2016, 11:00)

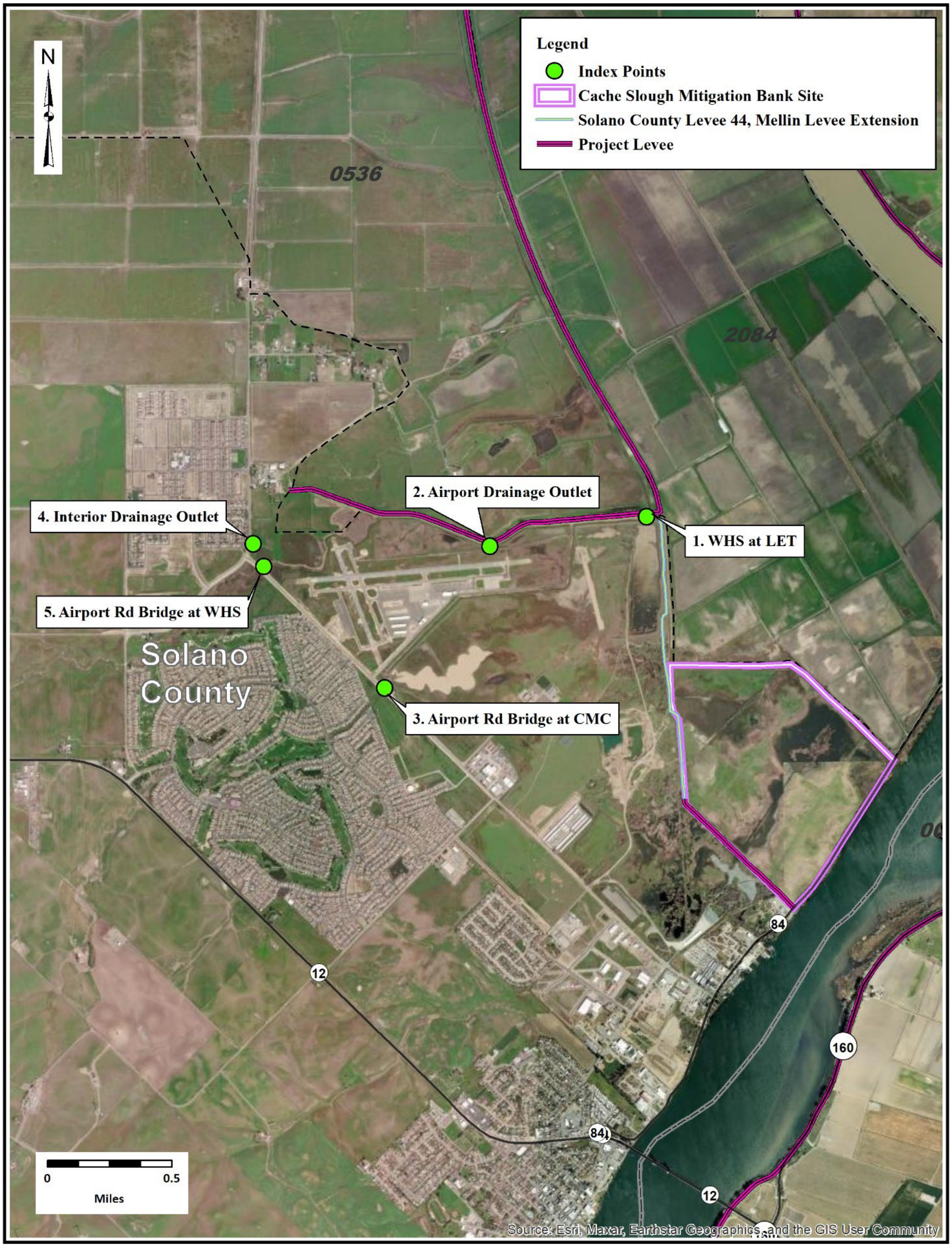

Figure 31. Watson Hollow Slough Index Point Locations

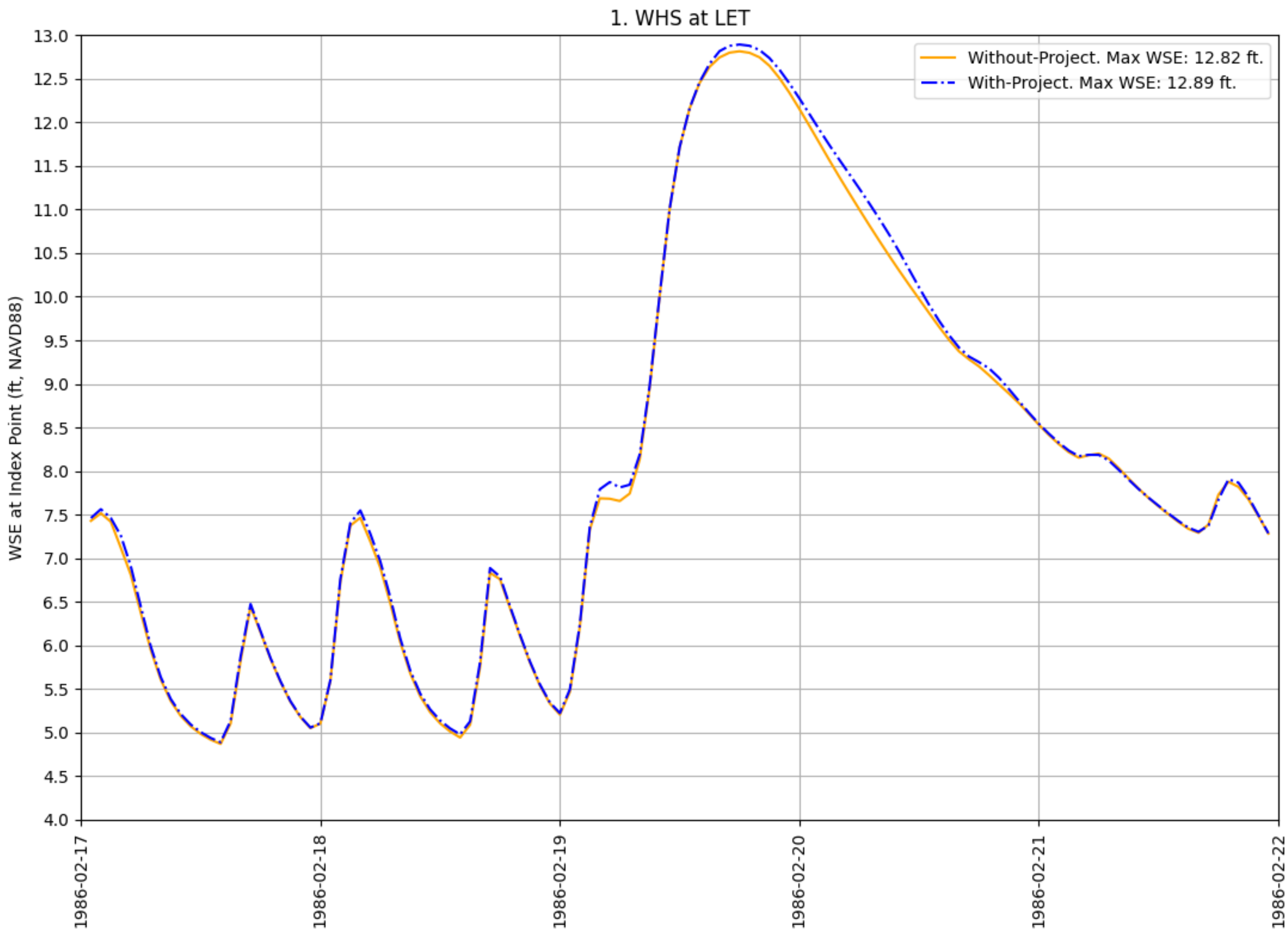

Figure 32. With- and Without-Project Stage Hydrograph at Index Point 1, 100-Year Rainfall Event

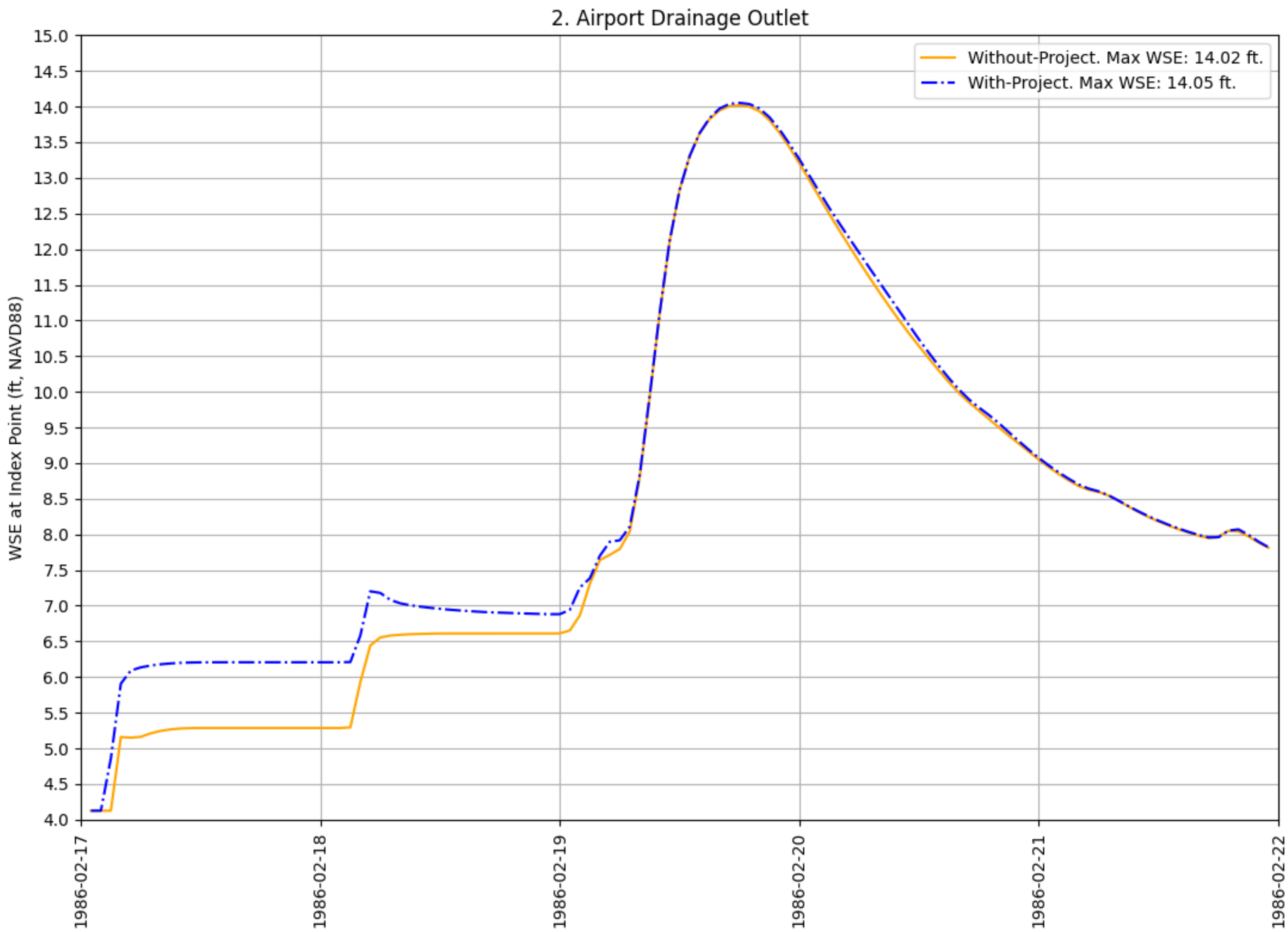

Figure 33. With- and Without-Project Stage Hydrograph at Index Point 2, 100-Year Rainfall Event

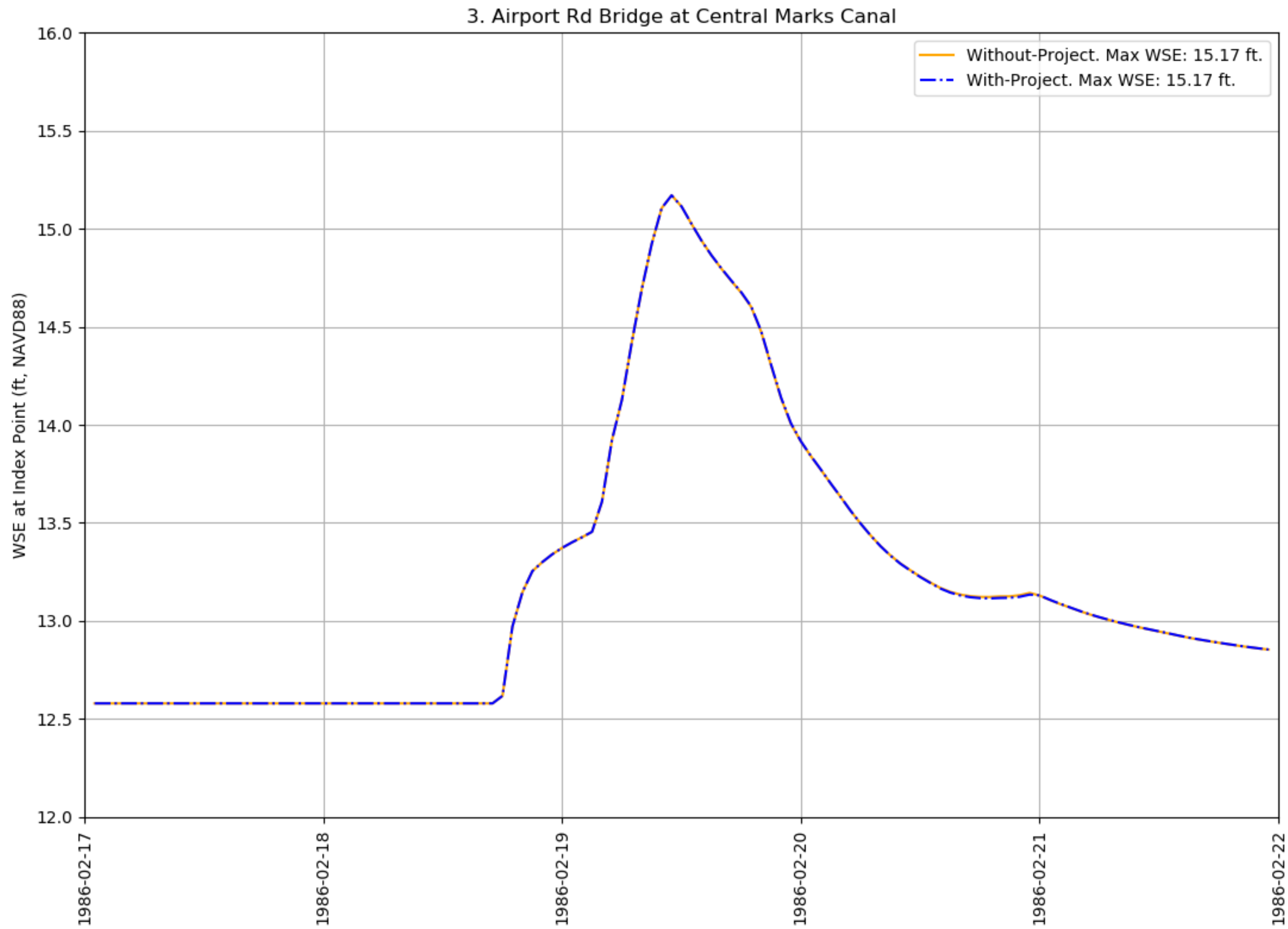

Figure 34. With- and Without-Project Stage Hydrograph at Index Point 3, 100-Year Rainfall Event

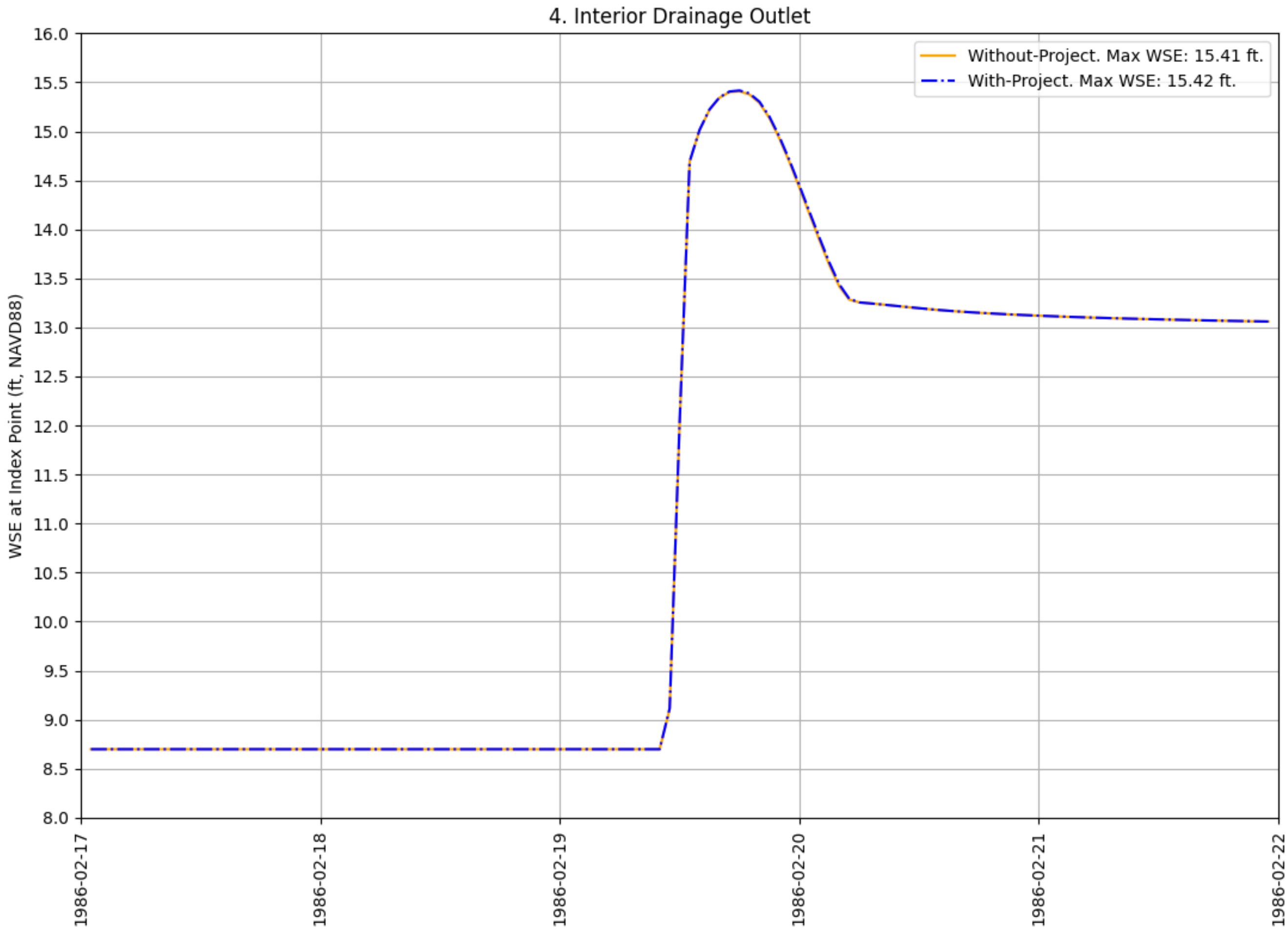

Figure 35. With- and Without-Project Stage Hydrograph at Index Point 4, 100-Year Rainfall Event

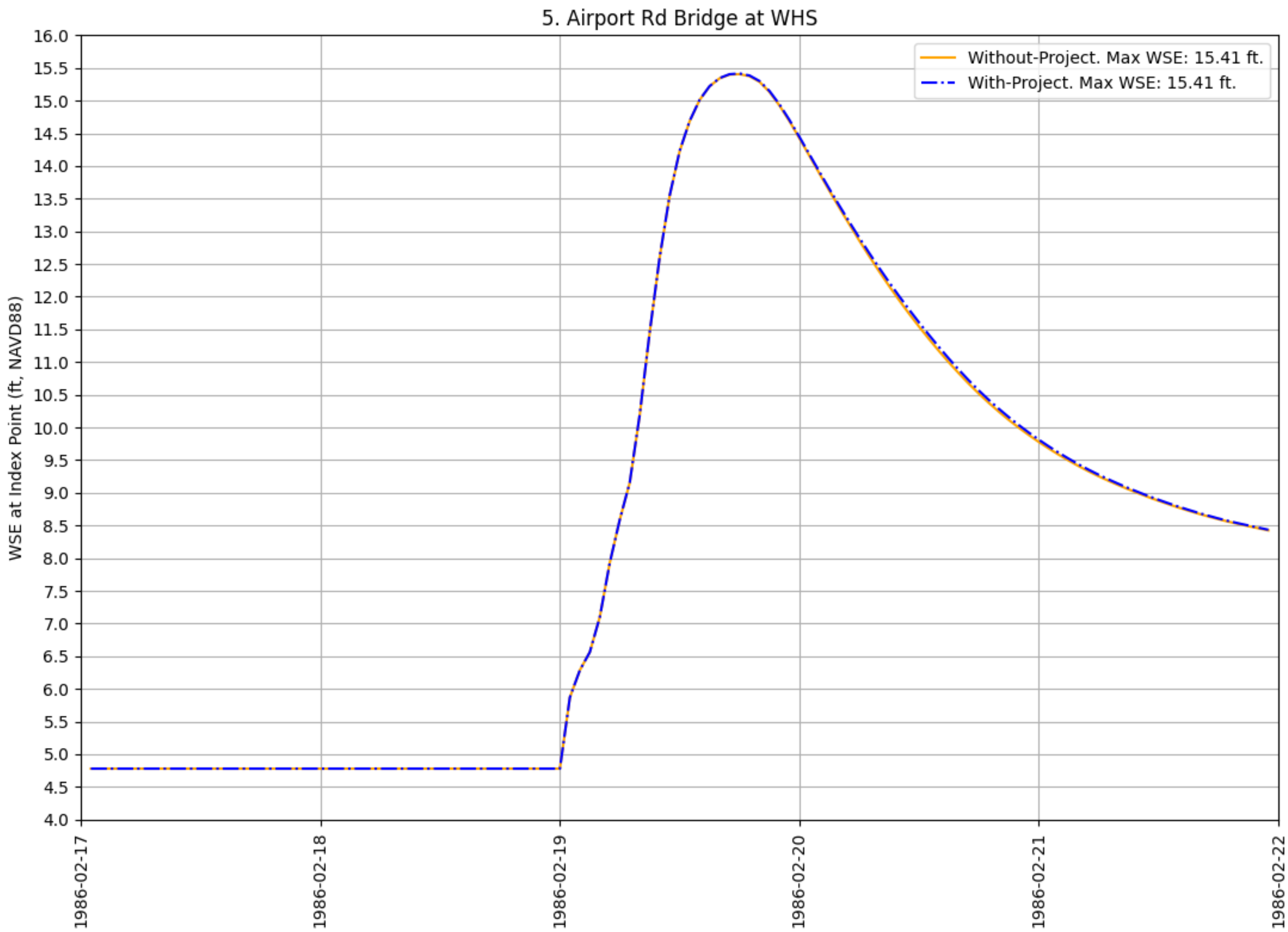

Figure 36. With- and Without-Project Stage Hydrograph at Index Point 5, 100-Year Rainfall Event

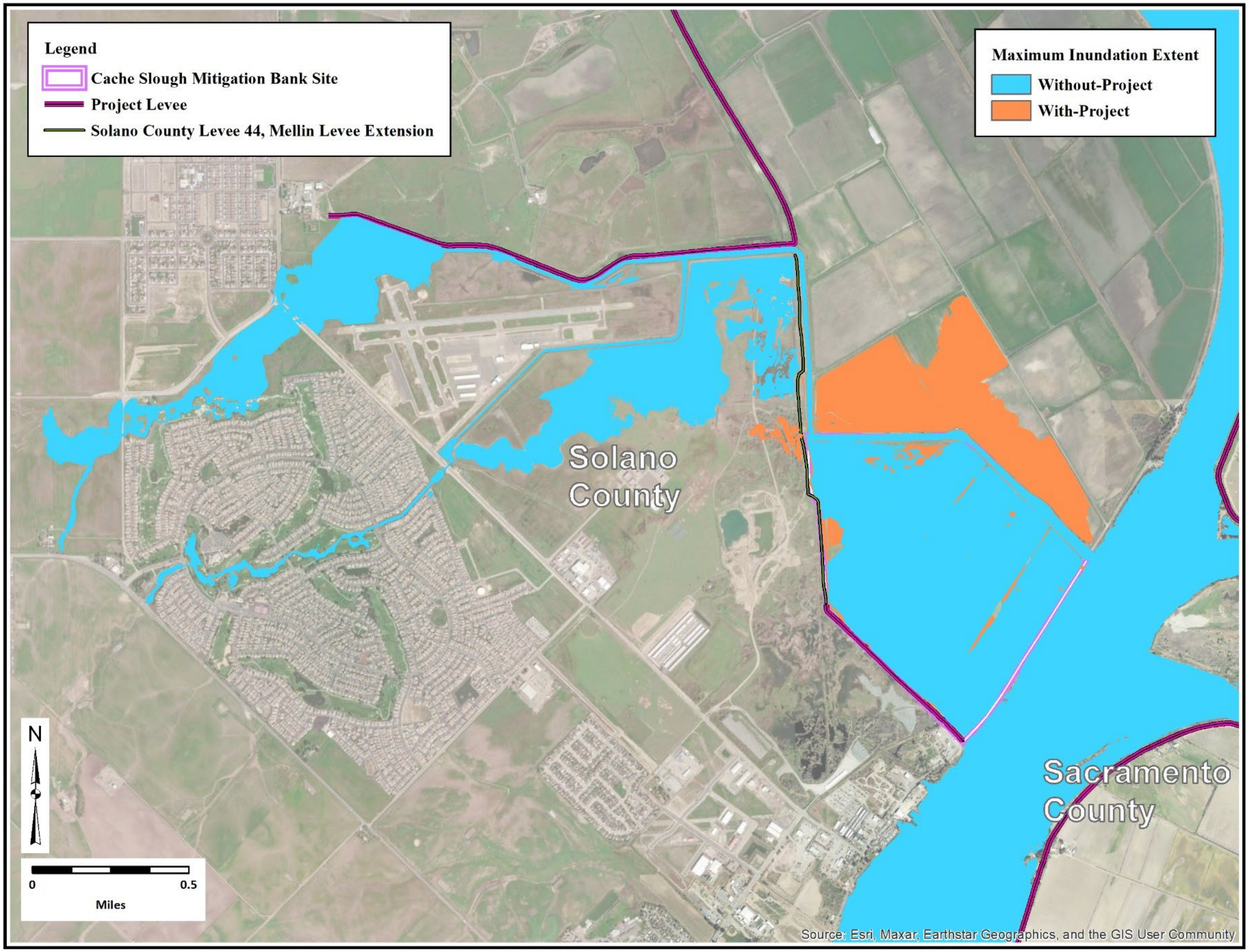

Figure 37. With- and Without-Project Maximum Flood Extent in Project Vicinity, 100-Year Rainfall Event