Appendix R – Hydrologic and Hydraulic Risk and Uncertainty Analysis: Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, Environmental Science Associates, August 2019.

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DRAFT HYDROLOGIC AND HYDRAULIC RISK AND UNCERTAINTY ANALYSIS

LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT

Prepared For:

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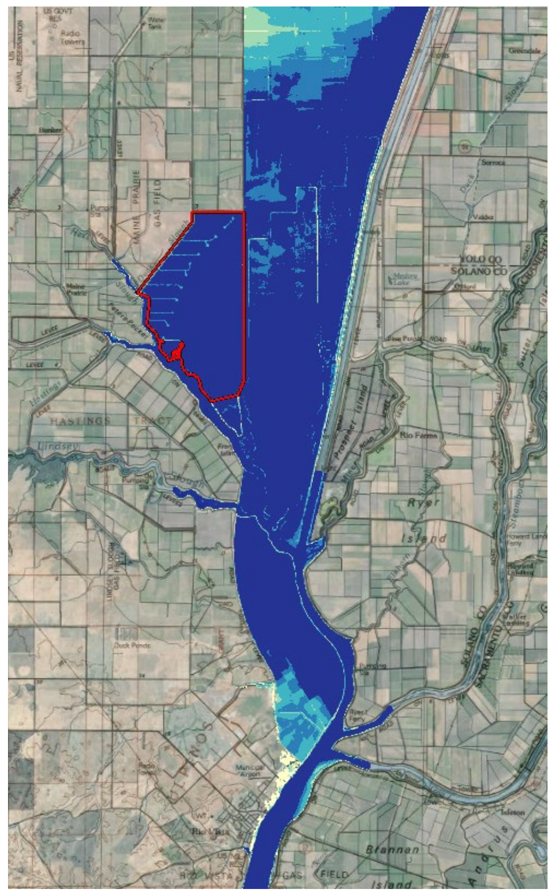
Date: August 2019



DRAFT HYDROLOGIC AND HYDRAULIC RISK AND UNCERTAINTY ANALYSIS

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August 2019

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LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT

Draft Hydrologic and Hydraulic Risk and Uncertainty Analysis

Executive Summary

The Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project), if approved, will create approximately 3,000 acres of natural freshwater tidal marsh in the Cache Slough Complex in the northern Sacramento-San Joaquin Delta (**Figure ES-1**) and increase the regional flood conveyance capacity of the Yolo Bypass. The Project is being funded by the California Department of Water Resources (DWR) to meet multiple objectives:

- To meet goals outlined in the State of California's Bay Delta Conservation Plan (BDCP) as well as the U.S. Fish and Wildlife Service's (FWS) Biological Opinion (BiOp) issued as part of the Long-Term Operational Criteria and Plan (OCAP) for coordination of the Central Valley Project and State Water Project. The Project is within the priority habitat restoration areas delineated in the 2008 FWS BiOp Delta Smelt Crediting Decision Model, and will create creditable acres for Delta Smelt that will satisfy DWR's obligations under the Delta Smelt BiOp and salmonids under the Salmonid BiOp.
- To meet regional flood management objectives to increase the conveyance capacity of the Yolo Bypass in a manner that is consistent with the 2017 DWR Sacramento Basin-Wide Feasibility Study (BWFS). By setting back the existing State-Federal levee along the west side of the Yolo Bypass, the Project will provide flood storage and reduce upstream flood stages in the Yolo Bypass.

The Project alterations would result in no adverse impacts to flood stages within the system for the range of hydrologic loadings analyzed. The region-wide system models have also been reviewed to verify that no significant change in the flow distribution at Fremont Weir or the Sacramento Weir would occur as a result of the Project. As the hydraulic impacts of the Project are localized, and generally result in stage decreases for the design events under consideration (including the 1957 authorized design flow), the Project's potential to transfer risk from one part of the system to another is considered to be negligible. Consequently, a detailed system performance calculation using HEC-FDA is not considered to be warranted. The deterministic analysis conducted for the Project is considered sufficient for describing the overall system performance for the without- and with-Project conditions and verifies that the reduction in assurance posed by the Project is negligible.

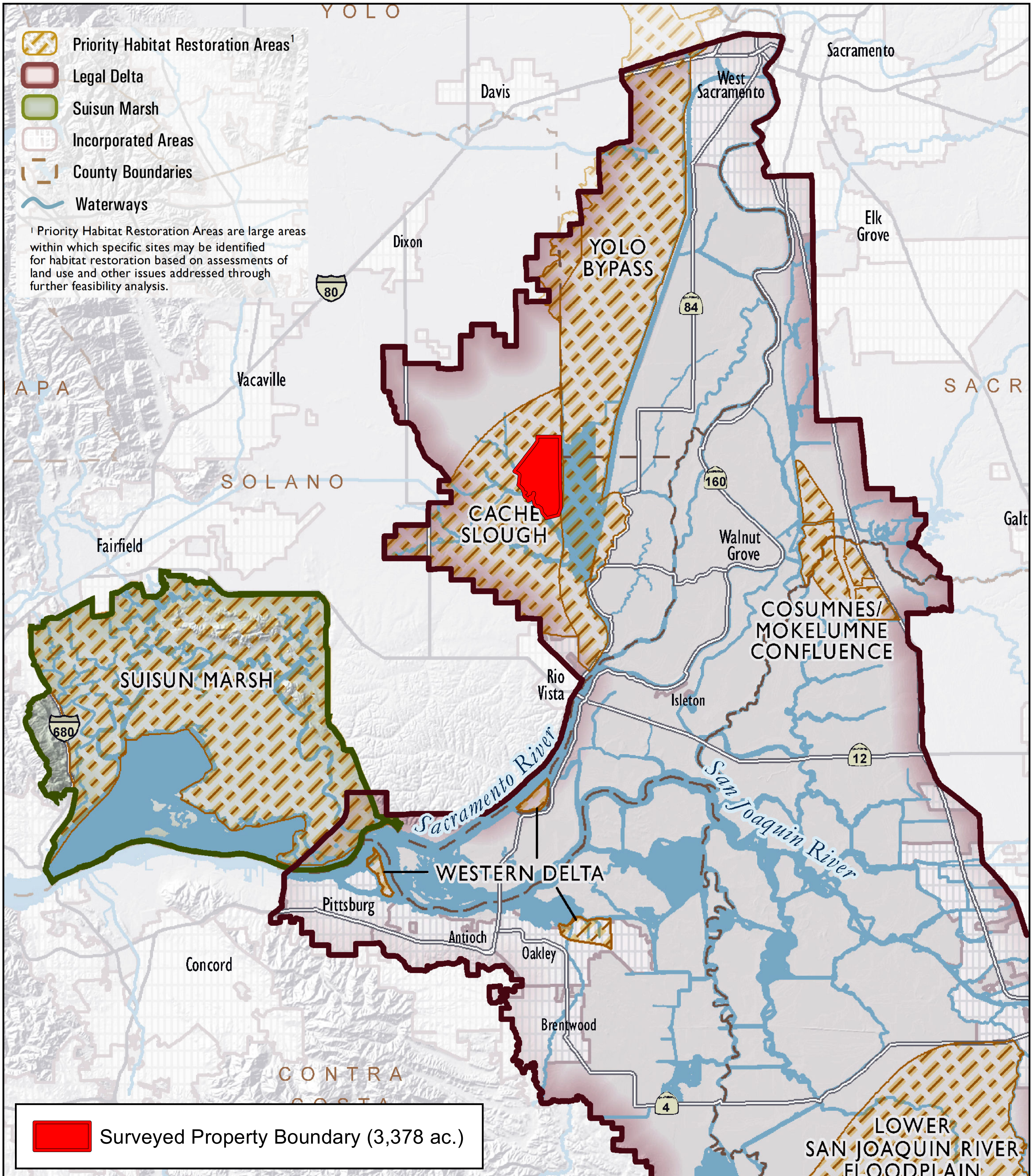

Figure ES-1
Location Map

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 3 6 12
Miles

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
Delta Stewardship Council, 2013

Prepared by:

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F01_Location_Map.mxd

LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT

Hydrologic and Hydraulic Risk and Uncertainty Analysis

Introduction

The Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Project) will create approximately 3,000 acres of natural freshwater tidal marsh in the Cache Slough Complex in the northern Sacramento-San Joaquin Delta (**Figure 1**), and increase the regional flood conveyance capacity of the Yolo Bypass. The Project is being funded by the California Department of Water Resources (DWR) to meet multiple objectives:

- To meet goals outlined in the State of California's Bay Delta Conservation Plan (BDCP) as well as the U.S. Fish and Wildlife Service's (FWS) Biological Opinion (BiOp) issued as part of the Long-Term Operational Criteria and Plan (OCAP) for coordination of the Central Valley Project and State Water Project. The Project is within the priority habitat restoration areas delineated in the 2008 FWS BiOp Delta Smelt Crediting Decision Model, and will create creditable acres for Delta Smelt that will satisfy DWR's obligations under the Delta Smelt BiOp and salmonids under the Salmonid BiOp.

- To meet regional flood management objectives to increase the conveyance capacity of the Yolo Bypass in a manner that is consistent with the 2017 DWR Sacramento Basin-Wide Feasibility Study (BWFS). By setting back the existing State-Federal levee along the west side of the Yolo Bypass, the Project will provide flood storage and reduce upstream flood stages in the Yolo Bypass.

DWR contracted EIP III Credit Co., LLC (EIP) to develop and, if approved, implement the Project as a multi-benefit project targeting both habitat restoration and flood risk reduction. Environmental Science Associates (ESA) is a subconsultant to EIP responsible for hydraulic analyses on the Project. This report documents the methods, data, and assumptions used to describe uncertainty in the model predictions and potential for the project to transfer risk to other parts of the system. This report also describes the difference in performance between a reduced alternative project configuration suggested by DWR (referred to in this report as the Delta Smelt Crediting, or DSC Project), and the preferred Project alternative.

Documentation of the hydrologic and hydraulic models developed for the respective flood and ecosystem restoration objectives used as to support this analysis have been prepared separately as part of the Project's overall Basis of Design Report documentation (ESA, 2019a and 2019b).

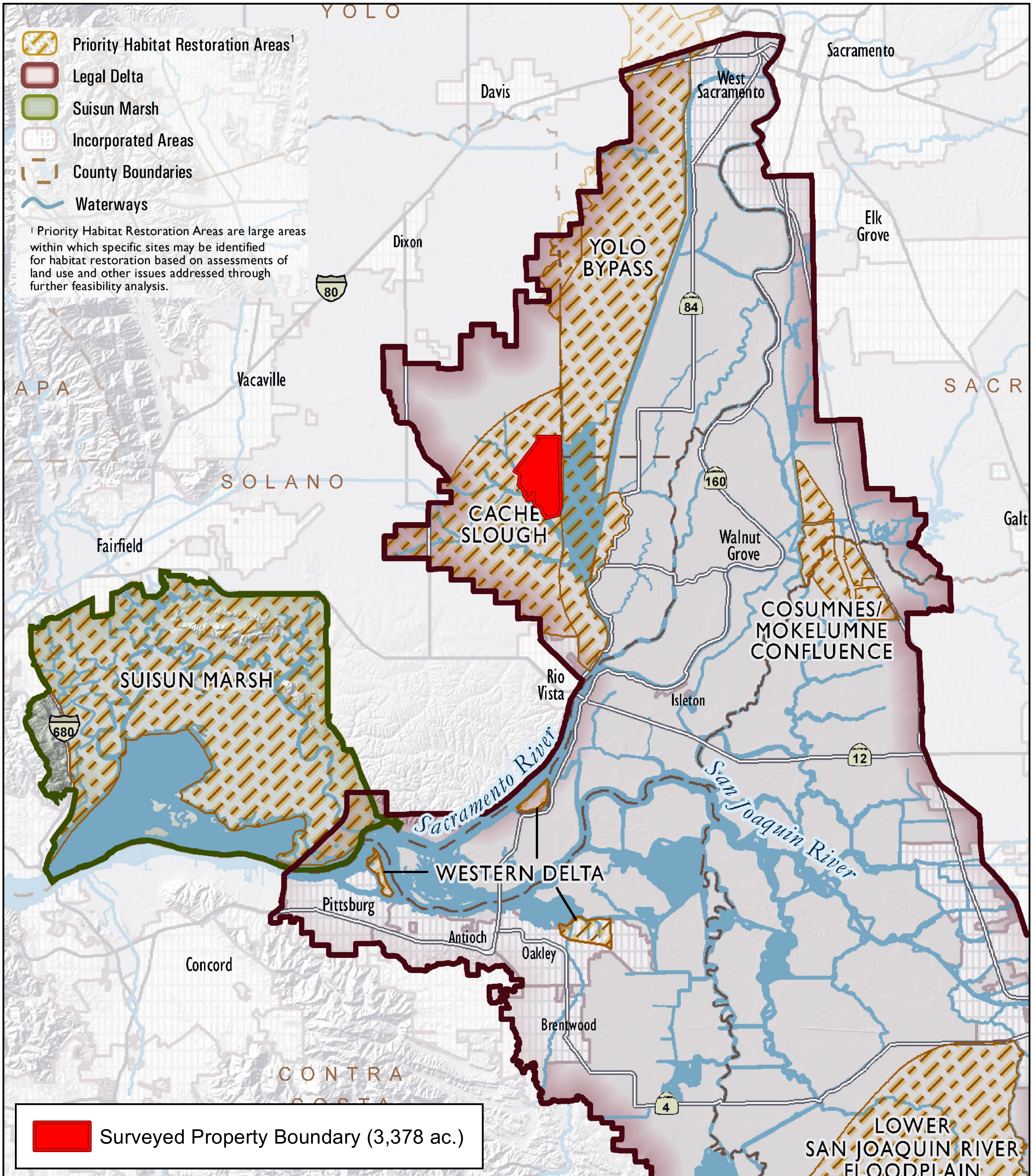

Figure 1
Location Map

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

Ecosystem Investment Partners

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
Delta Stewardship Council, 2013

Prepared by:
ESA

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Background

The Project is located within the Cache Slough Complex, in the northwest corner of the Sacramento-San Joaquin Delta in Solano and Yolo Counties. The Cache Slough Complex is considered ideal for tidal restoration by federal and state wildlife agencies as a result of its "connectivity to the Yolo Bypass floodplain, suitable elevations, high turbidity, high primary and secondary productivity, and use by Delta smelt, Chinook salmon, and other native fishes" (CDFW, 2017).

The Project is bounded to the north by Liberty Island Road, to the east by the Yolo Bypass, to the south by Cache Slough, and to the west by Duck Slough. With the exception of the levee system, land on the Project site ranges between El. -2.0 feet (NAVD 88) and El. 9.0 feet (NAVD 88), and generally slopes from west to east. Precipitation at the site is derived from frontal storms originating from the Pacific Ocean during the primary wet season between the months of October and May. The site receives a mean annual rainfall of approximately 17 inches (Solano County, 1999) and is characterized by poorly drained clay soils, with high runoff potential (USDA, 2018).

Historic Landscape

Up to the early 20th century, the majority of the site was part of the historic tidal tule marsh complex (**Figure 2**) that formed the low-lying southern portion of the Yolo Basin. The upper portions of the Yolo Basin were formed by Holocene basin deposits laid down by the Sacramento River and the two major west side tributaries, Cache Creek and Putah Creek (**Figure 3**). These deposits grade basin-ward into the plains of the north Delta, which is characterized by peat-rich muds (Helley and Harwood, 1983). Flood-basin deposits in this region are typically firm to stiff silty clay, clayey silt, and silt (Atwater, 1982).

The Yolo Basin was largely cutoff from the Sacramento River, except in times when the natural levees along the banks of the river overtopped, similar to flows cresting Fremont Weir today (Opperman et al., 2017). The Yolo Basin received seasonal runoff from the west side tributaries, including Cache Creek and Putah Creek, as well as groundwater seepage from the Sacramento River. These sources combined with freshwater tidal inundation, fed the historic freshwater tidal marsh and channels where the Project is located (PWA, 2008).

The Project is located in what is understood to have been part of the historic tidally-inundated marsh above Cache Slough. Vegetation on the majority of the Project site was tules (*Scirpus acutus,* also known as Hardstem Bulrush), a dense perennial wetland plant species which historically dominated the marshplains of the region. The density of tules and willows in the region are considered to be one of the reasons that these areas were not carefully surveyed prior to reclamation (Atwater, 1982). The site would have been relatively level, gradually draining southward into Cache Slough, with the marshplain edge dictated by elevation of the highest tides (PWA, 2008). As shown on Figure 2, a network of blind tidal channels formed along the banks of Cache Slough.

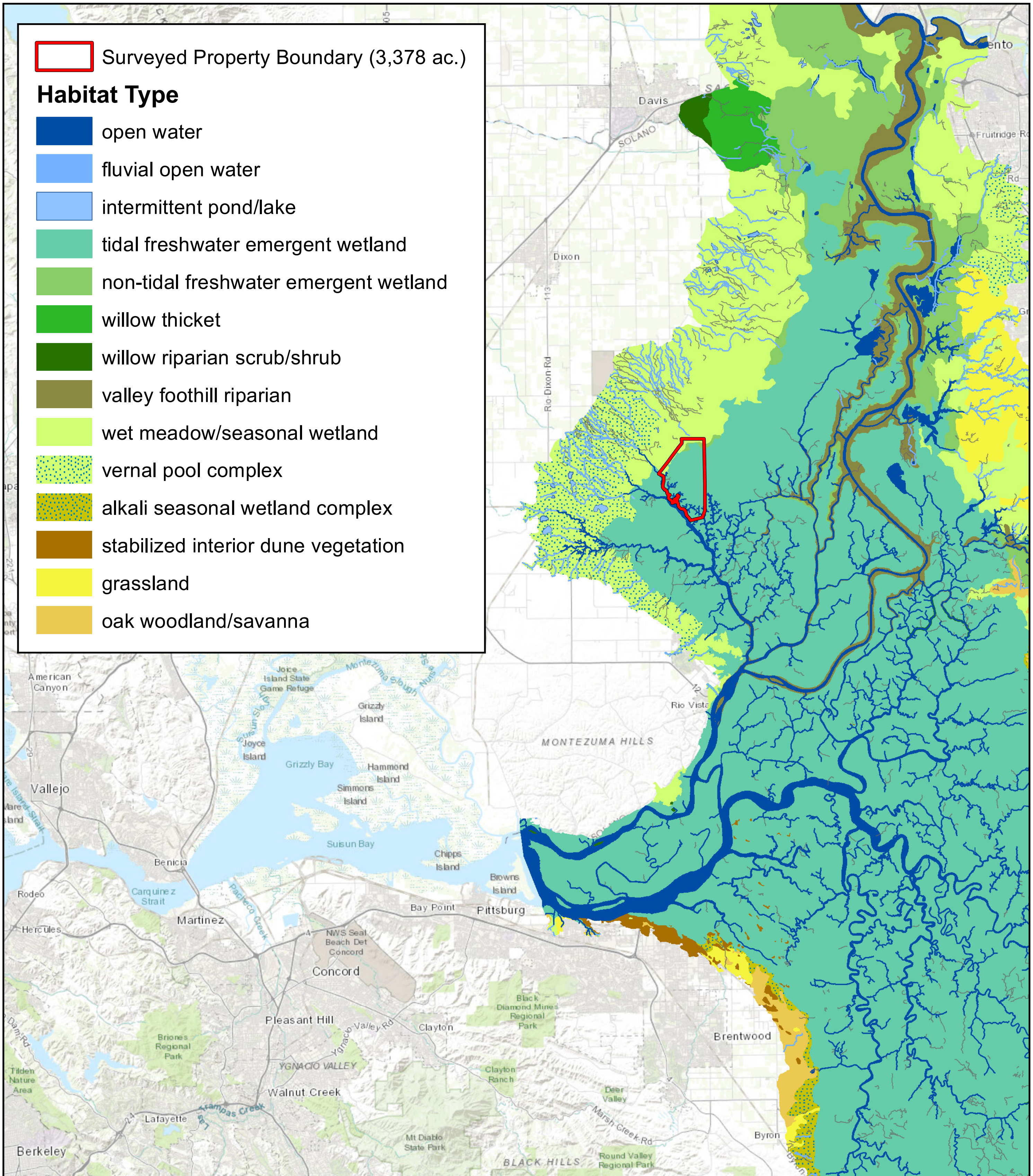

Figure 2
Historical Ecology

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 3 6 12
Miles

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
SFEI, 2012

Ecosystem Investment Partners

Prepared by:
ESA

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Figure 3
Geologic Map of Sacramento-San Joaquin Delta, California

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

Ecosystem Investment Partners

Prepared by:
ESA

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
Atwater, 1982

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F03_USGS_Geologic_Mapping.mxd

Existing Conditions

Beginning in the 1930's and continuing through the 1960's, a series of levee improvements were constructed along the east side of Cache Slough and the west side Yolo Bypass as part of the Sacramento River Flood Control Project (SRFCP) to develop and protect approximately 13,000 acres of agricultural land and associated structures and roads (U.S. Army Corps of Engineers [USACE], 1962). Following repairs in 1962, the southern portion of the original levee system experienced significant subsidence, and in 1986 a plan for a cross levee was finalized and then constructed by the USACE (URS, 2011 and USACE, 1986). The remnant levee system south of the cross levee was subsequently abandoned and breached in May 1992 by the USACE to create the Cache Slough mitigation area south of the Project (Stevens & Rejmankova, 1995). The existing levee system bounding the Project (**Figure 4**) is currently maintained and operated by Reclamation District (RD) No. 2098.

Until recently, the Project site was managed separately by three primary land owners (**Figure 5**):

- The Vogel Island portion of the project was originally purchased for use as a duck club. Historically, the island drained by gravity through a gated outfall structure into Cache Slough. During winter flood season the berms forming the perimeter of Vogel Island often overtop, flooding the property. These same berms prevent flood waters from draining once the island is inundated, creating a condition where water and potentially fish are trapped inside a temporary lake.

- The Bowlsbey Ranch property north and west of Lookout Slough has been operated and managed as irrigated pasture for livestock. The land is irrigated using water pumped from Hass Slough and drains generally from west to east through a network of agricultural ditches to a toe drain that runs parallel to western and northern sides of Lookout Slough, which collects in the southeast corner of the site before ultimately being pumped back to Hass Slough.

- The Liberty Farms property was used for agricultural production for many years before being converted to a duck club circa 2005. Although the northern portion of the property continues to be used for agricultural production, the majority of the site is seasonally flooded and drained through a series of artificial channels to manage vegetation on the duck club. The property is seasonally flooded using water sourced from Cache Slough and is drained via pumping to Shag Slough.

The State-Federal levee system ensures that the Project land is currently inaccessible to fishes, including Delta smelt, green sturgeon, Central Valley Spring Run Chinook salmon, Sacramento River Winter-run Chinook salmon, Central Valley steelhead, and longfin smelt, except during winter runoff events which periodically flood the Vogel Island tract.

The Project will establish tidal hydraulic connectivity to all three pieces of land by breaching the west (right bank) levee of the Yolo Bypass along Shag Slough. The existing pumping and irrigation channel network will be decommissioned and replaced with a network of tidal channels which will allow the site to flood and drain by gravity with the tides. In doing so, the Project will have a continuous supply of fresh water and suspended sediment which will promote establishment of a mosaic of subtidal, intertidal, and uplands habitat types.

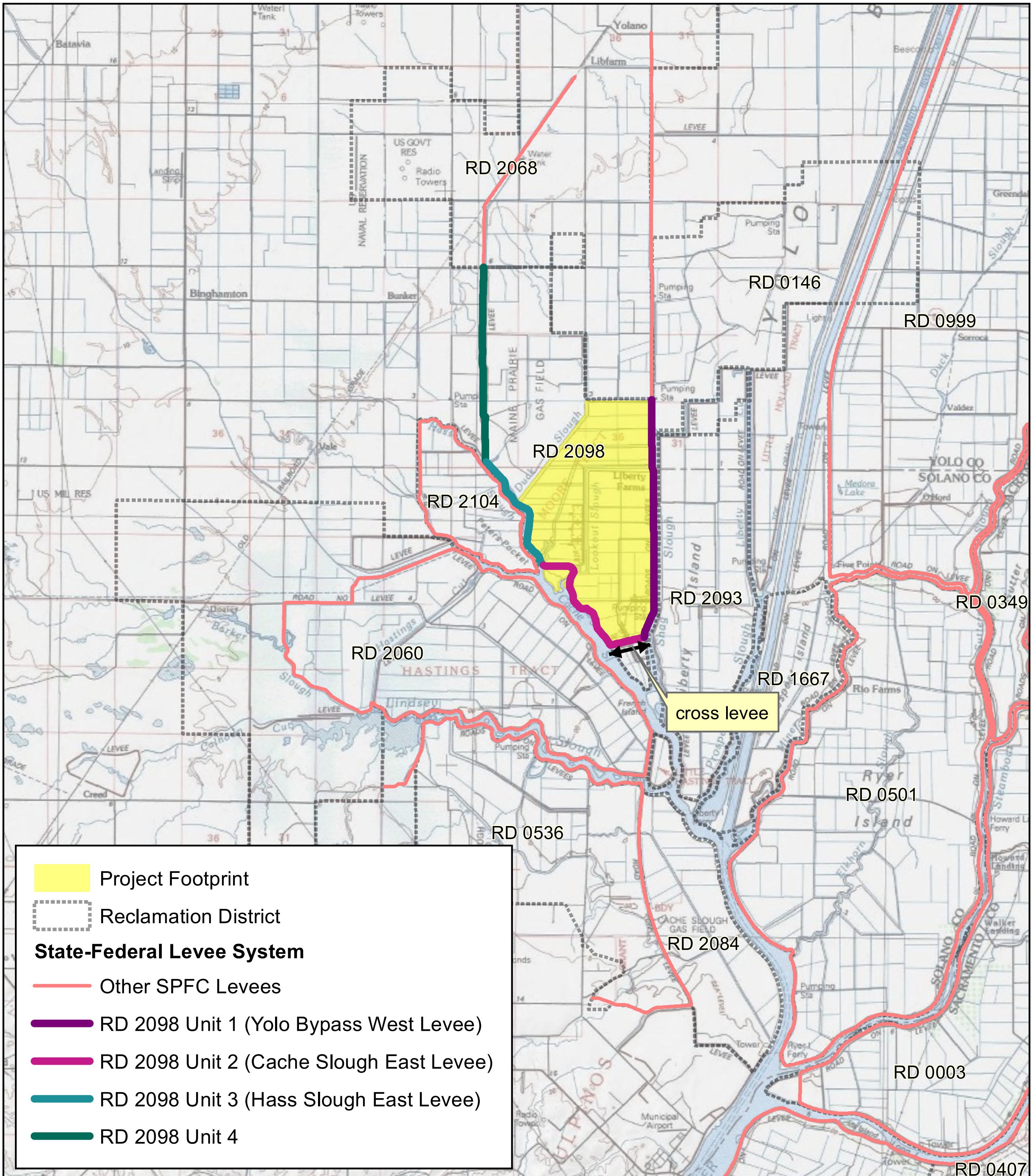

Figure 4
Existing Levee System

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 1 2
Miles

Ecosystem Investment Partners

Map Prepared Date: 4/28/2019
Map Prepared By: Brent Davis
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
CA Levee Database, CBI, DWR
ESRI Surface Layers

Prepared by:
ESA

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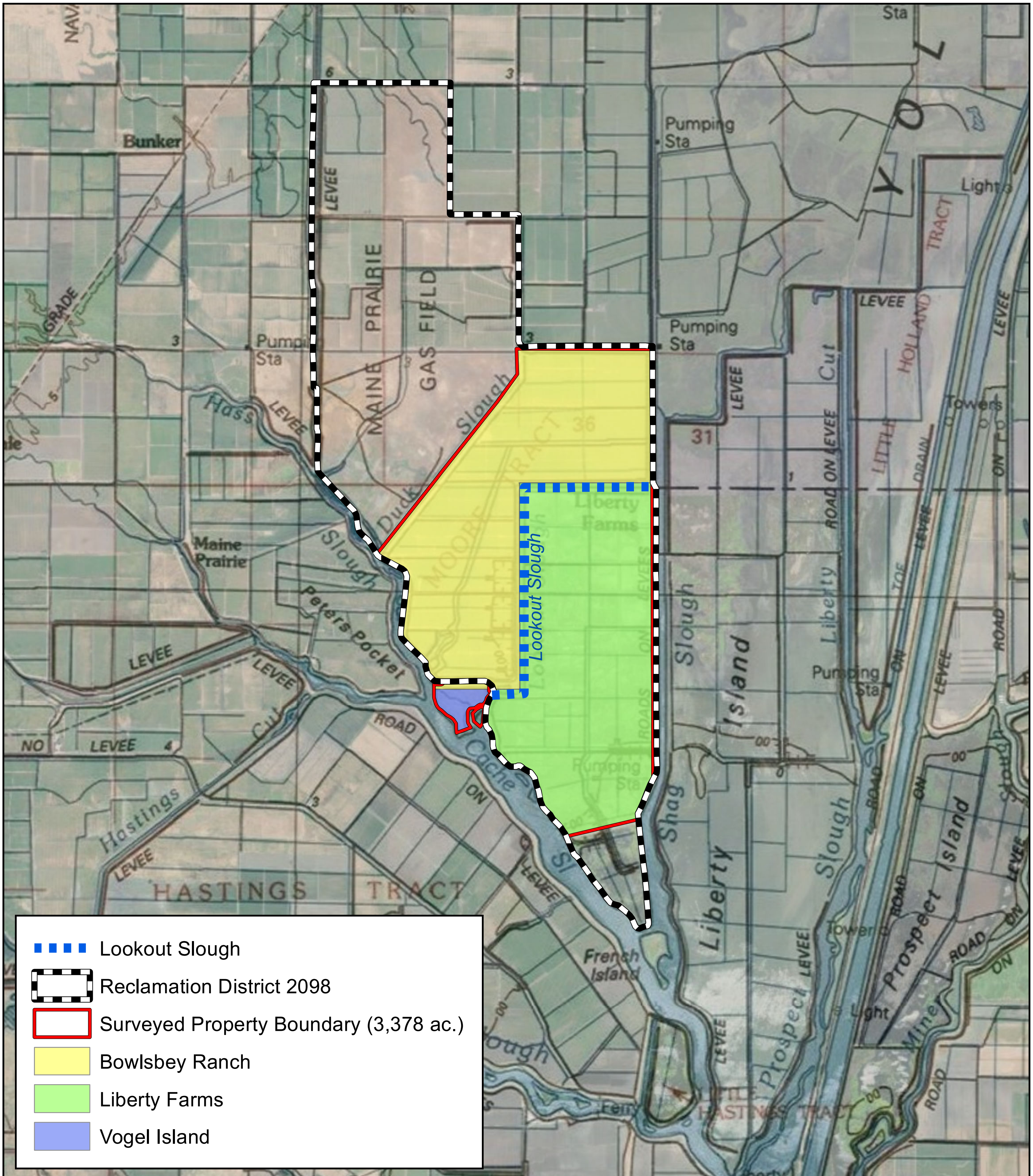

Figure 5
Land Ownership

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 0.25 0.5 1
Miles

Ecosystem Investment Partners

Prepared by:
ESA

Map Prepared Date: 4/28/2019
Map Prepared By: JPritchard
Base Source: Wood Rogers
Base Date: 10/24/2017
Data Source(s):

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F05_Property_Boundaries.mxd

Construction of the habitat restoration components of the Project necessitates alteration of the State-Federal levee system. To maintain the existing level of flood protection for lands north of the Project (RD 2068) and lands west of the Project (RD 2098), a new setback levee will be constructed along the northern and western boundaries of the project. The Project will also increase the conveyance capacity in this part of the Yolo Bypass, consistent with DWR's regional planning objectives (DWR, 2016).

Engineering Circular 1165-2-220 (USACE, 2018) states that any project proposing to alter a federal project in any way "*must not be injurious to the public interest or affect the USACE project's ability to meet its authorized purpose*." If that can be shown, then the Project can receive a Section 408 Permit before construction begins.

Alterations to be made as part of the Project classify the Project as falling under jurisdiction of Section 408:

1. Breaching and degrading the existing west (right) levee of the Yolo Bypass between Liberty Island Road and the southern end of Liberty Farms.
2. Improvements to the north (left) bank levee at Cache Slough and Hass Slough on the western side of the Project.

Purpose and Approach

The purpose of this analysis is to compare performance metrics for the existing condition, authorized design condition, and the condition resulting from the proposed Project alteration. The metric used in this analysis is assurance, also referred to as the conditional non-exceedance probability (CNP). The region-wide system models have been reviewed to verify that no significant change in the flow distribution at Fremont Weir or the Sacramento Weir would occur as a result of the Project. As the hydraulic impacts of the Project are localized, and generally result in stage decreases for the design events under consideration (including the 1957 authorized design flow), the Project's potential to transfer risk from one part of the system to another is considered to be negligible. Since the Project will result in no increases in stage for the scenarios analyzed, a detailed system performance calculation using HEC-FDA is not considered warranted.

For purposes of this analysis, the change in CNP is simply reflected as the change in water surface elevation for the events being analyzed relative to the baseline without-Project condition. The deterministic analysis conducted for the Project is considered sufficient for describing the overall system performance for the without- and with-Project conditions and verifies that the reduction in assurance posed by the Project is negligible.

These assumptions and overall approach were reviewed during pre-coordination activities with the USACE Sacramento District on January 15, 2019 and determined to be acceptable for purposes of the Project's Section 408 permit application.

Project Datums

All data for the project is referenced to the North American Datum of 1983 (NAD 83) and the California State Plane II (feet) coordinate system. All vertical elevations described in this report are referenced to the North American Vertical Datum of 1988 (NAVD 88) and are reported in units of feet.

Alteration of State-Federal Project – Preferred Concept Plan

The conceptual site design (**Figure 6**) was developed by Wood Rodgers, WRA, Inc. (WRA) and Beaver Creek Hydrology, LLC (Beaver Creek Hydrology) to restore the full tidal range to as much of the site as is practical, and to connect the site hydraulically to the Yolo Bypass during high water events. The project concept seeks to meet flood management objectives using the criteria outlined above, while also supporting habitat function. In addition to alterations to the levee system, a number of functional design components, such as a training levee and refugia areas, have been incorporated into the design. Many of these features are intended to address DWR's obligations in the respective Biological Opinions, and offer dual benefits in the form of enhanced flood risk reduction. The major project features and their intended functions are described below (WRA, 2019).

Setback Levee Improvements

A new setback levee is proposed on the northwestern and northern sides of the Project site. If approved, this levee would become part of the State-Federal levee system, protecting lands within RD 2098, north and west of the Project. The proposed levee would begin near the confluence of Hass Slough and Duck Slough; run parallel to Duck Slough on the northwestern side of the project; and upon reaching the northwestern corner of the Project, turn east and run parallel to the south side of Liberty Island Road; eventually tying into the Shag Slough levee system in the northeast corner of the Project site. The segment of levee running parallel to Duck Slough would be offset from the property line to provide a refugia habitat buffer on the land side for the endangered Giant Garter Snake (*Thamnophis gigas*).

Alteration of Cache Slough and Yolo Bypass Levees

Prior to being developed for agriculture, the majority of the Bowlsbey Ranch and Liberty Farms parcels were covered in tidal freshwater emergent wetlands, which drained to Cache Sough (Whipple et al., 2012). Today, the existing State-Federal levee system currently prevents the site from flooding and draining with normal tides. Breaching the levee system is necessary to restore tidal exchange on the Project site.

Alteration of the State-Federal levees requires careful consideration to ensure that risk is not transferred from one part of the system to another, and constrains what modifications can be made to re-establish tidal processes on the site. Tidal marsh considerations have been analyzed in parallel with the flood management design, and have been documented in a separate report (ESA, 2019). A brief description of the proposed modifications of the Cache Slough and Shag Slough levees follows below.

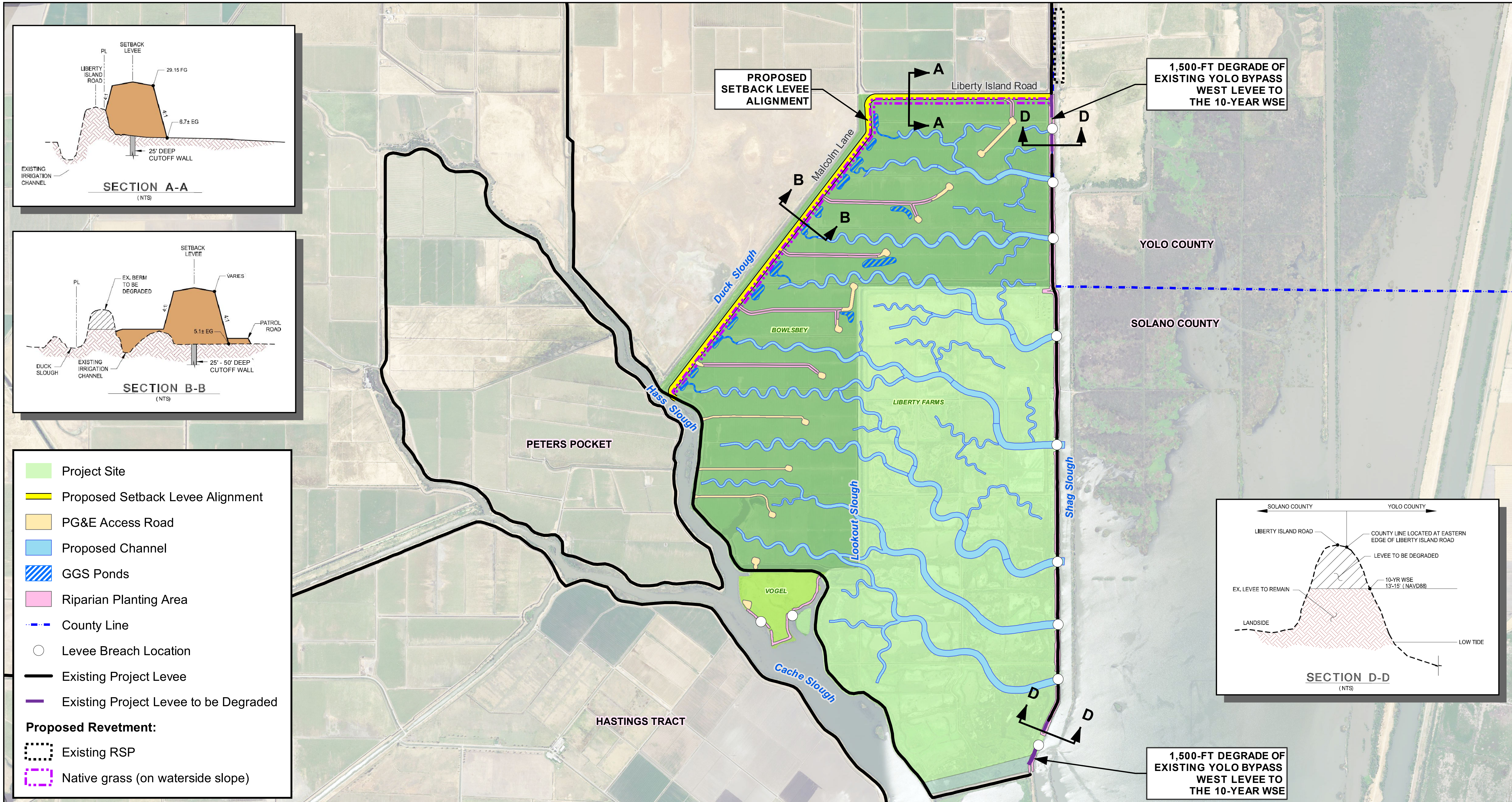

Figure 6
Conceptual Site Design

N W E S

0 0.25 0.5 1
Miles

Lookout Slough Tidal Habitat
Restoration and Flood Improvement Project

Ecosystem Investment Partners

Map Prepared Date: 8/6/2019
Map Prepared By: cmilligan
Base Source: Wood Rogers
Base Date: 10/24/17
Data Source(s):

Prepared by:
WOOD RODGERS

Path: J:\3000-s\3487_Ecosystem_Invest_Partners\3487003 Lookout Slough Preliminary Design\GIS\Tasks\WRA_TEMPLATES\Overall_Project_Exhibit_Landscape_20190806.mxd

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Yolo Bypass Levee Alteration

The Project proposes to breach the west (right bank) levee of the Yolo Bypass along Shag Slough at nine locations to provide hydraulic connectivity between the site and Shag Slough. This alteration would restore normal tidal exchange to the majority of the site and create habitat connectivity to Shag Slough. Two 1,500-foot long segments of the remainder of the existing levee would be degraded to match the elevation of the 10% ACE (10-year) design storm. The first of these would be located near the northern end of the Project, and act as an inlet spillway during high flow events to divert additional water onto the site. This inlet section would be degraded to approximately elevation El. 14.7 feet (NAVD 88). The second segment would be located near the southern end of the Project, and act as an outflow spillway during high flow events, and would be degraded to approximately El. 11.8 feet (NAVD 88).

Cache Slough Levee Alteration

Proposed modifications to the Shag Slough levee would hydraulically connect the Project site to the Yolo Bypass. During less frequent, high flow flood events this will create a condition where the water levels on the Project site will be slightly higher than those inside of Cache Slough. Significant increases to flood levels in Cache Slough and Hass Slough are considered to be unacceptable to RD 2060, RD 2068, and RD 2098 as portions of the levee systems maintained by these entities do not currently meet minimum freeboard requirements and suffer from years of deferred maintenance. Recognizing this, the Project seeks to avoid increasing stage in Cache and Hass Slough.

Historically, wind waves can grow to four feet or more during large storm events due to the combination of long fetch lengths in the Yolo Bypass and strong sustained winds (DWR, 2016). The Project proposes to connect the site to the Yolo Bypass floodplain during high flow events, which will increase fetch lengths against the remnant Cache Slough levee. The remnant embankment along Cache Slough would act as a wind-wave buffer providing an additional layer of safety for levees on the opposite sides of Hass Slough and Cache Slough. Wind-wave assessment analysis of the Project and its potential impacts are summarized by Wood Rodgers in a separate appendix to the Project's overall Basis of Design Report.

Following approval and construction of the Project, the remnant Cache Slough levee embankment would have water on both sides and would continue to serve as both a hydraulic barrier and wind-wave buffer between Cache Slough and the Yolo Bypass, taking on the function of a training levee.

Breach of Vogel Island Levees

The Project proposes to breach the uncertified agricultural levees that form the perimeter of Vogel Island at two locations to provide hydraulic connectivity to Cache Slough. This alteration would restore normal tidal exchange to the island and habitat connectivity to Cache Slough. In large flood events, the remnant levee segments would continue to overtop as they do today.

Tidal Channel Network

Tidal channel networks provide important low resistance pathways for distributing material and energy between the marsh habitat and adjacent bodies of water (Mitsch & Gosselink, 2015). In general, width and depth of the channel decrease between the channel inlets at Cache Slough and Shag Slough and the back of the site. Constructed channel top widths will range from 60 feet to 250 feet, with channel invert elevations ranging between 1.0 and -1.0 feet (NAVD 88) to limit growth of emergent vegetation. Constructed channel side slopes would vary, but be set to a maximum of 3:1. Additional site grading will be performed to remove man-made berms and existing drainage canals (including the previously realigned Lookout Slough) throughout the site to prevent short-circuiting of the new channel network. The proposed network has been laid out to take advantage of the existing topography which drains primarily from west to east towards Shag Slough, with additional provisions to provide connectivity to Cache Slough. The performance of the Project channel network and marsh plain grading plan was tested and further refined by WRA and Beaver Creek Hydrology (WRA and Beaver Creek Hydrology, 2019) using results from the tidal restoration hydrodynamic modeling analysis (ESA, 2019).

As the proposed tidal channel network has only been sized for daily tidal exchange, the hydraulic capacity of the channels is not anticipated to have a significant effect on flood routing during high water events in the Yolo Bypass. The overbanks and adjacent floodplains of the tidal channel network are anticipated to be covered with tule marsh vegetation. Although dense stands of tules provide significant hydraulic resistance during normal tidal conditions, their influence will be reduced significantly during high water conditions in the Yolo Bypass where depths of flooding on the site will exceed 10 feet or more.

Alteration of State-Federal Project – DSC Concept Plan

The DSC Concept Plan is essentially the same as the Preferred Concept Plan, with the exception that the existing west levee of the Yolo Bypass would be breached only, and segments of the remnant levee between the breaches would not be partially degraded (left in-place). This option is considered less beneficial from the perspective of achieving flood management objectives, but represents a “minimum” project configuration that would achieve the Project’s habitat restoration objectives.

Analysis

The USACE Sacramento District is ultimately responsible for determining whether a hydrologic and hydraulic system analysis is needed and, if so, also determining the appropriate scope of analysis based on the complexity of the proposed alteration. Based on pre-coordination meetings with the USACE Sacramento District, it was determined that if deterministic analysis of without- and with-Project conditions was conducted for a range of hydrologic loading scenarios (10% ACE, 1% ACE, and 0.5% ACE), and the Project implementation was demonstrated to have only localized effects, and would not result in increased water levels of more than 0.1 feet at key index points within the system, then more detailed performance computations at the index points would not be required.

System Performance Assumptions

The proposed project alterations are being evaluated relative to the Baseline Condition, as well as the Future Cumulative Condition Baseline scenarios described below. Per USACE EC 1165-2-220, Appendix F, Section F-3.f (USACE, 2018), all project features are assumed to be stable and functional to the top of containment (USACE, 2018) in this analysis. Levees are not assumed to breach or otherwise malfunction in the analysis of pre- and post-project conditions. Levees are allowed to overtop and spill water to storage areas adjacent to levees, without failing. The Project also is assumed to be stabilized to the authorized condition, and based on this assumption, fragility curves are not required.

Levees of the SPFC that do not meet the minimum project standard have been modeled as meeting the minimum authorized height (i.e., the 1957 design profile). Where existing top of levee heights exceed the authorized height, they are modeled as such (DWR, 2017). These assumptions reflect the ability of upstream projects to engage in maintenance and provide a conservative estimate of flow delivery in the area of interest. This approach is consistent with the assumptions used for LEBLS and similar projects in the region.

Baseline Condition

The Baseline Condition modeling assumes the following Early Implementation Projects (DWR, 2017):

- American River Common Features Project WRDA 96/99 sites
- Folsom Dam Joint Federal Project (JFP) – including water control manual updated considering forecast-based operations as of August 19, 2016
- Marysville Ring Levee
- Sutter Basin Project – Feather River West Levee Project
- Three Rivers Levee Improvement Project (TRLIA)
- Natomas Levee Improvement Project (NLIP)
- West Sacramento 2016 sites (Southport Levee Improvement Project)
- Hamilton City – Phase 1
- Star Bend (SBFCA)
- Bear River

Future Cumulative Condition

The Future Cumulative Condition scenario builds upon the assumptions in the Baseline Condition, and reflects full build-out of the elements of the recommended Yolo Bypass expansion option (Yolo Bypass Option 3) described in the BWFS (DWR, 2016) and reproduced on **Figure 7**. This includes implementation of the following features:

- **Upper Elkhorn and Fremont Weir Expansion** – a one-mile expansion of the Upper Elkhorn Basin with a corresponding expansion of Fremont Weir
- **Lower Elkhorn Expansion** – a 3,500-feet levee setback along the Lower Elkhorn Basin
- **Sacramento Weir and Bypass Expansion** – a 1,500-feet expansion of the Sacramento Weir and Bypass
- **Cache Creek Settling Basin** – measures to extend useful life of the Cache Creek Settling Basin and address concerns regarding mercury in its sediment
- **Levee Setback Near Willow Slough Bypass** – a 4,000-feet levee setback on the west side of the bypass north of Willow Slough and south of I-80
- **Levee Setback Near Putah Creek** – a 5,000-feet levee setback on the west side of the Yolo Bypass north of Putah Creek
- **Tie-in to Sacramento River Deep Water Ship Channel** – a gated weir to tie into the Sacramento River Deep Water Ship Channel and a closure structure to prevent high stages from reaching West Sacramento
- **Degradation of Step Levees and Lower Egbert Track Levees** – degrading remaining levee segments in the lower Yolo Bypass at the north end of Little Holland Tract and Liberty Island and degrading portions of the Lower Egbert Track (RD 2084) levees.
- **Lower Yolo Bypass Setback** – levee setback south of RD 2068 to Rio Vista, including removal of cross levee at southern boundary of RD 2098)
- **Build Weirs on Prospect Island Levee** – build weirs along portions of the Prospect Island west levee
- **Improved Flood Protection for Rio Vista and Highway 84** – flood protection improvements for the city of Rio Vista to address potential hydraulic impacts of Yolo Bypass capacity improvements
- **Fix-in-place Levee Improvements** – provide six feet of freeboard over the estimated 200-year flood flows (represented by the 110-percent scaling of the 1997 storm pattern)
- **Geotechnical Levee Improvements** – fix any remaining geotechnical inadequacies for urban areas unaddressed in the future baseline condition and fix known critical geotechnical deficiencies for rural and small communities.

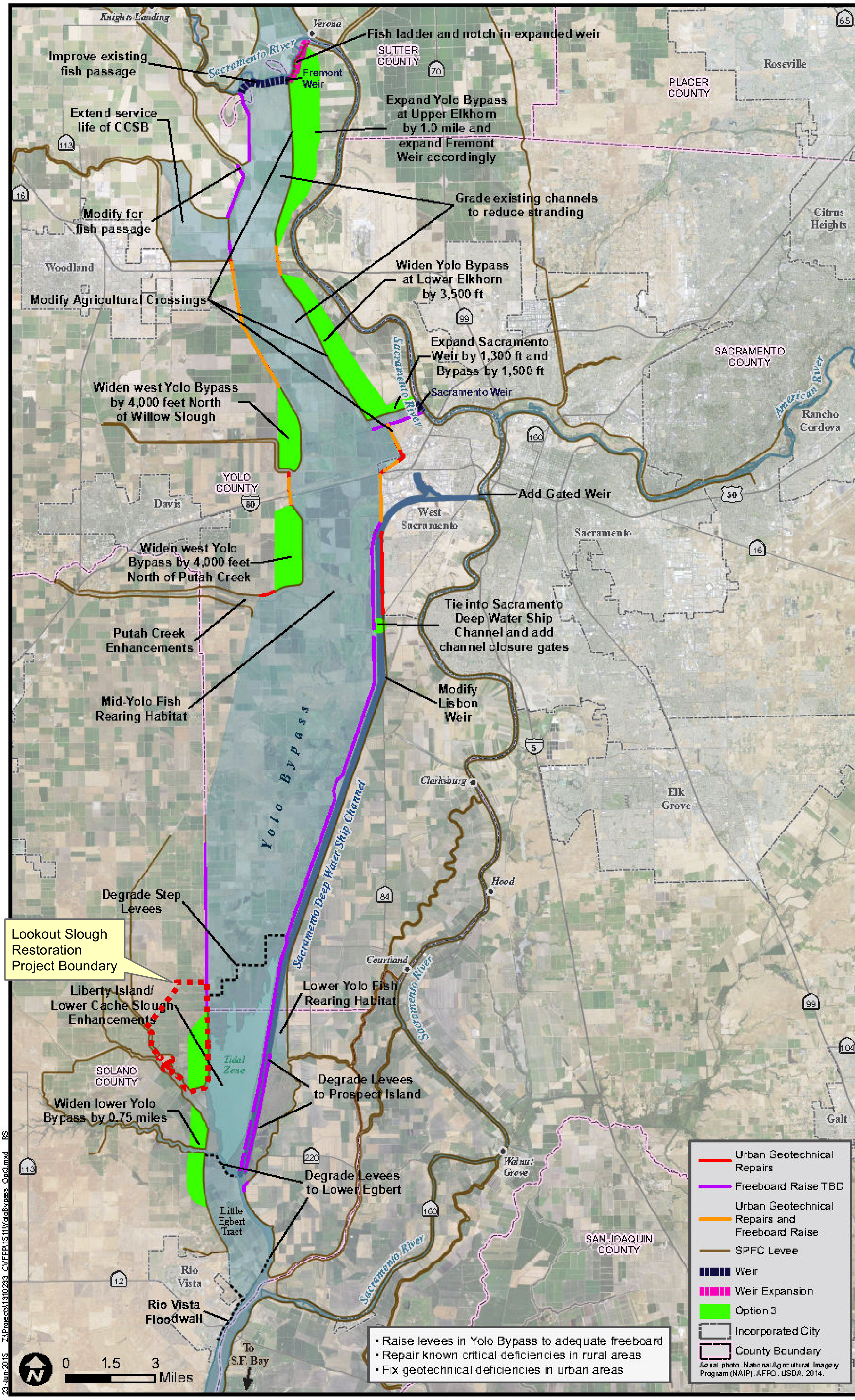

Figure 7
Future Cumulative Condition (BWFS Yolo Bypass Option 3)

Ecosystem Investment Partners

Prepared by: ESA

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

Map Prepared Date: 4/28/2019
Map Prepared By: JPritchard
Base Source: Wood Rogers
Base Date: 10/24/17
Data Source(s): DWR, 2016

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F07_BWFS_YB3.mxd

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Index Points

A total of eleven index points were selected as locations to review the hydraulic performance of the Project in both a Baseline and Future Cumulative Conditions scenarios. Shown on **Figure 8**, the following locations were identified during preliminary hydraulic analysis in close coordination with DWR and local interests:

1. West (left) bank of Yolo Bypass at County Road 155
2. Hass Slough at western boundary of RD 2098
3. Cache Slough near Hastings Cut
4. West (left) bank of Yolo Bypass at northern boundary of the Project
5. West (left) bank of Yolo Bypass at Yolo County/Solano County Line
6. Cache Slough at Confluence with Yolo Bypass
7. Lindsey Slough approximately 1 mile upstream of Hastings Island Road Bridge
8. Cache Slough at northern end of Little Egbert Tract
9. Cache Slough at Ryer Island
10. Cache Slough at southern end of Little Egbert Tract
11. Sacramento River at Rio Vista

Hydrology

Hydrologic input data for the hydraulic modeling was developed using data previously prepared by the USACE and DWR for regional planning studies. This includes historic flow record data used for calibration and validation of the hydraulic model parameters, as well as annual chance exceedance (ACE) design storm hydrology suitable for analyzing the 10% ACE (10-year), 1% ACE (100-year), and 0.5% ACE (200-year) storm events. The sources of hydrology data used for these analyses are described below.

CVHS Historic Patterns and Design Storm Scalings

Input time series data for evaluating the 10% ACE (10-year), 1% ACE (100-year), and 0.5% (200-year) design storms for existing conditions and future cumulative conditions were developed using information previously prepared by DWR for the LEBLS project (DWR, 2017) and BWFS (DWR, 2016), respectively. These hydrology datasets were prepared using data and tools originally developed for the Central Valley Hydrology Study (CVHS) completed by the USACE and DWR in 2013. The CVHS-based hydrology uses historic storm patterns, scaled to correspond to statistically-determined return period flows. As part of the BWFS, DWR identified the appropriate historic pattern and scalings for the 10% ACE (10-year), 1% ACE (100-year), and 0.5% (200-year) design storms for application to the Yolo Bypass (**Table 1**).

A summary of the flow inputs used in the hydraulic design analysis is provided in the subsequent hydraulic model boundary conditions discussion.

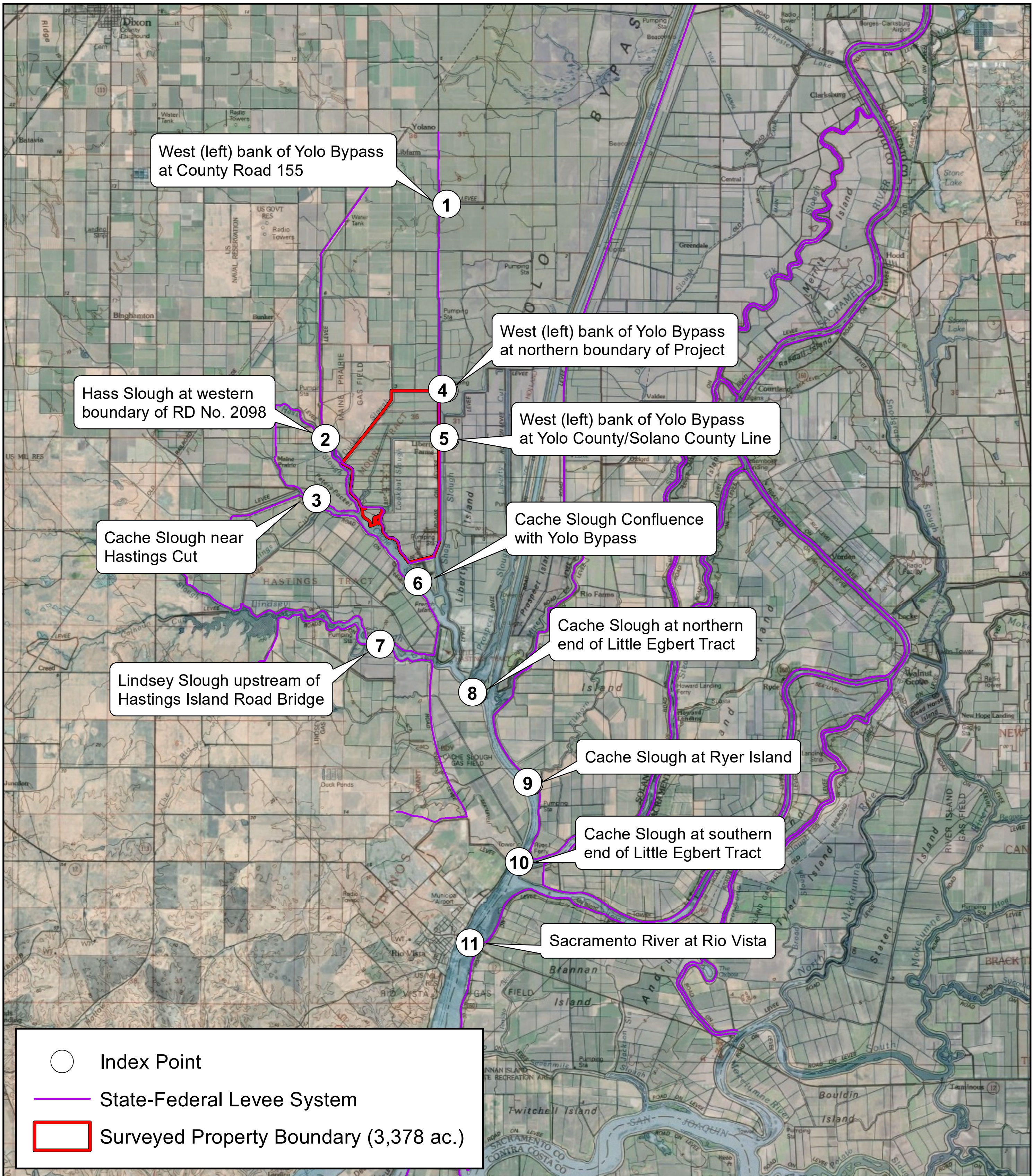


Figure 8
Index Points

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 7,500 15,000
Feet

Ecosystem Investment Partners

Prepared by:
ESA

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rogers
Base Date: 10/24/2017
Data Source(s):

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F08_Index_Points.mxd

TABLE 1
CVHS SCALED EVENTS USED FOR ANALYSIS (DWR, 2016)

ACE	Frequency	CVHS Historic Storm Pattern	CVHS Event Scale Factor
10%	10-year	1997	40%
1%	100-year	1997	95%
0.5%	200-year	1997	110%

Hydraulic Analysis

To address the complex interaction between Yolo Bypass flood flows and the tidal influences of the north Sacramento-San Joaquin Delta, a two-dimensional hydraulic model is necessary for supporting design of the Project. A general description of the modeling approach, tools, supporting data, and system performance assessment are provided in the following sections.

Parent-Child Model Nesting Concept

One cost-effective and computationally efficient technique that has been deployed successfully in numerical modeling applications is splitting computations between coarse, large scale region-wide models (parent models) and localized high-resolution subdomain areas (child models). It can often be useful to deploy this technique in series, whereby results from the parent model are used to define boundary conditions for the child model, particularly when the child model domain is defined appropriately so as to avoid erroneous biasing at the boundary conditions.

This report documents the development and analysis performed using a child model prepared specifically for design of the Project. Documentation associated with development and deployment of the parent model for establishing boundary conditions in the child model have been referenced where applicable.

Parent Hydraulic Model

One-dimensional HEC-RAS system models prepared previously by DWR were utilized as the parent models for this study. Data from the BWFS, incorporating downstream tidal dynamics was used for representing the Baseline Condition (DWR, 2016). Data from the BWFS recommended alternative for expanding the Yolo Bypass (Yolo Bypass Option 3) was utilized to represent the Future Cumulative Condition (DWR, 2016). The Baseline Conditions modeling of the Sacramento River system extends from Hamilton City to Collinsville, and includes the major tributary systems (Feather River and American River). The future cumulative conditions model is truncated above the Sutter Bypass and Tisdale Bypass systems, but otherwise covers the same geographic area as the existing conditions system model. The geographic coverage and quality of calibration make these models well suited as a source for establishing boundary conditions for a localized site-specific model.

Child Hydraulic Model

For on-site design, a high resolution two-dimensional child model was developed using the TUFLOW commercial software package. The child model builds upon and expands the calibrated two-dimensional model previously developed for analyzing and supporting design of the Project's tidal restoration components. This approach was reviewed during pre-coordination with the Hydraulics Section of the USACE Sacramento District, and is considered appropriate for advancing the Project through the USACE Section 408 Permit process. TUFLOW was approved for use and added to the USACE Hydrology, Hydraulics, and Coastal Software List in 2012, and both DWR and the USACE Sacramento District have expert staff trained in use and review of the software. For this project, the TUFLOW HPC (Heavily Parallelized Compute) finite volume solver has been used, allowing the software to run in simulation on NVidia GPU hardware. All modeling prepared for the Project utilizes the latest software version of TUFLOW (Build: 2018-03-AD-iSP-w64).

The relative extents of the parent and child models are shown on **Figure 9** and **Figure 10**. The child model boundaries are located at appropriate handoff points correlating with cross-sections in the respective one-dimensional HEC-RAS parent models. Boundary locations in the child model were selected to minimize distortions in the area of interest, and at locations where flow and stage could be discretized appropriately to avoid misrepresenting data received from the parent model. Upstream flows routed through the respective parent models are compiled at each of these locations and used as inputs to the TUFLOW model. Likewise, the modeled stage time series data output from the HEC-RAS system is used to define the downstream stage boundary of the TUFLOW model.

A detailed description of the TUFLOW model development, calibration, and validation is provided in the Hydrologic and Hydraulic System Analysis section of the Project's overall Basis of Design Report (ESA, 2019b).

Uncertainty in Stages for Computed Water Surface Profiles

Uncertainty is the result of imperfect knowledge concerning the present or future state of a system, event, situation, or (sub) population under consideration (USACE, 2017). Known sources of uncertainty relevant to the current analysis include (USACE, 1996):

- Uncertainty about future hydrologic conditions, including climate change. Recognizing this, the Project has incorporated an additional 1 foot of freeboard in the levee design.
- Uncertainty related to structural and geotechnical performance of water-control measures when these are subjected to rare stresses and loads caused by floods. For purposes of assessing the Project performance, the system is assumed to be stable up to the top of containment (no breaching) in accordance with USACE Section 408 guidance (USACE, 2018). This is anticipated to provide the most conservative estimate of flow deliveries and flood stages within the area of interest.
- Uncertainty arising from the use of simplified models to describe complex phenomena. Although the hydraulic models used to support this study have been calibrated and validated using historic flood records, residual uncertainty in both the model and its input parameters, such as Manning's roughness coefficients, is inevitable.

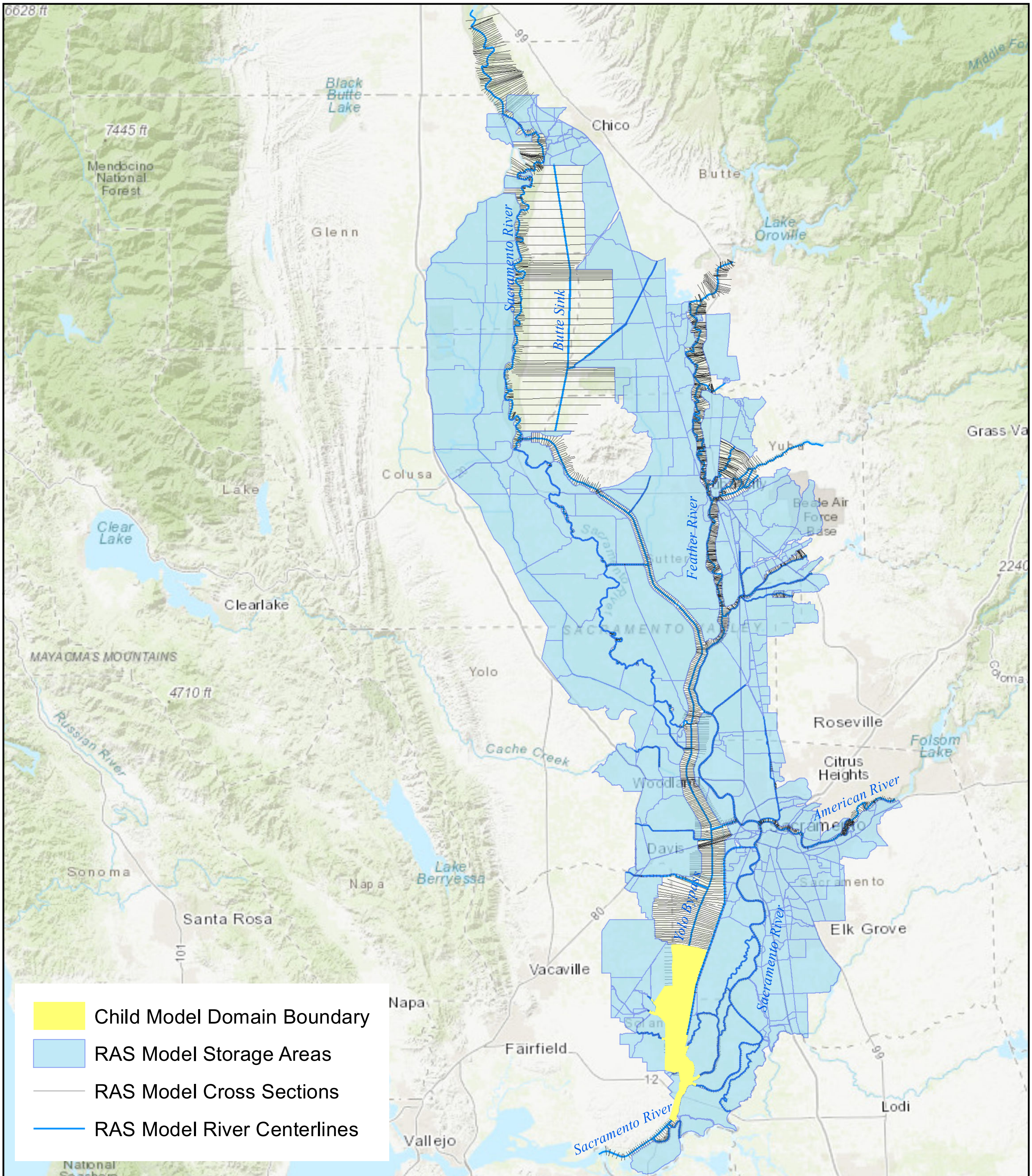


Figure 9
Parent-Child Model Schematic (Baseline Condition)

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 7.5 15
Miles

Ecosystem Investment Partners

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
DWR
ESRI Service Layers

Prepared by:
ESA

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F09_Parent_Child_Schematic_Baseline.mxd

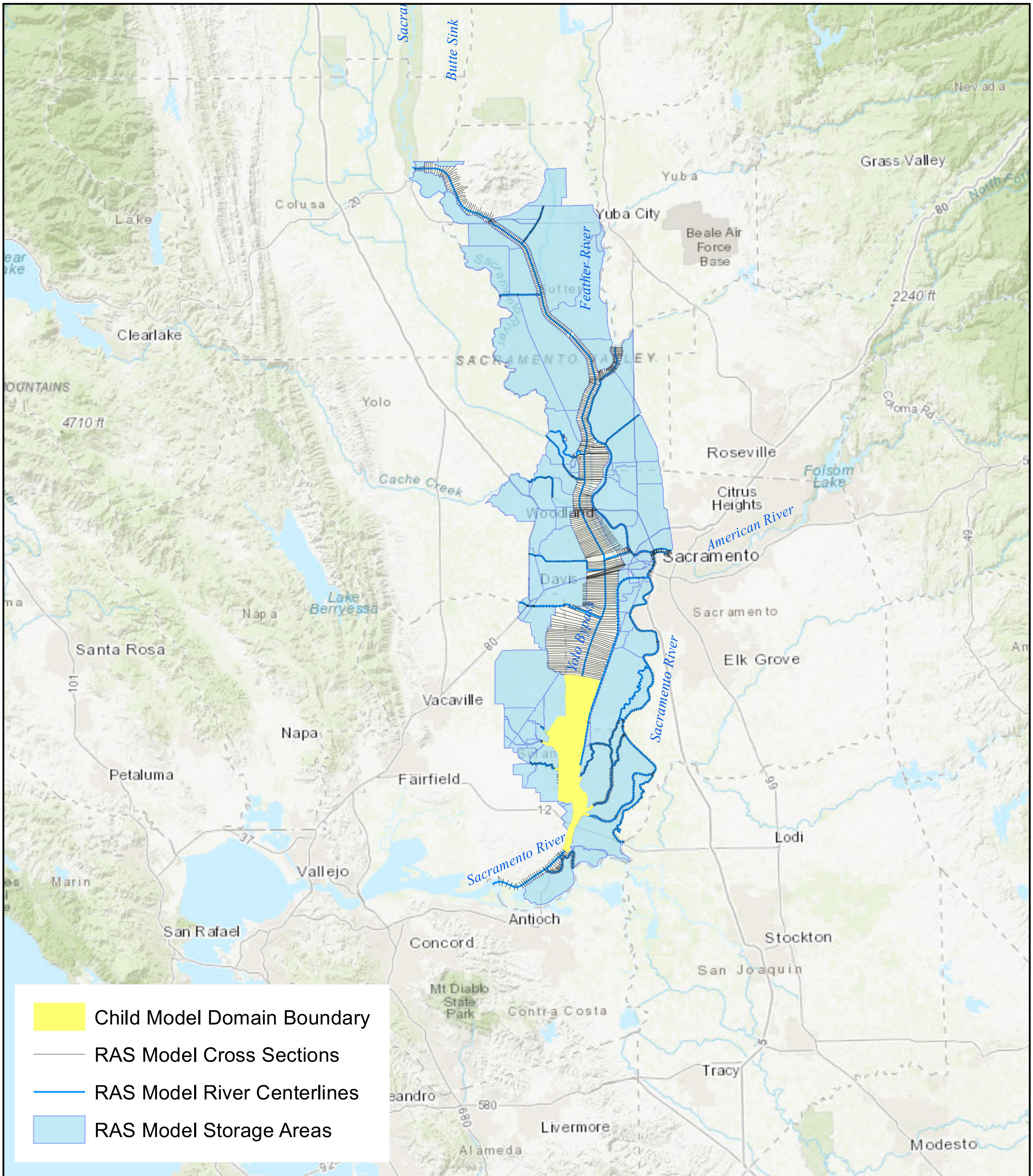


Figure 10
Parent-Child Model Schematic (Future Cumulative Condition)

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

0 7.5 15
Miles

Ecosystem Investment Partners

Map Prepared Date: 4/8/2019
Map Prepared By: Brent Davis
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):
DWR
ESRI Service Layers

Prepared by: ESA

Path: U:\GIS\GIS\Projects\18xxxx\D181197_00_Lookout_Slough_Restoration_1\03_MXDs_Projects\02_Flood_Task_System_HandH\F10_Parent_Child_Schematic_Future_Cumulative_Condition.mxd

For purposes of assessing stage uncertainty in the current study, a sensitivity analysis was performed to assess the upper and lower bounds of Manning's roughness for the given design discharges (10%, 1%, and 0.5% ACE). Per discussion with the USACE Sacramento District, Manning's roughness coefficients were adjusted globally by +/-20% relative to the calibrated values. This resultant range of stages is assumed reflect 95% of the error range in the Manning's roughness parameter, or two standard deviations above and below the mean. The standard deviation is assumed to be the total range of these values divided by four (USACE, 1996).

Figure 11 through **Figure 14** depict the spatial distribution of the standard deviation in stage based on adjusting the Manning's roughness coefficient +/-20% for the respective without- and with-Project conditions assessments for the Baseline and Future Cumulative Conditions. The Manning's roughness value reliability was assessed based on the ranges recommended by the USACE for cross-sections based on field surveys or aerial spot elevation (USACE, 1996) as summarized in **Table 2** below.

TABLE 2
MINIMUM STANDARD DEVIATION OF ERROR IN STAGE

Manning's n Value Reliability	Standard Deviation (in feet) for Cross Section Based on Field Survey or Aerial Spot Elevation
Good	0.3
Fair	0.7
Poor	1.3

SOURCE: USACE, 1996

Review of the standard deviation maps for the respective geometry conditions and design flow rates indicates that the reliability of the model's Manning's roughness coefficients can be characterized as good to fair in all cases. All of the maps exhibit a small standard deviation in the downstream portion of model domain inside of the Sacramento River and Cache Slough corridors. This effect is most prominent in the lower flow events (i.e., 10% ACE), and is likely due to the influence the tidal boundary exerts on these zones. In tidal zones, the inertia terms are more influential than the friction terms, reducing the model sensitivity to the bed roughness coefficient in these locations.

In the 10% ACE comparisons, a small portion in the northwestern portion of the model domain exhibits a standard deviation in excess of 1.3 feet (shown in orange on Figure 11 through Figure 14). This area is located west of a small agricultural berm within the Yolo Bypass which overtops in the 10% ACE event only as higher roughness coefficients are applied. During higher flow events this area is completely inundated and the model is less sensitive to changes in roughness, resulting in a lower standard deviation for the 1% ACE and 0.5% ACE events. The increased uncertainty in this localized portion of the model domain during the 10% ACE event is not considered to have a significant impact on the overall quality of the model results as it relates to describing the performance of the system without- and with-Project.

Change in System Performance

The hydraulic performance analysis consisted of analyzing the Baseline Condition and Future Cumulative Condition both without- and with-Project using a range of hydraulic loadings (10%, 1%, and 0.5% ACE) in unsteady state. For purposes of this Project, increases in water surface elevation are reflected as a reduction in assurance (conditional non-exceedance probability [CNP]). The results of the analysis are summarized in **Table 3**. The parent HEC-RAS system models have also been reviewed to verify that no significant change in the flow distribution at Fremont Weir or the Sacramento Weir occurs as a result of the Project (**Table 4**).

As the hydraulic impacts of the Project are localized, and generally result in stage decreases for the design events under consideration (including the 1957 authorized design flow), the Project's potential to transfer risk from one part of the system to another is considered to be negligible. These changes are not considered significant enough to warrant a detailed system performance calculation using HEC-FDA. The deterministic analysis conducted for the Project is considered sufficient for describing the overall system performance for the without- and with-Project conditions and verifies that the reduction in assurance is negligible.

Baseline Condition Performance Assessment

The Baseline Condition was analyzed without- and with-Project, as well as with the DSC concept, to identify hydraulic changes that would result from the proposed alterations. The assessment included hydraulic analysis of the authorized design flow capacity and assessment of the respective 10% ACE (10-year), 1% ACE (100-year), and 0.5% ACE (200-year) design storm events. The following section describes the changes in the hydraulic performance of the system created by the Project.

Change in Assurance

The resultant change in the Baseline Condition water surfaces at the respective index point locations is summarized in Table 3. In general, the Project results in localized stage reductions in the Yolo Bypass (improved performance) and does not increase stages in other parts of the system.

Future Cumulative Condition Performance Assessment

The Future Cumulative Condition was analyzed without- and with-Project to identify hydraulic changes that would result from the proposed alteration relative to the preferred Yolo Bypass expansion concept (Yolo Bypass Option 3) identified in the BWFS. The assessment included hydraulic analysis of the authorized design flow capacity, and assessment of the respective 10% ACE (10-year), 1% ACE (100-year), and 0.5% ACE (200-year) design storm events. The following section describes the changes in the hydraulic performance of the system created by the Project.

Change in Assurance

The resultant change in the Future Cumulative Condition water surfaces at the respective index point locations is summarized in Table 3. In general, the Project results in localized stage reductions in the Yolo Bypass and does not increase stages in other parts of the system for any of the frequency intervals analyzed relative to the Future Cumulative Condition.

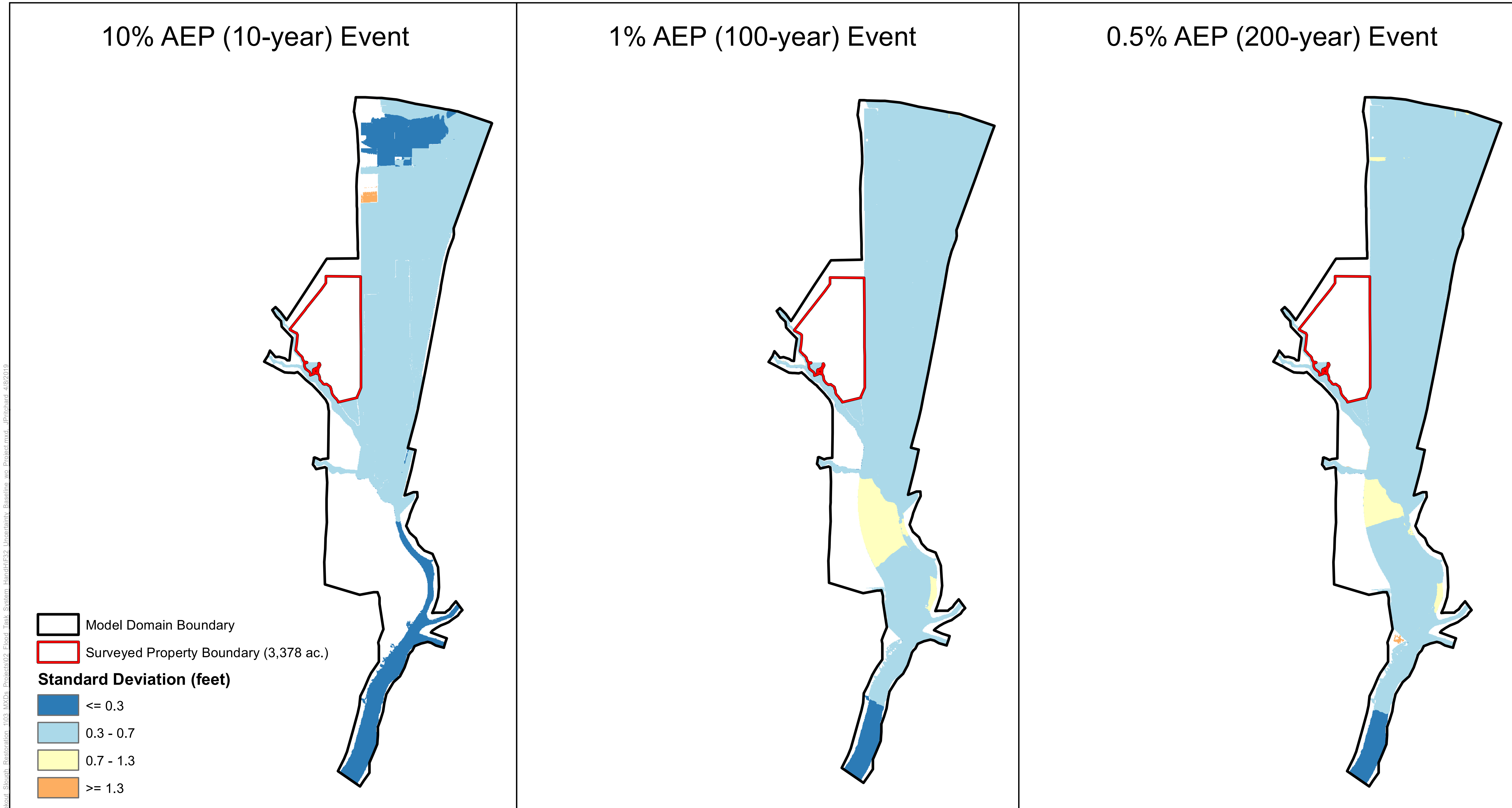
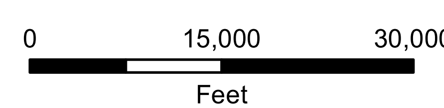


Figure 11
Stage Computation Uncertainty - Baseline Condition without-Project

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project



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Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):

Prepared by: ESA

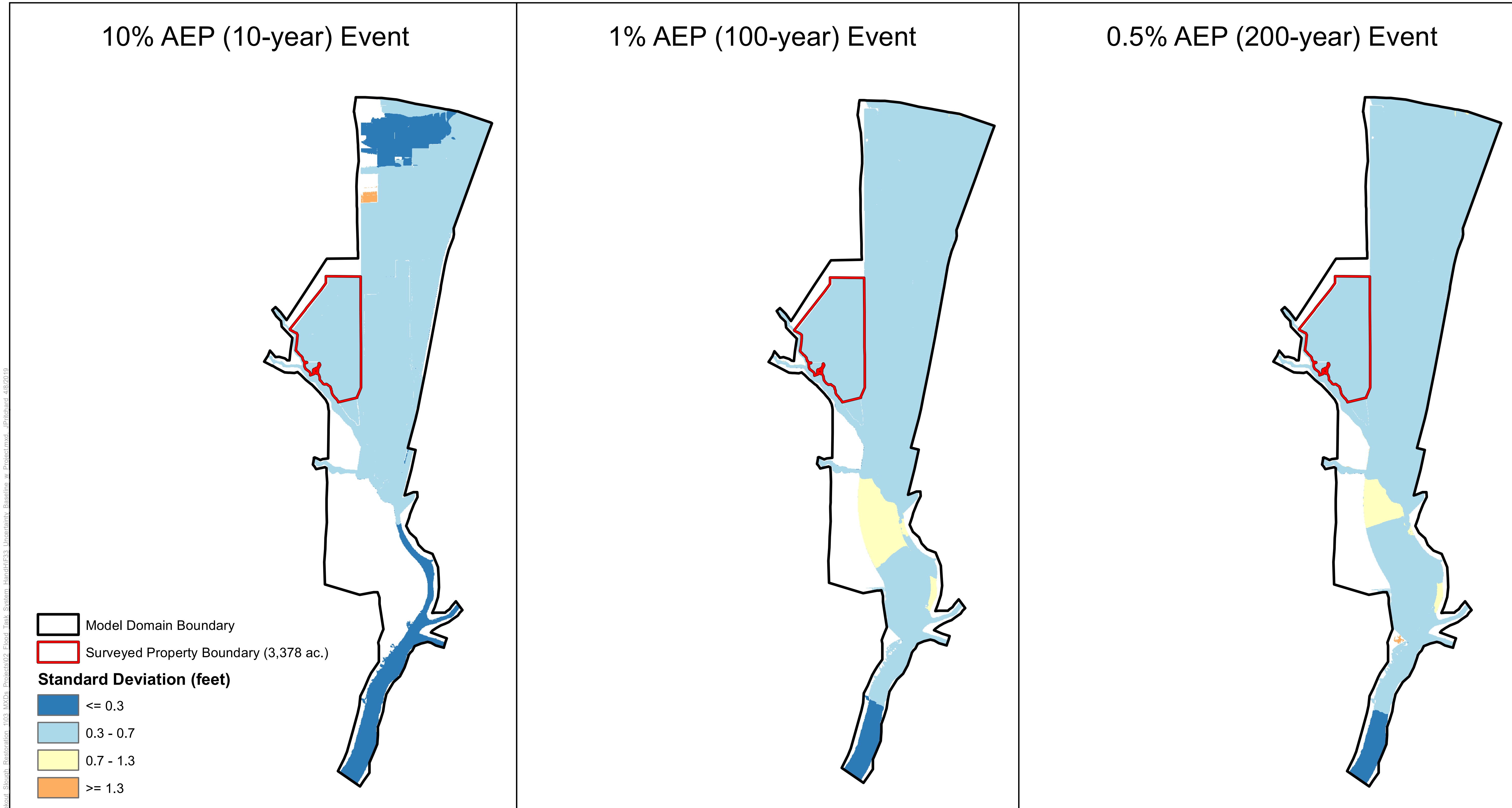

Figure 12
Stage Computation Uncertainty - Baseline Condition with-Project

0 15,000 30,000
Feet

Ecosystem Investment Partners

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):

Prepared by: ESA

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

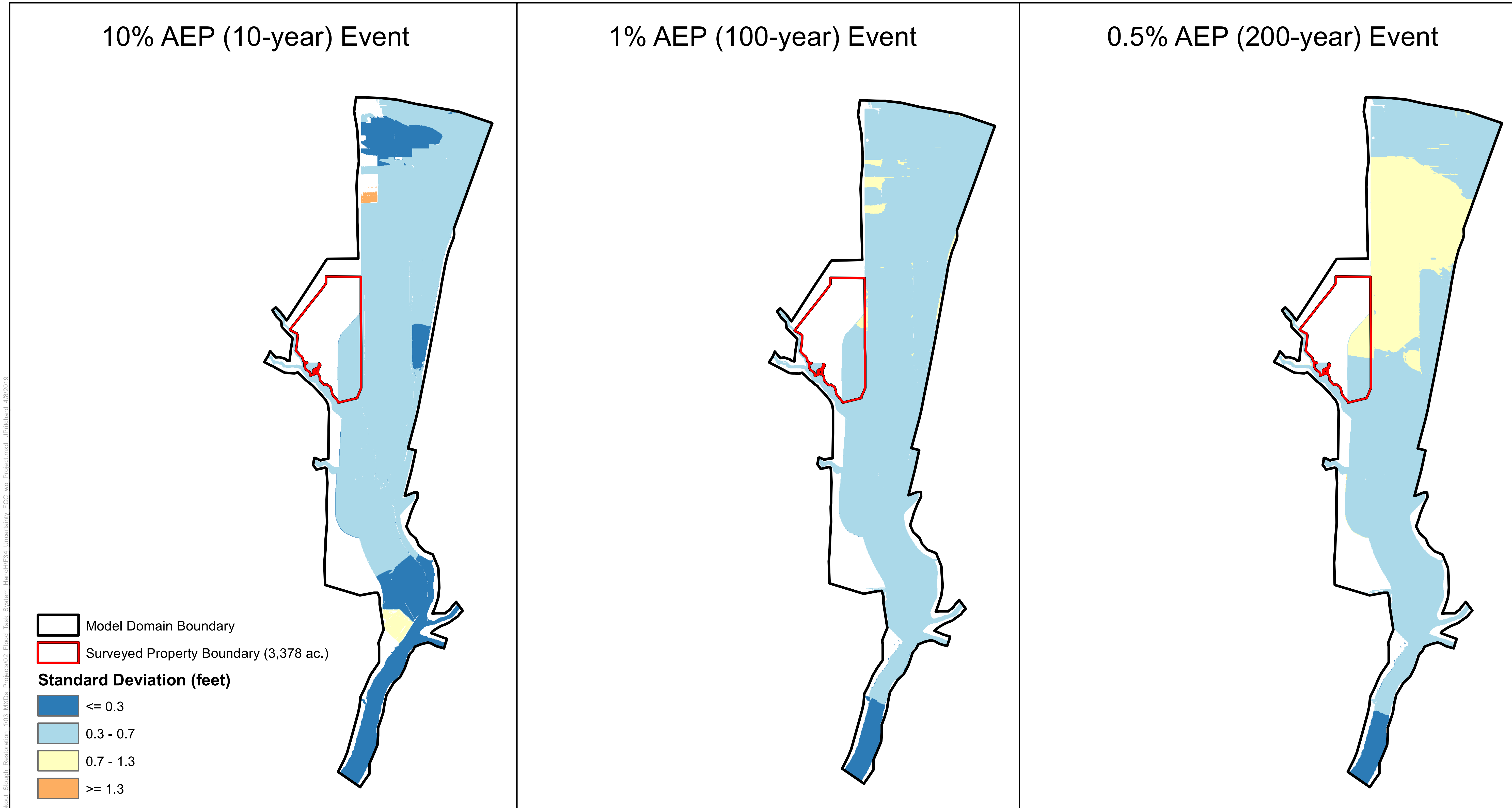

Figure 13
Stage Computation Uncertainty - Future Cumulative Condition without-Project

0 15,000 30,000
Feet

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

Ecosystem Investment Partners

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):

Prepared by: ESA

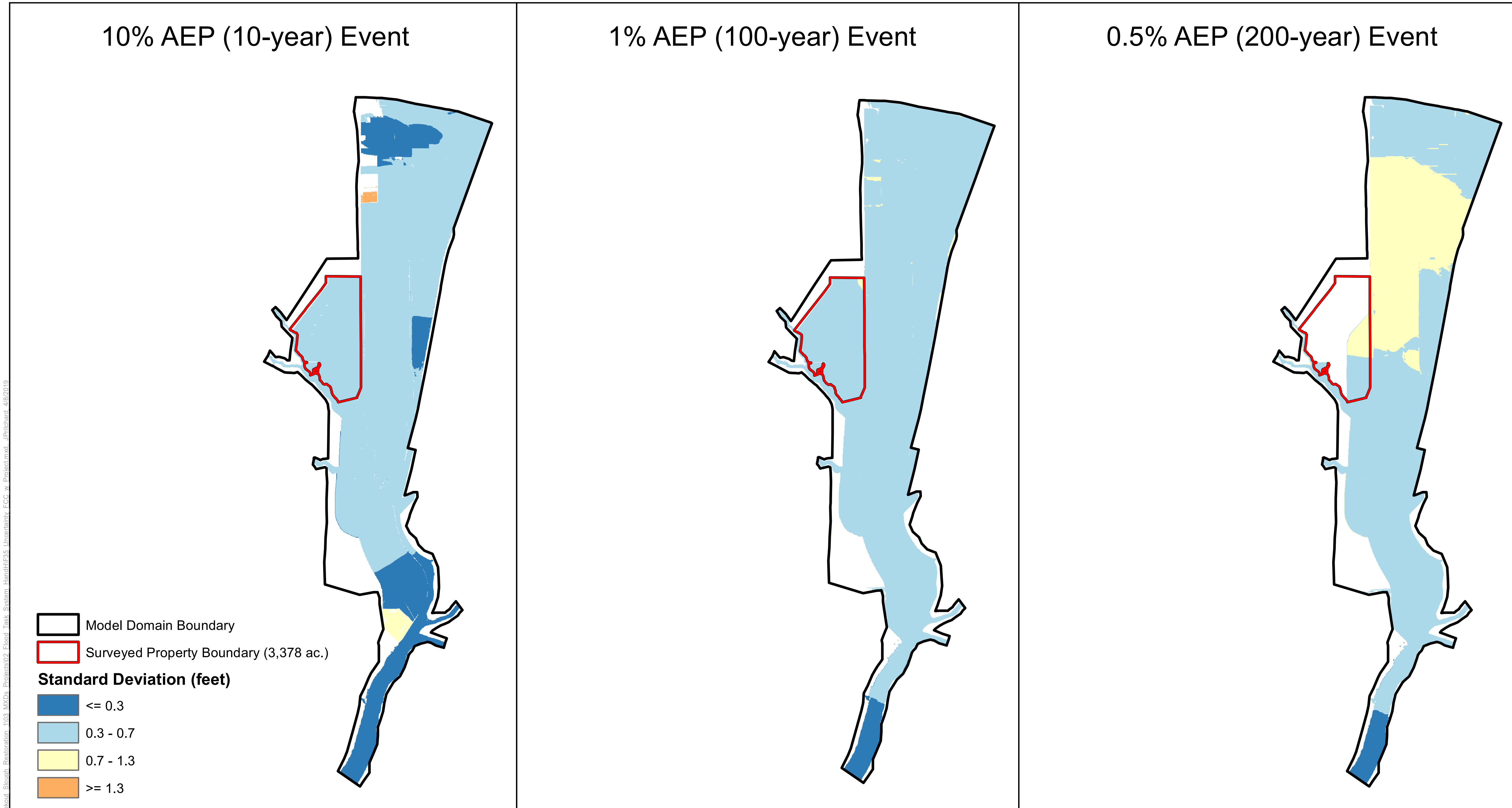

Figure 14
Stage Computation Uncertainty - Future Cumulative Condition with-Project

0 15,000 30,000
Feet

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project

Ecosystem Investment Partners

Map Prepared Date: 4/8/2019
Map Prepared By: JPritchard
Base Source: Wood Rodgers
Base Date: 10/24/2017
Data Source(s):

Prepared by:
ESA

TABLE 3
SUMMARY OF CHANGE IN ASSURANCE AT RESPECTIVE INDEX POINTS

Index Point	1957 Design WSEL (ft, NAVD 88)	Design Freeboard (feet)	Existing Top of Levee Elevation (ft, NAVD 88)	Condition	CNP	% ACE	WSEL (ft, NAVD 88) Without-Project	With-DSC Project	Change	With-Project	Change
1	22.83	6	28.65	Baseline	0.100	10%	19.74	19.72	-0.02	19.72	-0.02
					0.010	1%	23.85	23.76	-0.09	23.74	-0.11
					0.005	0.5%	24.63	24.52	-0.11	24.49	-0.14
				Future Cumulative	0.100	10%	20.16	20.15	-0.01	20.15	-0.01
					0.010	1%	23.26	23.21	-0.05	23.20	-0.06
					0.005	0.5%	23.92	23.85	-0.07	23.83	-0.09
2	17.88	3	20.86	Baseline	0.100	10%	13.01	13.00	-0.01	13.00	-0.01
					0.010	1%	18.65	18.63	-0.02	18.63	-0.02
					0.005	0.5%	19.58	19.54	-0.04	19.53	-0.05
				Future Cumulative	0.100	10%	11.98	11.97	-0.01	11.97	-0.01
					0.010	1%	17.02	16.99	-0.03	16.99	-0.03
					0.005	0.5%	18.12	18.11	-0.01	18.11	-0.01
3	17.88	3	20.86	Baseline	0.100	10%	13.01	13.00	-0.01	13.00	-0.01
					0.010	1%	18.65	18.63	-0.02	18.63	-0.02
					0.005	0.5%	19.56	19.52	-0.04	19.51	-0.05
				Future Cumulative	0.100	10%	11.98	11.97	-0.01	11.97	-0.01
					0.010	1%	17.00	16.97	-0.03	16.97	-0.03
					0.005	0.5%	18.12	18.11	-0.01	18.11	-0.01
4	20.46	6	24.88	Baseline	0.100	10%	14.81	14.34	-0.47	14.36	-0.45
					0.010	1%	20.80	20.38	-0.42	20.28	-0.52
					0.005	0.5%	21.77	21.34	-0.43	21.22	-0.55
				Future Cumulative	0.100	10%	14.28	13.89	-0.39	13.92	-0.36
					0.010	1%	19.24	18.81	-0.43	18.74	-0.50
					0.005	0.5%	20.22	19.82	-0.40	19.73	-0.49

TABLE 3
SUMMARY OF CHANGE IN ASSURANCE AT RESPECTIVE INDEX POINTS

Index Point	1957 Design WSEL (ft, NAVD 88)	Design Freeboard (feet)	Existing Top of Levee Elevation (ft, NAVD 88)	Condition	CNP	% ACE	WSEL (ft, NAVD 88)				
							Without-Project	With-DSC Project	Change	With-Project	Change
5	19.71	6	25.34	Baseline	0.100	10%	13.68	13.57	-0.11	13.57	-0.11
					0.010	1%	19.86	19.62	-0.24	19.59	-0.27
					0.005	0.5%	20.84	20.58	-0.26	20.55	-0.29
				Future Cumulative	0.100	10%	13.12	12.96	-0.16	12.95	-0.17
					0.010	1%	18.09	17.93	-0.16	17.90	-0.19
					0.005	0.5%	19.10	18.98	-0.12	18.95	-0.15
6	17.86	3	20.59	Baseline	0.100	10%	13.01	13.00	-0.01	13.00	-0.01
					0.010	1%	18.65	18.63	-0.02	18.63	-0.02
					0.005	0.5%	19.54	19.52	-0.02	19.52	-0.02
				Future Cumulative	0.100	10%	11.94	11.94	0.00	11.94	0.00
					0.010	1%	16.98	16.96	-0.02	16.96	-0.02
					0.005	0.5%	18.07	18.06	-0.01	18.06	-0.01
7	17.85	3	19.57	Baseline	0.100	10%	12.83	12.81	-0.02	12.81	-0.02
					0.010	1%	18.22	18.22	0.00	18.22	0.00
					0.005	0.5%	19.07	19.06	-0.01	19.06	-0.01
				Future Cumulative	0.100	10%	11.60	11.59	-0.01	11.59	-0.01
					0.010	1%	16.47	16.44	-0.03	16.44	-0.03
					0.005	0.5%	17.56	17.55	-0.01	17.55	-0.01
8	17.82	3	20.82	Baseline	0.100	10%	12.19	12.15	-0.04	12.15	-0.04
					0.010	1%	17.66	17.63	-0.03	17.63	-0.03
					0.005	0.5%	18.59	18.56	-0.03	18.56	-0.03
				Future Cumulative	0.100	10%	11.42	11.40	-0.02	11.40	-0.02
					0.010	1%	16.28	16.23	-0.05	16.23	-0.05
					0.005	0.5%	17.38	17.36	-0.02	17.36	-0.02

TABLE 3
SUMMARY OF CHANGE IN ASSURANCE AT RESPECTIVE INDEX POINTS

Index Point	1957 Design WSEL (ft, NAVD 88)	Design Freeboard (feet)	Existing Top of Levee Elevation (ft, NAVD 88)	Condition	CNP	% ACE	WSEL (ft, NAVD 88)				
							Without-Project	With-DSC Project	Change	With-Project	Change
9	15.08	3	21.71	Baseline	0.100	10%	11.40	11.28	-0.12	11.28	-0.12
					0.010	1%	16.09	16.09	0.00	16.09	0.00
					0.005	0.5%	17.21	17.21	0.00	17.21	0.00
				Future Cumulative	0.100	10%	10.96	10.96	0.00	10.96	0.00
					0.010	1%	15.61	15.57	-0.04	15.57	-0.04
					0.005	0.5%	16.69	16.68	-0.01	16.68	-0.01
10	12.42	3	11.85 (Restricted Height Levee El.)	Baseline	0.100	10%	11.41	11.36	-0.05	11.36	-0.05
					0.010	1%	13.98	13.99	+0.01	13.98	0.00
					0.005	0.5%	14.94	14.95	+0.01	14.94	0.00
				Future Cumulative	0.100	10%	10.26	10.25	-0.01	10.25	-0.01
					0.010	1%	13.85	13.85	0.00	13.85	0.00
					0.005	0.5%	14.80	14.80	0.00	14.80	0.00
11	12.01	3	22.99	Baseline	0.100	10%	10.54	10.54	0.00	10.54	0.00
					0.010	1%	11.88	11.88	0.00	11.88	0.00
					0.005	0.5%	12.43	12.43	0.00	12.43	0.00
				Future Cumulative	0.100	10%	9.63	9.63	0.00	9.63	0.00
					0.010	1%	11.96	11.96	0.00	11.96	0.00
					0.005	0.5%	12.52	12.52	0.00	12.52	0.00

TABLE 4
SUMMARY OF CHANGE IN FLOWS DOWNSTREAM OF FREMONT WEIR AND SACRAMENTO WEIR

Location	Design Flow (cfs)	Condition	CNP	% ACE	Peak Flow (cfs)			Volume (acre-feet)		
					Without-Project	With-Project	% Change	Without-Project	With-Project	% Change
Yolo Bypass Downstream of Fremont Weir	343,000	Baseline	0.100	10%	177,900	177,900	0.00%	4,037,500	4,037,500	0.00%
			0.010	1%	380,500	380,500	0.00%	5,787,100	5,787,000	0.00%
			0.005	0.5%	419,300	419,300	0.00%	6,785,400	6,785,200	0.00%
		Future Cumulative	0.100	10%	206,000	206,000	0.00%	3,926,800	3,926,800	0.00%
			0.010	1%	390,500	390,500	0.00%	4,437,000	4,436,800	0.00%
			0.005	0.5%	430,200	430,200	0.00%	5,111,900	5,111,700	0.00%
Sacramento Bypass Downstream of Sacramento Weir	112,000	Baseline	0.100	10%	31,800	31,800	0.00%	224,000	224,000	0.00%
			0.010	1%	109,300	109,300	0.00%	1,363,400	1,363,500	0.01%
			0.005	0.5%	122,600	122,600	0.00%	1,643,900	1,644,200	0.02%
		Future Cumulative	0.100	10%	39,800	39,800	0.00%	247,300	247,300	0.00%
			0.010	1%	114,500	114,500	0.00%	1,160,500	1,161,000	0.04%
			0.005	0.5%	128,800	128,900	0.08%	1,392,100	1,392,800	0.05%

Performance Relative to Authorized Design

The 1957 Profile is based on specified design discharges (not tied to a recurrence frequency) and adopted concurrent conditions at confluences of study streams (USACE, 1993). In this portion of the Yolo Bypass, the 1957 profile was based on flow extents and durations from the 1907 and 1909 floods (DWR, 2016; U.S. House, 1917). For the purposes of understanding the Project performance relative to the design condition, the design water surface and existing top of levee have been included Table 3.

Summary and Conclusion

This report documents the methods, data, and assumptions used to understand the potential impacts associated with a multi-benefit project that meets the objectives of habitat restoration while also improving flood conveyance in the Yolo Bypass. The Project as proposed, has been determined to create no adverse impacts to stage, while providing localized reductions in stage within the Yolo Bypass. The Project also provides superior performance relative to a single-benefit, DSC concept plan.

The analysis described in this report shows that the proposed Project alterations would not result in adverse impacts to the performance of the system. The region-wide system models have also been reviewed to verify that no significant change in the flow distribution at Fremont Weir or the Sacramento Weir would occur as a result of the Project. As the hydraulic impacts of the Project are localized, and generally result in stage decreases for the design events under consideration (including the 1957 authorized design flow), the Project's potential to transfer risk from one part of the system to another is considered to be negligible. The deterministic analysis conducted for the Project is considered sufficient for describing the overall system performance for the without- and with-Project conditions and verifies that there is no reduction in assurance.

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