# NAVIGABLE SLOUGH FLOOD MANAGEMENT STUDY

**Prepared for**

**County of San Mateo**

**City of South San Francisco**

**City of San Bruno**

**May 8, 2019**

# NAVIGABLE SLOUGH FLOOD MANAGEMENT STUDY

**Prepared for**

**May 8, 2019**

**County of San Mateo**
**City of South San Francisco**
**City of San Bruno**


**550 Kearny Street**
**Suite 800**
**San Francisco, CA 94108**
**415.896.5900**
**www.esassoc.com**

Prepared by: ESA

| | | |
|---|---|---|
| **Bend** | **Oakland** | **San Francisco** |
| **Camarillo** | **Orlando** | **Santa Monica** |
| **Delray Beach** | **Pasadena** | **Sarasota** |
| **Destin** | **Petaluma** | **Seattle** |
| **Irvine** | **Portland** | **Sunrise** |
| **Los Angeles** | **Sacramento** | **Tampa** |
| **Miami** | **San Diego** | |


**D17206.01**

# Navigable Slough Flood Management Study

# TABLE OF CONTENTS

## List of Tables



## List of Figures

# 1 STUDY PURPOSE

Navigable Slough is a remnant tidal channel which cuts through a commercial district in the City of South San Francisco. The slough is well-connected to San Francisco Bay, so the slough experiences daily tidal exchange and supports tidal marsh wetlands. However, when Bay water levels surge above their typical elevations, these high water levels are conveyed into Navigable Slough and can overtop the slough's banks, threatening the adjacent developed areas with flooding, as per FEMA's Special Flood Hazard Area mapping. In addition to the commercial areas immediately adjacent to the slough, low-lying Shaw Road could convey flooding south into the City of San Bruno's Belle Air residential neighborhood. This coastal flood hazard is exacerbated by watershed discharge through the slough and will be exacerbated in the future by sea-level rise.

The County of San Mateo, the City of San Bruno, and the City of South San Francisco (the Collaborative) entered into a Memorandum of Understanding (MOU) for an investigation of Navigable Slough to the Colma Creek confluence with the San Francisco Bay. In the past, Navigable Slough has received only limited flood management planning because it falls between the Colma Creek flood control zone to the north and the San Bruno Creek flood control zone to the south. The study described in this report provides recommendation for the Collaborative to mitigate near-term coastal flooding and that could potentially help the community and commercial properties adapt to future coastal conditions.

The goal of this study is to assess flood management measures that reduce flood risk from waters conveyed by and passing through Navigable Slough. To meet this goal, this study's objectives are:

- Collect existing data and mapping, and identify data gaps
- Collect new hydraulic and topographic to fill in data gaps
- Develop and apply hydraulic modeling to examine existing conditions' baseline flood hazard and the escalating hazard with sea-level rise
- Develop refined flood management measures
- Evaluate the measures relative to the criteria of flood risk reduction, environmental impacts, and cost.
- Recommend flood risk reduction measures

The study considers the increased flood hazard that will occur with future sea-level rise. Because sea-level rise will bring increased flood exposure to much of the nearby shoreline and developed areas, flood management measures that address sea-level rise for Navigable Slough will need to be integrated with a larger, regional strategy of flood management. Planning for this regional strategy is beyond the scope of this study, but being addressed by other County and City planning efforts.

# 2 SUMMARY OF FINDINGS AND RECOMMENDATIONS

Prior studies, new data collected for this study, and hydraulic modeling have characterized the flood hazard from Navigable Slough as follows:

- Navigable Slough is well-connected to San Francisco Bay, such that Bay water levels propagate nearly unimpaired throughout Navigable Slough and serve as the primary cause of flood hazard throughout the slough.
- In addition, Navigable Slough serves as conveyance channel for substantial watershed discharge, which further increases flood hazard, particularly in the upper slough (west of Highway 101) and middle slough (between Highway 101 and South Airport Boulevard), with a small effect in the lower slough (east of South Airport Boulevard).
- The typical highest annual astronomic tides (sometimes referred to as ‘king tides’) have been observed to cause shallow inundation on and around Beacon Street. This flooding’s pathway is most likely the South San Francisco’s storm drain network.
- Besides the storm drain pathway, flood exposure from Navigable Slough begins when 10-year water levels overtop the banks on the south bank of the middle slough, exposing developed parcels South San Francisco.
- The 100-year Bay water level event is likely to cause bank overtopping in both the middle and upper slough, with extent of inundated area somewhat limited by the limited locations for overtopping and the limited event duration. With 10-year watershed discharge concurrent with 100-year Bay water levels, the overtopping volume is likely to yield flows down Shaw Road and into the San Bruno neighborhood of Belle Air.
- Although an existing floodwall on the south bank of Navigable Slough would impeded flood propagation, this floodwall does not meet the FEMA accreditation standards to remove areas from the SFHA. In addition, the Belle Air neighborhood is exposed to coastal flooding from the east, originating from the San Francisco Airport and Millbrae Bay shoreline.
- Federal Emergency Management Agency (FEMA) flood mapping revisions, which are scheduled to take effect in the coming months, expand the developed portions of South San Francisco and San Bruno that are mapped into Special Flood Hazard Areas (SFHA). The enlarged SFHA are due to a combination of higher predictions for the 100-year Bay water level, soil consolidation and settlement that has likely lowered the land surface in developed areas, and different flood mapping methods. Although not as extensive, the combined 100-year Bay water level and 10-year watershed discharge event exhibits similar inundation patterns as the revised FEMA mapping. Buildings within the enlarged SFHA will face additional design and insurance requirements. The revised FEMA

mapping does not consider watershed discharge through Navigable Slough, but the influence of watershed discharge on design water levels would probably need to be considered when seeking FEMA accreditation for flood measures along the slough.

- Because much of shoreline and developed area in Navigable Slough's region is just at or above the current 100-year Bay water level, sea-level rise will cause an increase in the flood exposure from Navigable Slough and many other adjacent sections of the Bay shoreline. For example:
  - with 1 ft of sea-level rise, the 1-year Bay water level event will pose a similar hazard as today's 10-year Bay water level event
  - with 2 ft of sea-level rise, the 1-year Bay water level event will pose a similar flood hazard as today's 100-year Bay water level event
  - with 3 ft of sea-level rise, monthly high tides will pose a similar flood hazard as today's 100-year Bay water level event

- Sea-level rise will cause similar increases in flood hazard for portions of the shoreline adjacent to Navigable Slough, exposing the developed areas around Navigable Slough to alternative flood sources. Therefore, flood management for Navigable Slough will need to be integrated with regional flood management strategies to provide meaningful flood risk reduction.

Based on the existing and future flood hazards from Navigable Slough, the following flood management measures are potential options for reducing flood risk and, in the case of the last measure, also improving the shoreline for habitat and recreation:

- Measure 1: Storm drain outfall flap gates to prevent slough waters from backing up through the storm drain network and inundating developed areas.

- Measure 2: Floodwalls, typically constructed from vinyl or steel sheet piles, serve as barriers to flooding and can be installed in the limited space between the slough wetlands and developed parcels. Two shorter stretches of floodwall may each be sufficient to remove some parcels from the FEMA SFHA. Because of sea-level rise, floodwalls would eventually be needed for the entire slough shoreline.

- Measure 3: An alternative to flood barriers around the entire slough shoreline would be the installation of self-regulating tide gate on the east side of the South Airport Boulevard culvert. A self-regulating gate allows tidal exchange for typical water levels, but then uses pre-set floats to close the gate when higher water levels threaten flooding. Because flood storage volume within the slough is small relative to the potential watershed discharge volume, installing a tide gate would also require a new pump station.

- Measure 4: Shoreline line habitat and recreation enhancements can be implemented in concert with and potentially as mitigation for the preceding flood protection measures. Portions of the banks adjacent to the slough could be graded to increase connectivity of the banks to the waters of the slough, both for the existing tide range and for upwards transition with sea-level rise. The existing trail along the lower slough could be raised and integrated with flood protection, both to reduce flood hazard for the trail itself and the developed parcels behind it.

To reduce the existing and future flood risk from Navigable Slough, the following actions are recommended:

- Near-term (within two years)
    - Install flap gates on storm drain outfalls connected to Beacon Road (Measure 1).
    - Facilitate repair of the existing floodwall on private property along the south bank of the upper slough.
    - Raise awareness and collect data via outreach and education of the affected stakeholders, with activities such as monitoring king tides and other flood events.
- Medium-term (within next two decades, for up to one foot of sea-level rise)
    - Install flap gates on all public and private storm drain outfalls which discharge to the slough.
    - Conduct economic assessment and public outreach to expand evaluation of floodwalls (Measure 2) and full slough tide gates (Measure 3). Based on this additional evaluation and evolving regional strategies, select one of these measures for the upper and middle slough. The lower slough will likely require floodwalls, unless regional strategies supersede. Consider phasing measures to prioritize removing parcels from FEMA SFHA.
    - Coordinate flood management measures with shoreline habitat and recreation enhancements (Measure 4).
- Long-term (beyond two decades, for sea-level rise in excess of one foot)
    - As necessary, raise floodwalls to pace sea-level rise.
    - Coordinate with regional strategies and physically connect to adjacent flood management measures to provide contiguous shoreline protection.

# 3 EXISTING FLOOD HAZARD AND MANAGEMENT

This section describes the existing flood hazard posed by water flowing into Navigable Slough from San Francisco Bay and through Navigable Slough from the upstream watershed. This assessment is based on prior data, as well as new field data and hydraulic modeling conducted for this study. Technical details for these assessments can be found in the cited study documents, Appendix A (for new field data), and Appendix B (for new hydraulic modeling). This section provides a narrative summary of the flood hazards for existing conditions and the increasing flood hazard to come with future sea-level rise.

## 3.1 Study Area Setting

Navigable Slough is a remnant tidal channel that cuts through a commercial district in South San Francisco (Figure 1). At its downstream end, the slough connects via Colma Creek to San Francisco Bay. The slough channel extends 3,200 ft upstream from the confluence with Colma Creek, passing through culverts under South Airport Boulevard and Highway 101. These roadway undercrossing are used to delineate the slough into its lower, middle, and upper reaches (Figure 2). Also shown on this figure are parcel boundaries and shading to indicate public or privately-owned parcels. While the lower slough and most of middle slough are publicly owned, a portion of the middle slough and all of the upper slough are within privately-owned parcels. The slough's watershed, which extends to the west of Highway 280 (Figure 1, Michael Baker International, 2016), is estimated to cover just over 1,000 acres. Runoff from the western two-thirds of the watershed is routed to the slough through a half-mile-long box culvert that runs from just east of the Tanforan shopping center to the upper slough. The remaining, lower portion of the watershed drains to the slough through multiple local storm drains and outfalls.

Prior to development (Figure 3a), Navigable Slough was a tidal channel meandering through vegetated marsh that extended as far inland as today's Spruce Avenue. As part of development, the slough was truncated to its present-day extent and fill was added to raise the adjacent marsh. Upstream portions of the slough were configured to serve as lower portions of Colma Creek, with the connecting channel between Colma Creek and Navigable Slough completely filled in. As late as 1956, development was limited in the parcels adjoining the slough and some of the land adjacent to the slough were still identified as marsh (Figure 3b). As the remaining land adjacent to the slough was further filled and developed, Colma Creek was re-aligned to the south, to join with Navigable Slough and then flow to the Bay (Figure 1).

## 3.2 Hydraulic Assessment Methods

Navigable Slough has only been subject to limited hydraulic assessments, as an ancillary part of other studies (e.g. Moffat & Nichol, 2016). Therefore, this study focused on characterizing the flood hazards from the slough Navigable Slough including field data collection to observe the slough's geometry and hydraulic features, and development and calibration of a hydraulic model of the slough. In addition to simulating the observed conditions, the hydraulic modeling was also used to simulate a range of flood scenarios, to provide predictions for the depth and extent likely to occur under these scenarios.

### 3.2.1 Field Data Collection

Several types of field data were collected in and adjacent to Navigable Slough, to quantify the slough's geometry, to record water levels fluctuations, to observe stormwater discharge, and to inventory storm drain outfalls (Figure 4). The slough geometry was measured with surveyor-grade RTK-GPS equipment. Key elements which were surveyed include culvert/outfall elevations, representative cross sections in each reach of the slough, the slough's thalweg, and top-of-bank elevations. Three water level gauges were deployed, one in each of Navigable Slough's reaches, so the conveyance capacity of the culverts that separate the reaches could be characterized. Discharge measurements were made in the slough's largest storm drain outfall, a 4-ft by 8-ft box culvert that drains a large fraction of the slough's watershed and discharges to the upper slough. All the storm drain outfalls which were visible at low tide, a total of fifteen outfalls, were photographed, surveyed, and measured for size (Table A-1). Details about the outfalls, as well as the other field data, can be found in Appendix A.

### 3.2.2 Hydraulic Modeling

A two-dimensional (2D) HEC-RAS model was developed for Navigable Slough. The model geometry was derived from ESA survey data (Section 3.2.1), LiDAR data, and a previous HEC-RAS model of Colma Creek (WRECO, 2017). Model calibration was performed for two week-long periods in February and April of 2018, using observed watershed discharge data and adjusted tides from the NOAA Presidio tide gage as boundary conditions. Model output from three locations corresponding to the water level gauges in in the upper, middle, and lower slough (Section 3.2.1) were compared with the gauges' observed water levels. This comparison indicates that the model predicts water levels to within a few tenths of a foot of observed water levels.

The model was used to simulate a range of scenarios, consisting of different downstream San Francisco Bay water levels, upstream watershed discharges, and flood management measures. The results of these simulations characterize the potential extent of flooding from different flood events, as well as the flood reduction offered by particular flood management measures, including floodwall options and a self-regulating tide gate.

The model's development, application, and results are further described in Appendix B.

## 3.3 Past Flooding Events

The history of past flooding from Navigable Slough provides direct evidence of flood exposure from the slough, as well as context for the flood predictions and mapping in the subsequent sections. In general, the existing flood problems that have been observed in the vicinity of Navigable Slough are shallow inundation, less than a foot deep, that may be aggravated by the combined occurrence of high Bay water levels and local runoff (FEMA, 2017).

The only recent recorded flooding from Navigable Slough reported by South San Francisco and San Bruno occurred on December 4, 2017. According to observed water levels at the Golden Gate, the high tide on December 4, 2017 was similar to the 1-year or 'king tide' event (more on these events in Section 3.4.1 below) and was not accompanied by any rainfall. These high tide conditions resulted in shallow flooding on parts of Beacon Road and some connected driveways, as shown in Figure 5. The likely flooding source for this event was high water in the slough backing up through storm drain outfalls at South Airport Boulevard and into the storm drain network along Beacon Road where it overtopped low-lying storm drain inlets. Additional details about the storm drain network can be found in the description of the measure to address this flood pathway, Section 4.1.

Looking back over a longer time frame, even higher water levels have occurred in the slough. For instance, staff at the South San Francisco – San Bruno Water Quality Control Plant (SSF-SB WQCP), located at the mouth of Colma Creek (Figure 1), placed markers at the high water line for events in January 2001 and January 2005 that were surveyed as part of this study and found to be just below the 10-year Bay water level (Table 1). On these days, an inch or less of rainfall occurred. In February 1998, another event occurred with approximately 10-year Bay water levels and two inches of rainfall. The highest observed Bay water level on record, similar to the 100-year event, occurred in January 1983 (USACE, 1984). While the recorded water levels suggest these events probably produced some shallow inundation similar to the observed flooding in December 2017, flooding from Navigable Slough in these events was not notable enough to be reported by the Cities for this study.

# 3.4 Flood Event Frequency and Mapping

This section summarizes technical analyses performed by ESA and others to further characterize the flood exposure from Navigable Slough under existing conditions, and consider potential flood events and future flood hazard due to sea-level rise.

## 3.4.1 Bay Water Levels

Ocean water level fluctuations at the Golden Gate propagate through and are modulated by the San Francisco Bay. The majority of ocean water level fluctuations are caused by astronomic tides. As indicated by their name, these tides are caused by the interaction of ocean waters with the astronomic forces created by the earth, the sun, and the moon. As such, these tidal fluctuations are well-known and can be predicted with high accuracy to occur within a well-determined range. Three common tidal datums, or statistical averages to characterize the astronomic tide levels, are shown in Table 1: mean higher high water (MHHW), mean sea level (MSL), and mean lower low water (MLLW). Average water levels for the highest astronomic tides of each year, colloquially referred to as ‘king tides’, are also shown in Table 1.

Astronomic tides are augmented by other atmospheric ad oceanic processes which can further raise bay water levels above the predicted astronomic tide range. The processes which raise ocean water levels are mostly associated with winter storm events, so the resulting water level increase is often termed ‘storm surge’. Storm-related processes include lower atmospheric pressure and winds. In addition, changes in large-scale oceanic circulation, particularly during winters with El Nino conditions, can cause higher-than-normal water levels for several months at a time. Depending on the intensity of each of these processes, as well as the coincident occurrence of all of them relative to astronomic tides, storm surge can result in water levels about three feet above the typical tide range.

The bay water levels with 100-year, 10-year, and 1-year return intervals are also shown in Table 1. ‘Return interval’ is common nomenclature, but note that the strict statistical definition of these water levels are the water levels that have a 1%, 10%, and 99% chance of being exceeded in any given year, respectively. For context, the elevation of the 2001 and 2005 high water levels observed at the mouth of Colma Creek, adjacent to the SSF-SB WQCP are also shown in Table 1.

**Table 1. San Francisco Bay water level elevations at the mouth of Navigable Slough**

| ***Bay Water Level Event*** | ***Elevation (ft NAVD88)*** |
|---|---|
| 100-year | 10.4 |
| Highest water level on record, 1/26/1983 | 9.6 |
| 10-year | 9.1 |
| Observed at SSF-SB Water Quality Control Plant, 1/8/2005 | 8.9 |
| Observed at SSF-SB Water Quality Control Plant, 1/10/2005 | 8.3 |
| 1-year (king tide) | 8.1 |
| Mean Higher High Water (MHHW) | 6.8 |
| Mean Sea Level (MSL) | 3.3 |
| Mean Lower Low Water (MLLW) | -0.7 |

**Sources:** Tidal datums, 100-year, 10-year, and 1-year - AECOM (2016); Highest water level on record – USACE (1984); 2001 and 2005 high water level markers installed by surveyed by ESA (Appendix A)

The 10-year and 100-year Bay water level scenarios were simulated with the hydraulic model to characterize the existing flood hazard from these scenarios, assuming no inflow from the watershed. As shown in Figure 6, model results for the 10-year event show the Bay water level occurring uniformly all the way through to the upper slough. Along most of the slough, the 10-year water surface elevation is contained within the channel banks. However, model results show that water does overtop the middle slough's south bank, propagate along ditch at the toe of the Highway 101 embankment and penetrate into a parking area between two buildings. The model may be overpredicting the actual inundation in this area because K-rail barriers observed on the edge of the parking area were not surveyed for this study and hence not included in the model.

The 100-year Bay water level is 1.3-ft higher than the 10-year level. As a result, model results for the 100-year event show more extensive inundation, as shown in Figure 7. According to the model results, the 100-year Bay water level would cause overtopping of the middle slough's south bank, inundating most of the area between the middle slough and Beacon Street as well as some areas to the south of Beacon Street. Note that these model results do not reflect other flooding sources to the south of Navigable Slough, i.e. San Bruno Creek and San Francisco Bay across the San Francisco International Airport, so they may under-represent potential inundation in areas south of Navigable Slough.

### 3.4.2 Watershed Discharge

ESA estimated design discharges from the Navigable Slough watershed using HEC HMS. In addition to this study, several prior estimates of watershed discharge have been made for Navigable Slough, as summarized in Table 2. These estimates vary by up to a factor of two, with a large portion of the variation between studies probably due to the different assumed watershed areas. Compared to FEMA (2017) and Schaaf & Wheeler (2015), ESA (2018), used the larger watershed that was delineated for the South San Francisco Storm Drain Master Plan (Michael Baker International, 2016). Comparing the discharge per unit area, the ESA estimates are in between the higher rates from FEMA (2017) and lower rates from Schaaf & Wheeler (2015).

The discharge data collected for this study provides a point of reference for these predicted discharges. The discharge data were collected within the outfall of the large box culvert that drains about two-thirds of watershed area into the upper slough (Figure 4). During three rainfall events occurring in March-April 2018, peak discharges in the culvert were about 85-95 $ft^3/s$ (Figure A-3). These rainfall events, while heavy, were not exceptional, having peak rainfall rates of about 0.15 in/hr and total accumulations of about three-fourths of an inch.

Discharge estimates for Navigable Slough were not explicitly provided in the South San Francisco Storm Drain Master Plan report (Michael Baker International, 2016). However, the master plan does propose a facility improvement for the existing box culvert where ESA's discharge measurements were made. Since this box culvert receives flow from about two-thirds of the slough's watershed, it is a good indicator of the total estimated discharge to the slough. The master plan proposes upgrading the existing single 4-ft by 8-ft box culvert to two 5-ft by 12-ft box culverts. The conveyance area of the proposed twin culverts, 120 $ft^2$, is consistent with ESA's higher predicted discharges.

As indicated by Table 2, the 100-year discharge estimated for this study is higher than previous estimates, and may be overstating the flood risk from watershed discharge. However, as indicated by the Schaaf & Wheeler (2015) channel capacity analysis, the slough only has the capacity to convey 192 $ft^3/s$ with the downstream Bay water level at MHHW, the FEMA minimum downstream boundary level. So even the lower estimates of 100-year discharge are at least 50% higher than this channel capacity, indicating that flood risk from the watershed would need to addressed in the upper and middle slough. In the lower slough, the wider channel and higher channel banks have more capacity to convey watershed discharge without overtopping. As part of more detailed design of flood measures, the watershed delineation and its capacity to convey discharge to Navigable Slough should be studied in more detail.

**Table 2. Predicted watershed discharge to Navigable Slough**

| | ***FEMA (2017)*** | ***Schaaf &Wheeler (2015)*** | ***ESA (2018)*** |
|---|---|---|---|
| **Watershed area (acres)** | **256** | **603** | **1,011** |
| **Watershed Event** | **Discharge ($ft^3/s$)** | **Discharge ($ft^3/s$)** | **Discharge ($ft^3/s$)** |
| 100-year | 300 | 360 | 786 |
| 10-year | 200 | 215 | 430 |
| 1-year | n/a | n/a | 243 |

**Sources:** In addition to sources noted at top of each column. ESA (2018) used watershed delineation from Michael Baker International (2016).

For purposes of assessing base flood elevations for riverine-controlled sections that discharge to tidal basins, such as Navigable Slough, FEMA guidance (FEMA, 2016) specifies the 100-year watershed discharge event be simulated with MHHW as the downstream boundary condition. Model results for these conditions are shown in Figure 8. According to the model results, inundation extents for this event are similar to those associated with the 100-year Bay water level with no watershed runoff (Figure 7). While inundation south of the middle slough is nearly identical, the inundated area both north and south the upper slough is more extensive. This suggests that the watershed source may be a bigger source of flood exposure in the upper slough than Bay water levels.

### 3.4.3 Combined Tidal and Discharge Events

Waterways such as Navigable Slough, that are affected by both downstream tidal basins and watershed discharge, need to consider the combination of these two processes when assessing flood hazard. These two processes are partially correlated in their occurrence frequency, since winter storms cause both storm surge in the downstream tidal basin and rainfall in the watershed.

The approach adopted in this study, which is provided as guidance in Santa Clara County (SCVWD, 2009), is to analyze two events, the 100-year Bay water level combined with the 10-year watershed discharge, and the 10-year Bay water level combined with the 100-year watershed discharge. Then, at each location along the slough, whichever event yields the higher water level is selected at the design water level for that location.

The modeling results for peak water levels for these two events are shown in Figure 9. Overall, the inundated areas are similar, and show increased flood exposure as compared to the prior events that included just 100-year Bay water levels (Figure 7) or 100-year watershed discharge (Figure 8). The event with 100-year Bay water level and 10-year watershed discharge results in higher water levels in the lower slough (Figure 9a). The event with the 10-year Bay water level and 100-year watershed discharge results in higher water levels in the upper slough and the areas inundated from overtopping from the upper slough (Figure 9b). Water levels and flooding extent are essentially the same in the middle slough and the areas inundated from overtopping from the middle slough. Also, the inundated area south of the middle slough is similar across several events (Figure 7-Figure 9), indicating flooding in this area is constrained by slightly higher ground to the south.

FEMA assessments for Navigable Slough, both the current effective and the proposed preliminary mapping, only include the coastal flooding source of the Bay, and do not include riverine contributions. FEMA assessments are discussed in more detail in the following section.

### 3.4.4 FEMA Mapping

Over the past decade, FEMA has been planning for and implementing updates to its Flood Insurance Rate Maps that include Navigable Slough. These maps show FEMA’s assessment of Special Flood Hazard Areas (SFHA) that are susceptible to inundation during the 1% annual chance flood event (also called the 100-year flood event). Within SFHAs, buildings must meet more rigorous floodproofing design criteria and building owners who fund their loans with federally-backed mortgages must purchase flood insurance as part of the National Flood Insurance Program (NFIP).

The current effective FIRM is shown in Figure 11. The analyses used to create this FIRM were initiated in the 1970s and first adopted in 1981 (FEMA, 1981). Revisions have been made since then, such as consideration of the highest Bay water levels that occurred in 1983 and updating the vertical datum, with the current map becoming effective in 2012. According to this current FIRM, the areas adjacent to Navigable Slough are not within the 1% (100-year) SFHA, but are located within the 0.2% (500-year) floodplain. Since the areas adjacent to the slough were anticipated to be inundated less frequently than the 100-year return interval, property owners have not been required to purchase flood insurance. However, by mapping areas around the slough into the 500-year floodplain, the FIRM indicates that these areas are still exposed to flood hazards. For purposes of developing the current effective FIRM, the 500-year Bay water level was estimated to be only three tenths of a foot higher than the 100-year Bay water level (FEMA, 2012).

The preliminary FIRM (Figure 12), which is anticipated to become the effective map in the coming months, is the result of nearly a decade of planning and analyses by FEMA, in coordination with the Bay area communities and flood control agencies. This substantial map revision incorporates longer water level records, two-dimensional modeling of Bay waves and water levels, and new inland flood propagation methodologies to map the SFHA. The preliminary mapping, like the current mapping, does not include Navigable Slough's watershed discharge; the only flooding from Navigable Slough that is mapped is for Bay water levels.

In this preliminary map, a substantial portion of the developed parcels north and south of Navigable Slough, including the Belle Air neighborhood in San Bruno, are mapped into the 1% (100-year) SFHA, with adjacent, slightly higher areas designated as in the 0.2% (500-year) floodplain. The enlarged 100-year SFHA in the preliminary mapping appears to be the result of three differences as compared to the current mapping: an increase in the 100-year Bay water level, assumed settlement of the fill placed in developed areas, and new methodologies for propagating flood water levels inland. The cities appealed this preliminary map, but after proceeding through the FEMA review process, the appeal has been denied. Because of these factors, if FEMA accreditation is sought for flood management measures to address Navigable Slough flooding, the project sponsors should engage with FEMA during planning and design to identify appropriate hydrologic and hydraulic analyses for design water levels and the freeboard criteria.

## 3.5 Sea-Level Rise

Over the last century, the tide gauge at the Golden Gate has recorded sea-level rise at a rate of 0.64 ft/century (NOAA, 2018). In addition to these observed sea-level rise trends, the best available science, as reviewed specifically for California (Griggs et al., 2017), predicts that sea-level rise will continue and accelerate throughout this century and into the next century. Because specifics about future greenhouse gas emissions and climate response cannot be fully known in advance, the exact sea-level rise scenario that will occur is not precisely known at this time. However, considering a range of all but the most extreme scenarios, sea-level rise by 2100 is projected to be between one and five feet in San Francisco Bay.

Even if sea-level rise is stays within the lower end of this range by 2100, several contributing factors all point to increasing future flood hazard. For all future scenarios, sea-level rise is projected to continue increasing beyond 2100. So even if higher levels of sea-level rise do not occur by 2100, they will become increasingly likely in the next century. In addition, climate change may also cause increased precipitation intensity and watershed discharge (Cayan et al., 2016; Dettinger et al., 2016). Since watershed discharge contributes to flood water levels within Navigable Slough, addressing the threat from sea-level rise would also provide adaptation to more frequent and intense watershed discharge.

Given the projections for increasing sea-level rise, as well as the contributing factors above, this study considers sea-level rise as part of existing conditions that will increase flood hazard. While increased precipitation due to climate change could also increase flood hazard, this process is considered a secondary factor and was not considered for this study. Given the dominant role of the Bay in setting the local flood hazard, adapting to sea-level rise will be the primary challenge and doing so will also afford some protection from higher precipitation as well.

California recently adopted new guidance to plan for sea-level rise (OPC, 2018). The guidance recommends considering range of scenarios and includes flexibility for local priorities to inform final decisions. Interpreting this guidance for Navigable Slough, this study considers flood management measures that minimizes flooding for up to three feet sea-level rise. Three feet corresponds to state guidance recommended for typical coastal housing up to 2070 or, if risk tolerance is higher, up to 2100.

Figure 10 shows hydraulic modeling results for the 100-year Bay tide level increased by one foot of sea level rise, with no watershed discharge. With this increase, model results show overtopping from Navigable Slough extending down Shaw Road and into the Belle Air neighborhood. Also note that north of Navigable Slough, the inundation from the slough merges with inundation from Colma Creek.

# 3.6 Discussion

The current FEMA FIRM suggests that the developed areas around Navigable Slough are right on the cusp of being mapped into the SFHA, as indicated by the area's designation of being in the 500-year floodplain. The assessments done for this study also demonstrate how close the slough is to this tipping point: the 100-year Bay water level is likely to just start inundating the adjacent shoreline (Figure 7), and adding watershed discharge (Figure 9) or one foot of sea-level rise (Figure 10) results in similar inundation extents as the preliminary FEMA map (Figure 12). Overall, this proximity to the 100-year inundation threshold is consistent with the flood management approach to date, which was to place fill on former salt marsh until the ground surface elevation just exceeded the 100-year flood level. This approach left limited capacity to accommodate ground surface settlement, sea-level rise that has already occurred, and watershed discharge. Future sea-level rise will pose additional adaptation challenges.

In addition, with additional sea-level rise, flooding becoming an increasingly regional issue, with developed areas exposed to flooding across multiple segments of the shoreline. Hence, dynamic hydraulic modeling becomes less critical and simpler approaches, such as projecting Bay water levels inland, are adequate for characterizing flood exposure. For example, the inundation exposure to the 100-year event and three feet of sea-level rise, as mapped by the Bay Conservation and Development Commission's (BCDC) Adapting to Rising Tides project, is shown in Figure 13. For this case, inundation of two feet or more is nearly continuous along the Bay shoreline and propagates as far inland as a thousand feet or more beyond Highway 101.

# 4 DESCRIPTION OF PROPOSED FLOOD MANAGEMENT MEASURES

Based on the understanding of the existing flood hazards and management, as well as other site opportunities and constraints observed during site visits, the following four flood management measures were developed as potential alternatives to reduced flood exposure (Measures 1-3) and enhance habitat and recreational uses of the slough's shoreline (Measure 4).

## 4.1 Measure 1: Storm Drain Flap Gates

ESA's 2018 field survey identified numerous culvert outfalls to Navigable Slough. As shown in Figure 14, several of these outfalls are associated with the South San Francisco storm drainage network but many others were likely installed by private parcels bordering the slough. Few of these outfalls had flap gates to prevent backwatering of high water from the Slough into the storm drains, and some of the existing flap gates were in poor repair.

As evidenced by the December 2017 flooding of Beacon Street, the South San Francisco storm drain network provides a conduit for high water levels from Navigable Slough to inundate Beacon Street and adjacent parcels via the outfalls to the slough on either side of South Airport Boulevard (Figure 14). While specifics of the storm drain connections under South Airport Boulevard are only known to the degree provided by SSF in the mapping developed for its 2016 storm drain master plan (Michael Baker International, 2016), it appears that backwater from the outfalls was transmitted up the storm drains along South Airport Boulevard and Beacon Street to where it overflowed in low-lying areas (Figure 5).

ESA's 2018 field survey found three storm drain outfalls near South Airport Boulevard, two in the lower slough and one in the middle slough. The lower slough outfalls measure 18 inches and 24 inches in diameter; neither had a flap gate. The middle slough outfall, 36 inches in diameter, has a metal flap gate which appeared to be generally intact, but its operational performance was not evaluated.

To address this existing flooding pathway through the storm drain network, flap gates can be installed on the slough outfalls. In addition to traditional design of a hinged metal flap to close off an outfall, an alternate design with similar performance consists of a flexible valve that closes by curling up and opens by unfurling to allow discharge when water is present in the pipe behind the valve.

Three South San Francisco storm drain lines discharge into the upper slough. Backwatering through these lines has not yielded reports of inundation on city streets during recent years' king tides. So, these outfalls may not warrant installing flap gates in the near term. However, to the extent any outfall to Navigable Slough connects to pipes and collection points in low-lying developed areas, flap gates may be warranted. Further, if floodwalls were installed on Navigable Slough to obtain FEMA accreditation, any outfalls crossing such a floodwall would need flap gates installed to meet accreditation standards.

# 4.2 Measure 2: Floodwall Barriers

As shown by the modeling results described in Section 3, several sections of middle and upper sloughs do not contain the 100-year flood event (Figure 9). In addition, the existing floodwalls along these slough reaches do not meet FEMA crest elevation, geotechnical, and structural accreditation criteria. To reduce flood risk from Navigable Slough in the upper and middle sloughs, new flood barriers could be constructed along the boundaries between the slough and the adjacent developed parcels. Because of the lack of space between Navigable Slough and the developed land immediately adjacent to the slough, a floodwall is likely the only feasible type of flood barrier in this location. A levee, for example, would be approximately 40 ft wide (assuming 4 ft height, 16 ft top width and 3:1 side slopes), requiring a substantial footprint in developed parcels, wetlands, or both. Potential floodwall segments should extend long enough to connect to adjacent portions of the flood management system.

The crest elevation of a floodwall should, at a minimum, be designed to contain the present day design flood elevation, and, preferably, meet FEMA accreditation criteria to remove or help remove developed parcels from the FEMA SFHA. In anticipation of ultimately trying to achieve FEMA accreditation for all of Navigable Slough, the hydraulic modeling was used to estimate what the 100-year water levels in the slough would be if flood waters were fully contained. For the upper and middle slough, the assumed FEMA freeboard requirement is three feet above the 100-year water level, since these reaches are primarily influenced by watershed discharge. For the lower slough, the assumed FEMA freeboard requirement is two feet, since this reach is primarily influenced by Bay water levels. The resulting floodwall design elevations for existing conditions and with three feet of sea-level rise are summarized in Table 3.

**Table 3. Floodwall design elevations**

| | | | Floodwall design elevation (ft NAVD) | |
|---|---|---|---|---|
| **Slough Reach** | **Existing 100-yr water level (ft NAVD)** | **Freeboard (ft)** | **Existing** | **+3 ft SLR** |
| Upper reach | 11.7 | 3.0 | 14.7 | 17.7 |
| Middle reach | 11.6 | 3.0 | 14.6 | 17.6 |
| Lower reach | 10.4 | 2.0 | 12.4 | 15.4 |

**Sources:** Exiting water levels from ESA (2018); freeboard from FEMA.

In some stretches where the existing ground surface adjacent to the slough banks is 10 ft NAVD or higher, vinyl sheet pile may have sufficient structural strength to meet the existing floodwall design elevations, since vinyl sheet pile can typically extend up to four feet from the ground surface and still be able to withstand the hydrostatic forces during the design flood event. However, in areas where the existing ground surface is lower, such as the south bank in the upper slough, the floodwall would need to extend at least six feet above the existing ground surface. This height could challenge the structural capacity of vinyl sheet pile, so either steel or fiber-reinforced polymer sheet pile would likely be needed. In addition, all but a few stretches with higher existing ground (e.g. just east of South Airport Boulevard) would need steel or fiber-reinforced polymer sheet piles to meet the design elevations for three feet of sea-level rise. Therefore, while more expensive initially, the most-cost effective long-term floodwall design is likely to be steel or fiber-reinforced polymer, rather than vinyl that would need to be replaced in the future to meet the demands of sea-level rise.

Floodwalls designed to the future condition of three feet of sea-level rise would rise six to nine feet above the ground surface. If this height causes concerns about aesthetics and access to the slough, steel sheet pile floodwalls could be constructed in two stages. In the first stage, the floodwalls would be built to support the full wall height structurally, but constructed only to the height required under existing conditions. The crest elevation could then be raised in the future by three or four feet with a concrete cap wall bolted onto the steel sheet pile base. While this approach would incur additional construction costs in the future, a net-present value analysis indicates that the overall difference in cost is only 5-10% (ESA, 2018).

### 4.2.1 Alignment Options

All of Navigable Slough's shoreline will need new floodwalls to contain the 100-year flood once Bay water levels experience two feet or more of sea-level rise. However, some stretches of the slough's shoreline are at lower elevations and currently exposed to overtopping at water levels below the 100-year water level. Therefore, this study considered three possible floodwall alignments/phasing options, as illustrated in Figure 15 and described below.

The proposed alignments are wholly located on private parcels (in the upper slough) or located along the public/private parcel boundaries (middle slough) (Figure 2). The floodwall would presumably be aligned along the developed land edge, to protect as much developed property from flooding while also minimizing fill in the slough wetlands. The implementing agency would need to acquire land or right-of-way easements for the floodwall's footprint and for ongoing operations and maintenance.

#### 4.2.1.1 Option A: South Middle Slough

Because Navigable Slough is the only flood source for the SFHA that lies to the south of the middle slough, a FEMA-accredited floodwall along this reach could enable approximately ten parcels to be removed from SFHA. At the east end of Option A, tying into high ground may be sufficient for FEMA accreditation under current conditions. With sea-level rise, the high ground to the east will be subject to bank overtopping as well, however, and the floodwall will need to be extended. On the west end, the alignment shown in Figure 15 is the most direct way to tie-in with the Highway 101 embankment, but the this alignment would cut off a vegetated area adjacent to the slough. The vegetated area landward of the proposed floodwall appears to be above the typical tide range and probably does not include tidal wetlands. However, it may include some seasonal wetlands so, to reduce impact, the floodwall would likely need a new flap-gated culvert to enable drainage. This approach would cut off the area from inundation and associated salinity resulting from extreme water levels, but this uplands vegetation is not likely to rely on this source of inundation for survival.

#### 4.2.1.2 Option B: South Upper Slough

Low ground beyond the south bank of the upper slough continues down Shaw Road and into the City of San Bruno neighborhood of Belle Air. This low ground is one of several flood pathways which result in a large portion of the Belle Air neighborhood being mapped into the SFHA in the preliminary FIRM (FEMA, 2015). Therefore, a floodwall along the sought bank of the upper slough could contribute to a plan for removing the Belle Air neighborhood from the SFHA but would not be the sole solution.

An existing concrete wall with a top elevation of 10-10.5 ft NAVD extends along the eastern half of the upper slough's south bank and ties into higher ground of the Highway 101 embankment at its east end. On the west end, the concrete wall ends near the large box culvert where ESA monitored discharge (Figure 4). West of the concrete wall, the ground along the slough's banks is higher (Figure A-7) and are have a low wooden wall along the top of bank. This study's hydraulic modeling demonstrates that the wall does offer some actual flood risk reduction, as the model results for the 100-year Bay water level event show only minor inundation landward of the existing floodwall (Figure 7).

Several portions of the concrete wall crest have been damaged, resulting in low points along the wall of just over 9 ft NAVD. Even fixing these damaged sections of the existing wall would provide some additional flood hazard reduction. Where the wall is not damaged, its existing crest elevation is not high enough to meet FEMA freeboard criteria for accreditation. In addition, the wall's structural and geotechnical capacities have not been evaluated or documented. Because the existing floodwall is not FEMA-accredited, FEMA mapping does not consider the wall when projecting Bay water levels inland. Because of these deficiencies and uncertainties relative to FEMA accreditation criteria, a replacement wall is assumed to be needed for this location.

Removing parcels south of this alignment from the SFHA will require coordination with other flood management measures besides just this segment of shoreline along upper Navigable Slough. Shaw Road is a flood pathway that joins low-lying areas on either side of Highway 380 into a contiguous SFHA (e.g. Figure 9). So even if an accredited floodwall is built along upper Navigable Slough, flooding across San Francisco International Airport or the Milbrae shoreline just south of the airport could be considered a flood source for areas north of Highway 380, via Shaw Road. If both of these other flood pathways were blocked with FEMA-accredited measures, then this entire region could be removed from the SFHA.

If flood management measures to address these three flood pathways that affect Belle Air are not addressed on a similar schedule, then a closure device to cut off the Shaw Road connectivity under Highway 380 could be considered. A common type of closure device is a heavy metal barrier or flood gate that could be connected to the Highway 380 underpass and swung across Shaw Road when flooding threatens. An active-closure device such as this would need to be manually closed and could be designed to block flooding from either direction. Passive-closure flood gates are also available which would lie flat within the Shaw Road roadbed until they automatically deploy via buoyancy in response to rising flood waters. While this reduces operational demands, these types of closures have a designated wet side, so would need to be installed in duplicate or only block flooding from one direction. Finally, there are closure devices that consist of large flexible bladders that are deployed by filling with water and stacking to create a levee-like structure across the opening. While these types of devices may have lower capital costs, they require significantly more time and training to deploy. A structure more than three feet high may be needed to block Shaw Road, which is both more time consuming to build with flexible bladders and may not be acceptable to FEMA in an accredited system.

#### 4.2.1.3 Option C: Entire Upper & Middle Slough

The third option illustrated on Figure 15 is to surround all of middle and upper sloughs with floodwalls. This would provide a consistent level of flood protection for the entire area. Because the floodwalls would form closed loops around the upper and middle slough, this option would likely be able to achieve FEMA-accreditation.

On the north side of the slough, floodwalls should be set back from the channel as far as possible to preserve connectivity between the tidal channel and adjacent tidal marsh. For the middle slough, the north-side alignment would need to be coordinated with the utility company that owns the power towers near the end of Marco Way. Building the floodwall north of the power towers, as shown in Figure 15, would preserve the tidal marsh at their base, but would complicate maintenance access to the towers. If the floodwall were built to the south of the towers, mitigation would need to be provided for impacts to tidal wetlands cut off from the tidal channel by the floodwall.

### 4.2.2 Construction Methods and Access

Along the banks of the slough, much of the floodwall alignment looks to be accessible via parking lots. Access permission would be needed from these private parcel owners and in some instance storage facilities may need to be temporarily re-located. The segments along Highway 101 and South Airport Boulevard would probably be accessed from these roadways, and therefore require temporary lane closures.

Sheet piling can be installed with conventional driving equipment, e.g. drop or vibratory hammers. In some cases, for larger efforts, steel sheet piling may benefit from specialized equipment, e.g. hydraulic ramming anchored with previously driven piles. The design would need to consider soil conditions, to confirm that piles will not encounter rock or other impenetrable materials.

## 4.3 Measure 3: Self-Regulating Tide Gate

While floodwalls could be used to improve flood protection along low-lying sections of Navigable Slough, as described in the prior measure, with increasing sea-level rise the extent and height of floodwalls would need to be increased. Once sea-level rise exceeded about two feet, the entire shoreline of Navigable Slough would likely need floodwalls.

An alternative approach to shoreline floodwalls is to limit the influx of Bay waters into the slough. This could be achieved by adding a self-regulating tide gate to the downstream (east) side of the slough’s South Airport Boulevard culvert (Figure 16).

A self-regulating tide gate has a hinged gate which can close off flow into the culvert, like the tide gates proposed for the storm drain outlets. However, this type of gate is augmented with floats that keep the gate open when water levels remain below a threshold and then trigger closure when the water levels exceed this flood threshold (Figure 17). This threshold would be set between the typical tidal range and larger flood events. By keeping the gate open for typical tides, the gate would allow for the tidal exchange which supports the tidal marsh habitat upstream of South Airport Boulevard.

The tide gate would be installed on the downstream side of the culvert under South Airport Boulevard. By using the existing structure, this location would minimize impacts of a new structure while also being far enough downstream to protect a substantial portion of the slough. The existing culverts under Highway 101 are a less desirable location for a tide gate because less of the slough is upstream of this location, two tide gates would be needed since there are two culverts, and nearly the same watershed discharge would need to be managed in a smaller storage volume upstream of the tide gate when it closes.

The existing South Airport Boulevard culvert would serve as part of the control structure and provide a structural foundation for the tide gate. (The structural capacity of the existing culvert to host a tide gate has not been assessed for this study.) Since the lower slough is downstream of South Airport Boulevard, the lower slough would require alternative flood protection measures, such as floodwalls, once sea-level rise exceeds one foot.

With sufficient design and documentation, the tide gate may be sufficient to remove middle and upper Navigable Slough as a coastal flood source. To remove the parcels west of South Airport Boulevard from SFHA status would require several additional steps to address coastal and riverine flood hazards.

To address coastal flood hazards, the tide gate would need to be integrated with other flood barriers that meet FEMA accreditation standards and prevent water from flowing overland and into areas behind the tide gate. While much of South Airport Boulevard is not in the current SFHA, FEMA may not consider it ‘high ground’ sufficient to block SFHA, but instead only consider it an unaccredited embankment. If this is the case, then a new tidal barrier that links up to the tide gate would be needed, such as flood walls along the lower slough. For the areas south of upper slough to be removed from the SFHA, the potential coastal flood pathway from south of Highway 380, along Shaw Road would need to be blocked. This pathway could either be blocked at the SFO and Millbrae Bay shoreline, or where with a closure device where Shaw Road crosses under Highway 380, as described for Measure 2.

To address the riverine flood hazard, the tide gate will need to be accompanied by a pump station to convey watershed discharge past the tide gate. Even when the tide gate is configured to close just above typical high tide, preserving the largest possible volume for watershed discharge, there is not enough storage volume to prevent the 1-year watershed discharge event from overtopping the banks of the upper and middle sloughs (Figure B-19). The pump station is likely to need at least a capacity of 200 $ft^3/s$, based on ESA’s assessment of watershed runoff. The exact capacity suitable for meeting FEMA interior drainage criteria was not determined. To do so, a better understanding of peak watershed discharge (e.g. Section 3.4.2) and FEMA’s design event is needed. Also, there may be tradeoffs between pump size and constructing floodwalls at some low points along the upper and middle slough. Low floodwalls could provide additional storage volume at lower cost than additional pumping capacity. A value-engineering approach to different combinations of pump station and floodwalls was beyond the scope of this study.

## 4.4 Measure 4: Shoreline Habitat and Recreation Enhancements

Navigable Slough, as compared to many other urban channels which have been squeezed to minimum widths and whose banks are armored with concrete, hosts substantial tidal mudflats and marshes. Recognizing these existing features, shoreline habitat and recreation enhancements can be implemented in concert with and potentially as mitigation for the preceding flood protection measures.

In addition to managing the shoreline for flood hazard reduction, the shoreline and Navigable Slough itself offer additional benefits as habitat for plants and wildlife and as recreation for walkers, bicyclists, and birders. By integrating flood management with these other benefits, the multiple benefits of the shoreline can be preserved to the greatest extent possible.

The ‘green’ benefits identified below are focused on habitat and recreation objectives. These measures could be pursued solely for their own objectives, or as compensatory mitigation for impacts from one or more of the preceding flood management measures. The very limited space within the slough and between the slough shoreline and development preclude the implementation of other green enhancements, such as a horizontal levee, where the green enhancements themselves also provide flood reduction benefits.

### 4.4.1 Improve Wetlands and Ecotone Transition Habitat

Portions of the banks adjacent to the slough are currently above the range of all but the most extreme flood water levels, and therefore are largely inhabited by upland weeds and other non-descript plants. Since these areas are adjacent to the tidal slough channel, they could be re-graded to increase connectivity of the banks to the waters of the slough, both for the existing tide range and for upwards transition with sea-level rise. The location of these potential improvement areas are shown in Figure 18. The three eastern sites appear to be located on publicly-owned land (Figure 2), whereas the western site is located on private land.

### 4.4.2 Raise Bay Trail Along Lower Slough

The existing trail along the lower slough could be raised and integrated with floodwalls and/or added fill, with the objectives of both reducing flood hazard for the trail itself and the developed parcels behind it (Figure 19). As elevation is added to prevent flooding, the trail can be raised as well, such that this public access corridor, along with its views of the slough and its wildlife, are preserved.

# 5 EVALUATION OF FLOOD MANAGEMENT MEASURES

## 5.1 Evaluation Criteria and Methods

### 5.1.1 Flood Hazard Reduction

The fundamental criteria for flood management is the capacity of a measure or plan to reduce flood hazard to assets in the project area. For this study, the flood hazard reduction of Measures 1-3 was assessed using the understanding of the slough's hydraulics developed from site observations and hydraulic modeling. Proposed conditions for Measures 2 and 3 were simulated with the hydraulic model (Appendix B) and compared with existing conditions to demonstrate flood hazard reduction for the 100-year design water levels. The measures' adaptive capacity, the capacity to address seal-level rise, was also considered.

### 5.1.2 Environmental Impacts

Important criteria when constructing large physical flood barriers are their environmental impacts, which must be described and mitigated through the California Environmental Quality Act (CEQA) and regulatory agency permitting process. For flood management measures, the most consequential impacts are likely to be long-term damage or infill of wetlands. For instances when a measure cannot avoid these impacts, offsetting mitigation would be required by the permitting agencies, at an additional cost to the project. While jurisdictional delineation of wetlands is not in the scope of this study, initial consideration of potential wetlands impacts has been considered and barrier designs seek to minimize impacts. A jurisdictional delineation of wetlands and waters is recommended early in the project development process to quantify potential impacts and identify mitigation strategies. Additionally, a botanical survey following the CDFW Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities (CDFW, 2009) is recommended to determine presence of rare plants in the marshes within Navigable Slough, such as California seablight.

Habitat changes, both temporary and permanent, and including any discharge of fill material into waters of the U.S. or of the State, or construction within San Francisco Bay Conservation and Development Commission (BCDC)'s 100-foot shoreline band jurisdiction, could trigger compensatory mitigation requirements from regulatory agencies. The proposed project will need to consider potential changes to tidal elevations and corresponding effects on existing tidal marsh habitat, aquatic species, and upland bird nesting habitat throughout Navigable Slough, and potentially downstream.

There may be an opportunity to enhance existing habitat within the Slough by planting native species and removing non-native, invasive species in the channel. Incorporating enhancements into design to provide a project with "self-mitigating" elements would assist in regulatory permitting. A specific discussion of salt marsh harvest mouse (SMHM) habitat and anticipated mitigation strategies is provided below.

### 5.1.2.1 Salt Marsh Harvest Mouse Habitat

ESA assessed the potential for presence of salt marsh harvest mouse (SMHM) habitat within the project area during a field reconnaissance conducted on July 2, 2018, by Joseph DiDonato, Wildlife Biologist and Erika Walther, ESA Wildlife Biologist (Appendix C). At least three areas along Navigable Slough have relatively large marsh plains covered in dense pickleweed ranging in height from 1-1.5 ft. These include the mouth of Navigable Slough at Colma Creek, the area immediately east of Highway 101, and the area immediately west of Highway 101. These three areas have the potential to support SMHM strictly based on the vegetative makeup, their location within the tidal elevation, and their continued existence as a natural marsh plain within the San Francisco Bay. These areas are connected by fringe marsh habitat along both sides of the channel.

Due to the species' status as a state Fully Protected species, the California Department of Fish and Wildlife does not allow for a presence/absence survey to determine whether or not the site is unoccupied; and the U.S. Fish and Wildlife Service (USFWS) is supporting this approach. For purposes of formal agency consultation, the USFWS is expected to assume the presence of SMHM at Navigable Slough based on the lack of surveys to demonstrate the species' absence, the presence of suitable habitat, and the site location within the mouse's historic range on the San Francisco Peninsula.

Because the resources agencies have assumed the species' presence, compensatory mitigation may be required for completion of the permitting process. Design elements that can be demonstrated to enhance the current distribution of pickleweed habitat may fulfill this requirement and would be beneficial to regulatory review. Additionally, site clearance measures to ensure take of individuals is avoided may be required. This typically includes hand removal of pickleweed vegetation, biological clearance surveys of construction areas, and installation and monitoring of exclusion fencing. These measures would affect contractor means and methods during project implementation.

### 5.1.2.2 Cultural Resources

ESA reviewed existing background materials related to cultural resources in the vicinity of the Navigable Slough Area of Potential Effects (APE), including the Draft CEQA document for the Colma Creek Flood Control Maintenance Project and the supporting cultural resources study (Basin, 2015), and the CEQA document for the South San Francisco / San Bruno Water Quality Control Plant Capital Improvement Project and the supporting cultural resources study (Koenig, 2014). Based on this review, there are no previously recorded cultural resources (including architectural and archaeological resources) in the approximately 3,000-foot-long Navigable Slough APE, from the mouth at Colma Creek to the western upstream end of the slough.

In 2015, Basin Research Associates (Basin) completed background research and an assessment of cultural resources for the adjacent Colma Creek Flood Control Maintenance Project, which included the downstream 850 feet (260 meters) of Navigable Slough (Basin, 2015). Background research included a records search at the Northwest Information Center (NWIC) of the California Historical Resources Information System (File Nos. 14-0524 and 14-0813) and a review of reference material from the Bancroft Library, University of California at Berkeley and Basin Research Associates, San Leandro. Basin also contacted the Native American Heritage Commission and several Native American tribes/individuals with an interest in the project vicinity. The intent of the research was to identify historic properties (prehistoric and historic-era resources) that may be listed, determined, or potentially eligible for inclusion on the National Register of Historic Places (National Register) and the California Register of Historical

Resources (California Register) and that could be affected by the Colma Creek Flood Control Maintenance Project. The background research included the Colma Creek Flood Control Maintenance Project area and a ¼-mile radius (which includes the Navigable Slough APE).

Based on the results of this research (as of January 2015) no cultural resources had been previously recorded in the Navigable Slough APE.

The nearest recorded resource is CA-SMA-380 (P-41-002164). The site is "... an apparent prehistoric shell midden" mapped south of Littlefield Avenue between the railroad tracks and the north side of Colma Creek. Evidence of the site was noted in three of eleven 2-inch diameter GeoProbe samples at a depth of approximately 16.5 to 21 feet (5.2 to 8.9 m) below both historic and natural fill. Additional discussion is provided in Navigable Slough Flood Study: Data Inventory and Data Gaps Analysis (Appendix C)

On December 13, 2017 an ESA archaeologist conducted an archaeological pedestrian survey of areas along the banks of Navigable Slough in South San Francisco. Ground visibility was limited to approximately 10% due to dense vegetation along the slough banks. Certain sections of bank were inaccessible due to heavy vegetation. The ground in the accessible areas appeared very disturbed by modern activity, and a great deal of modern trash was present throughout. Soil was a compact light brown sandy silt (modern fill) and medium compact dark brown silt (marsh deposits). No historical or prehistoric materials or sites were encountered during the survey.

Based on the results of this research (as of January 2015) no cultural resources had been previously recorded in the Navigable Slough APE. However, any ground disturbing activities proposed on the channel banks would impact archaeological resources should they exist. Several Native American tribes have an interest in the general project vicinity and would need to be consulted (per the requirements of Public Resources Code Section 21080.3.1 and Section 106 of the National Historic Preservation Act).

To further ascertain the potential for a future project on Navigable Slough to impact buried archaeological resources, ESA has completed an updated records search at the NWIC and a surface survey of the Navigable Slough APE. There are no changes to the baseline conditions concluded by Basin in 2015 (i.e. no known cultural resources are in the Navigable Slough APE). Given the moderate to high archaeological sensitivity of the Navigable Slough APE, ESA recommends conducting an additional assessment that considers the depth of ground disturbing activities associated with the proposed project. If feasible, geotechnical borings within the Navigable Slough APE would further determine whether subsurface buried archaeological resources exist in the APE that would be potentially impacted by the project. ESA would also update and revise the Native American consultation for the project (per the requirements of Public Resources Code Section 21080.3.1 and Section 106 of the National Historic Preservation Act).

#### 5.1.2.3 Other Key Environmental Issue Areas

Project implementation would include major construction, resulting in potential short-term impacts to water quality, air quality, noise, traffic and circulation, and adjacent land uses. These types of short-term construction related impacts are typically mitigated to a less than significant level by the implementation of standard Best Management Practices (BMPs), such as SWPPP implementation and dust control. Sheet pile driving related to installation of flood walls as the potential to result in significant short term noise impacts, which may not be mitigable to less than significant. However, sheet pile and pile driving operations are typical construction practices.

Specific mitigation measures would be identified in a Mitigation Monitoring and Reporting Program developed as part of the CEQA review process.

Aesthetics and access affect the way in which residents and other stakeholder experience Navigable Slough and its adjacent open space. Since flood management includes new structures along the shoreline, measures have the potential to affect aesthetic values such as views of the slough and access to the slough shoreline. Design features that enhance public access to the shoreline can provide public benefit and assist in meeting public access goals for key regulatory agencies, such as BCDC.

### 5.1.3 Cost Estimate

While additional flood management can provide definite public benefits, the cost to achieve these benefits is an important consideration. For this study, opinion of probable implementation costs ("cost estimate") were developed for the flood management plans, based on the conceptual-level flood management measures. In addition to construction itself, the cost estimates also include related soft costs for engineering, design, and permitting. To account for uncertainties surrounding these costs, the estimates assumes a 30% contingency. The estimates include design and environmental compliance allotments, but do not include environmental mitigation or right-of-way costs. The cost estimates made for this study are rough order of magnitude estimates in 2018 dollars and have an anticipated accuracy range of +50%/-30%. Further design efforts are needed to reduce uncertainties and improve the accuracy of the cost estimate.

Additional details about the estimates of probable costs can be found in Appendix D.

## 5.2 Evaluation Results

### 5.2.1 Measure 1: Storm Drain Flap Gates

#### 5.2.1.1 Flood Hazard Reduction

Flap gates could be installed on existing storm drain outfalls at a relatively modest cost. This would prevent high water in the slough from backing up storm drains and inundating low-lying areas during high tides. This effect was observed along Beacon Street during king tides in 2017, indicating that tide gates could have an immediate benefit in reducing flood hazards in the area. Once installed, flap gates are adaptable to future conditions as they will continue to function as tide levels increase with future sea-level rise. With sea-level increases greater than three feet, the storm drain system may not be able to discharge by gravity and additional pumping capacity may be needed to prevent flooding from poor stormwater drainage.

#### 5.2.1.2 Environmental Impacts

Impacts associated with installation of tide gates would be expected to be short term and minimal. Final design and configuration would need to be confirmed relative to jurisdictional features and sensitive species habitat, but it is anticipated that these improvements could be made with limited impacts.

#### 5.2.1.3 Cost Estimate

Assessing connectivity and operational conditions of the three flap gates which drain the Beacon Street area to Navigable Slough, as well as design, installing flap gate is estimated to cost $45,000.

### 5.2.2 Measure 2: Floodwall Barriers

#### 5.2.2.1 Flood Hazard Reduction

The existing floodwall along the south side of the upper slough, though not FEMA-accredited, provides some reduction flooding of 100-year event. The wall is damaged in sections, which should be repaired if wall replacement is not scheduled for the near future.

Option A and Option B could address overtopping from stretches of the middle and upper slough at a level sufficient for FEMA accreditation *for those stretches*. For very watershed discharge events, the increased flood protection along these stretches would reduce the storage volume of the overbank areas, which would raise water levels within the slough and increase the flood hazard on other stretches of the slough, particularly within the upper slough, that are just above the current predicted water levels. To remove developed parcels from the SFHA via a FEMA Letter of Map Revision (LOMR), Option A and B would require other steps to address other potential flood pathways into these parcels.

Option C, floodwalls encircling all of the upper and middle slough, could fully manage Navigable Slough as a flood source at levels to FEMA accreditation criteria. However, areas south of the upper slough would still be connected to other flood pathways via Shaw Road. If these other flood pathways across SFO and from Millbrae’s Bay shoreline are not addressed by other projects, a closure device could be added across Shaw Road where it passes under Highway 380.

By using steel or fiber-reinforced polymer for the sheet piles, the floodwall could be raised to adapt to at least three feet of sea-level rise. In the longer term as sea-level rise approached and exceeded two feet, floodwalls or similar barriers would also be needed to address bank overtopping from the lower slough.

#### 5.2.2.2 Environmental Impacts

Installation of floodwalls would likely result in temporary and permanent impacts to jurisdictional features and sensitive species habitat provided by the slough vegetative complex. However, these impacts would be limited to the upper fringe, along the development/tidal channel border where the floodwalls would likely be installed. Floodwalls, while costlier to construct than levees, were selected to minimize the extent of impact as compared to levees. Mitigation measures to ensure individual SHMH are not impacted, including pre-construction clearance and fencing installation, and acquisition of regulatory permits from USACOE, USFWS, CDFG, RWQCB, and BCDC, including establishment of compensatory mitigation and construction mitigation measures, would be anticipated. However, because work can be conducted from the adjacent areas, placement of sheet pile floodwalls could be considered a minimal impact relative to the extent of available habitat. Noise impact associated with pile driving to surrounding properties would likely be considered short-term, but significant and unavoidable.

### 5.2.2.3 Cost Estimate

The cost estimate for the three floodwall barrier options shown in Figure 15 are listed in Table 4. These costs assume steel sheet pile is used for the floodwalls and that the floodwalls are built to a crest elevation that can accommodate three feet of sea-level rise (i.e. last column of Table 3). While vinyl sheet pile could be less expensive initially and be sufficient for FEMA accreditation, vinyl sheet pile's structural capacity would limit the floodwalls' capacity to be built for three feet of sea-level rise.

**Table 4. Cost estimate for Measure 2: Floodwalls**

| Floodwall Option | Cost Estimate* |
|---|---|
| Option A | $1.6M |
| Option B | $4.0M |
| Option C | $16M |

* In 2018 dollars, for planning purposes only. Estimates include contingency, design, and environmental compliance, but do not include environmental mitigation or right-of-way costs. The estimates' anticipated accuracy range is +50%/-30%.

## 5.2.3 Measure 3: Self-Regulating Tide Gate

### 5.2.3.1 Flood Hazard Reduction

The self-regulating tide gate could address the coastal flood source of Bay water levels propagating up Navigable Slough. A pump station would also be required to offset the tide gate's obstruction of watershed discharge. As is the case for Measure 2, the tide gate and pump station would need to be augmented with other regional flood management measures to address other flood pathways to the SFHA west of South Airport Boulevard.

With sea-level rise, the tide gate would need to close with increasing frequency. Once sea-level rise reached about two feet, tide gate closures could occur as often as once a day, and begin to mute the tide range within the upper and middle slough. Sea-level rise would also increase the pumping capacity requirements of the pump station.

### 5.2.3.2 Environmental Impacts

Installation of a full slough self-regulating tide gate would be specific to the facility installation footprint. Temporary and permanent impacts to jurisdictional features would likely be associated with implementation of these enhancements, and acquisition of regulatory permits from USACOE, USFWS, CDFG, RWQCB, and BCDC, including establishment of compensatory mitigation and construction mitigation measures, would be anticipated. Potential long-term alteration of tidal influence, and corresponding alterations in vegetative assemblage distribution would need to be confirmed based upon final design. It is anticipated that these tide gate operations would be designed to mimic as closely as possible current tidal conditions within the slough, and that potential impacts would be minimal for up to two feet of sea-level rise. Above two feet of sea-level rise, the tide range in the upper and middle sloughs would begin to be muted, and muting would increase with increasing sea levels.

### 5.2.3.3 Cost Estimate

The cost estimate to install a self-regulating tide gate on the east side of the South Airport Boulevard, as well as a 200-$ft^3/s$ pump station to manage watershed discharge when the tide gate is closed, is $19M. The majority of this cost is associated with the pump station. Other measures that tie-in to the tide gate, to address other flooding pathways to the SFHA west of South Airport Boulevard are not included, making this measure comparable to Measure 2's Option C, in that both are intended to address upper and middle Navigable Slough as a flood source.

### 5.2.4 Measure 4: Shoreline Habitat and Recreation Enhancements

#### 5.2.4.1 Flood Hazard Reduction

Because of Navigable Slough's limited fetch and storage volume capacity, natural habitats and recreation enhancements do not have the space to create 'green infrastructure' that is capable of attenuating flooding. Instead, these enhancements help achieve other multi-use benefits of the slough and shoreline.

#### 5.2.4.2 Environmental Impacts

Effects related to enhancing the slough shoreline would be specific to the footprint of specific enhancement. Temporary and permanent impacts to jurisdictional features would likely be associated with implementation of these enhancements, and acquisition of regulatory permits from USACOE, USFWS, CDFG, RWQCB, and BCDC, including establishment of compensatory mitigation and construction mitigation measures, would be anticipated.

#### 5.2.4.3 Cost Estimate

The cost estimate for habitat enhancements for all four enhancement sites identified in Figure 18, a total of 1.27 acres, as well as raising and improving the trail along the south side of the lower slough is $600,000.

## 5.3 Summary of Evaluations

A summary of the evaluations of the four measures considered in this study is provided in Table 5. Measure 1 could have immediate benefits in terms of reducing flood risk from existing high tides, and would have minimal environmental impacts and a relatively modest estimated cost of $45,000. Measure 2 includes three alternative floodwall alignments, which could be phased to keep pace with sea-level rise. The estimated costs range from $1.6M for a middle slough alignment (Option A) to address existing flooding levels, to $16M for a wall around all of middle and upper slough (Option C) built to withstand three feet of sea-level rise. Option C has the potential to support to remove parcels from the SFHA, and contribute substantially to a regional flood management system. An operable flood barrier on Shaw Road could work in tandem with a flood wall to reduce flood hazards in the Belle Air neighborhood. Depending on the floodwall alignment, there is potential for floodwall construction to impact existing tidal wetlands and possible cultural resources along Navigable Slough. However, Measure 4 identifies several areas where wetlands could be created or enhanced to offset the potential impacts of flood management measures. Measure 3 consists of a self-regulating tide gate at South Airport Boulevard to exclude high tides from the middle and upper sloughs. A pump station would be needed in conjunction with the tide gate to pump watershed discharge out of the slough when the tide gate is closed.

Among the measures evaluated, this option has the highest estimated cost at $19M. A tide gate has the potential to cause impacts to tidal wetlands by muting the tide range as sea-level rise increases to two feet and higher.

**Table 5. Summary of evaluation results for Navigable Slough flood protection measures**

| Measure | Hydraulic Changes | Enviro. Compliance | Cost Estimate* |
|---|---|---|---|
| 1: Storm drain flap gates | • Prevents known backwatering onto streets | • May include very minor amounts of wetlands fill | $45k |
| 2: Floodwalls<br>A) S. Bank Mid Slough<br>B) S. Bank Upper Slough<br>C) Entire Mid & Upper Slough | A) Possible LOMR for ~15 parcels<br>B) Possible LOMR when SFO and Millbrae also protected or w/closure on Shaw Road at Highway 380<br>C) LOMR & part of regional flood system | • Need to probe for cultural resources<br>• Align in developed areas to limited wetland impacts<br>• May disconnect some uplands habitat | A) $1.6M<br>B) $4.0M<br>C) $16M |
| 3: Self-regulating tide gate & pump station | • Tide gate closes when water level approaches bankful<br>• Pump station, ~200 $ft^3/s$ capacity, to manage watershed discharge | • Minor fill at tide gate<br>• Beyond 2+ ft SLR, gate closures will progress to muting daily tides | $19M |
| 4: Shoreline enhancements | n/a | Mitigation for flood control measures' impacts | $600k |

* In 2018 dollars, for planning purposes only. Estimates include contingency, design, and environmental compliance, but do not include environmental mitigation or right-of-way costs. The estimates' anticipated accuracy range is +50%/-30%.

# 5.4 Funding Opportunities

One possible way to offset costs is to seek grant funding opportunities from outside agencies. To improve the chances of acquiring grant funding, projects need to fulfill grants' objectives, such as FEMA grants that seek to reduce flood damages or multi-objective grants that seek to combine flood protection with restoration (e.g. Bay Area's Measure AA). Grant assistance programs that could provide funding for components of Navigable Slough flood management are listed in Table 6 below. Funding under these programs is subject to availability of governmental appropriations.

FEMA awards grants each year for communities to undertake mitigation projects to prevent future loss of life and property resulting from hazard impacts, including flooding. Mitigation projects that are eligible for hazard mitigation assistance include, for example, property acquisition, structure elevation, floodproofing, and minor flood control projects, such as the installation or modification of culverts, and stormwater management activities such as creating retention and detention basins. Ineligible projects generally include major flood control projects such as constructing or improving levees and floodwalls. These projects are ineligible because catastrophic failure is a possibility and the potential for loss of life and property is too great. FEMA's grants are awarded to states that, in turn, provide subgrants to local governments and communities (subapplicant). The applicant selects and prioritizes subapplications developed and submitted to them by subapplicants and submits them to FEMA for funding consideration.

A screening-level economic analysis could provide an indication of the likely feasibility of the proposed flood management. If benefit-cost ratios are confirmed as favorable when analyzed more robustly, this refined economic analysis can be provided as rationale for securing grant funding.

**Table 6. Grant assistance programs**

| Mitigation Grant Program | Purpose | Additional Information |
|---|---|---|
| Flood Mitigation Assistance (FMA) | Reduce or eliminate claims against the NFIP by reducing long-term risk of flood damage to buildings insurable under NFIP | Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation<br><br>FEMA https://www.fema.gov/flood-mitigation-assistance-program |
| Pre-Disaster Mitigation (PDM) | National competitive program focused on mitigation project and planning activities that address multiple natural hazards | Cal OES http://www.caloes.ca.gov/cal-oes-divisions/hazard-mitigation/pre-disaster-flood-mitigation<br><br>FEMA https://www.fema.gov/pre-disaster-mitigation-grant-program |
| Repetitive Flood Claims (RFC) | Reduce flood claims against the NFIP through flood mitigation; properties must be currently NFIP insured and have had at least one NFIP claim | FEMA https://www.fema.gov/media-library-data/20130726-1621-20490-8359/rfc_08_guidance_final_10_30_07.pdf |
| Severe Repetitive Loss (SRL) | Reduce or eliminate the long-term risk of flood damage to SRL residential structures currently insured under the NFIP | FEMA https://www.fema.gov/pdf/nfip/manual201205/content/20_srl.pdf |
| Hazard Mitigation Grant Program (HMGP) | Activated after a presidential disaster declaration; provides funds on a sliding scale formula based on a percentage of the total federal assistance for a disaster for long-term mitigation measures to reduce vulnerability to natural hazards | Cal OES http://www.caloes.ca.gov/cal-oes-divisions/recovery/disaster-mitigation-technical-support/404-hazard-mitigation-grant-program<br><br>FEMA https://www.fema.gov/hazard-mitigation-grant-program |

| Mitigation Grant Program | Purpose | Additional Information |
|---|---|---|
| Proposition 1 Climate Ready Grants | Climate Ready Grants are focused on supporting planning, project implementation and multi-agency coordination to advance actions that will increase the resilience of coastal communities and ecosystems | Coastal Conservancy http://scc.ca.gov/climate-change/climate-ready-program/ |
| Measure AA | San Francisco Bay-specific program for restoring habitat, protecting communities from floods, and increasing shoreline public access | San Francisco Bay Restoration Authority http://sfbayrestore.org/sf-bay-restoration-authority-grants.php |
| Continuing Authorities Program (CAP) | CAP is to plan, design, and construct flood damage reduction projects. CAP projects do not require project-specific authorization from Congress. | U.S. Army Corps of Engineers, San Francisco District https://www.spn.usace.army.mil/Missions/Projects-and-Programs/Continuing-Authorities-Program/ |

# 5.5 Recommended Next Steps

This study's initial assessment of flood hazards and potential flood management mitigation measures were discussed with the Collaborative. Following are the resulting near-term and long-term recommendations that the Collaborative would like to prioritize and pursue to improve mitigate flood risk along the Navigable Slough shoreline.

- **Near-term** – Near-term actions address existing and frequent flooding issues, do not conflict with other measures which may be implemented in the future, and are relatively low-cost.
    - Install flap gates on storm drain outfalls connected to Beacon Road (Measure 1). Prior to additional design, conduct additional site assessments, e.g. reviewing as-built plans for existing stormwater infrastructure and/or CCTV pipe inspections.
    - Discuss and potentially facilitate repair of the existing floodwall along the south bank of the upper slough on that appears to be on private property. Effort would begin with outreach to property owner, to obtain as-builts if they exist, and discuss results of the hydraulic model and extent of overland flooding to the adjacent jurisdiction. Facilitation could include engineering, permitting, and/or funding assistance.
    - Begin targeted outreach and education of the affected stakeholders, with activities such as monitoring king tides and other flood events. Could also continue to update stakeholders via public communications in the form of meetings, web page, and/or email newsletter.

- **Medium-term** – Medium-term actions have the potential to mitigate flooding for up to one foot of sea-level rise, could be designed with the potential to adapt to sea level rise, and may require selecting a preferred approach to avoid conflicts or duplication between measures, and have higher costs.
    - Install flap gates on all public and private storm drain outfalls which discharge to the slough. Could be only encouragement of individual property owners or a larger project across multiple properties with willing owners to share economies of scale and potentially provide public agency assistance in the form of engineering, permitting, and/or funding. Consider coordination with planning department to include flap gates in design guidance and review process for new construction. [South San Francisco to lead, with support from County]
    - Conduct economic assessment and public outreach to expand evaluation of floodwalls (Measure 2) and full slough tide gates (Measure 3). Based on this additional evaluation and evolving regional strategies, select one of these measures for the upper and middle slough. Plan for and implement preferred measure via funding procurement, engineering design, environmental review and construction. The lower slough will likely require floodwalls, unless regional strategies supersede this approach. Consider phasing measures to prioritize

removing parcels from FEMA SFHA. [County to lead, with support from South San Francisco and San Bruno]
   - Coordinate flood management measures with shoreline habitat and recreation enhancements (Measure 4). Selecting which enhancements to implement may depend on which measures are selected, potential need for mitigation, and/or other regional recreation planning. [Collaboration with County, San Francisco, and San Bruno, with lead eventually depending on implementing agency]

- **Long-term** – Long-term actions are for implementation to address sea-level rise in excess of one foot, which is not anticipated until after two decades. These measures could also be considered as options when implementing medium-term measures.
   - As necessary, raise floodwalls to pace sea-level rise. [Collaboration with County, San Francisco airport, and San Bruno, with lead agency determined through an agreement such as an MOU using the New Flood and Sea Level Rise District as the platform.
   - Coordinate with regional implementation and investment strategies and physically connect to adjacent flood management measures to provide contiguous shoreline protection. [Lead agency will be determined through terms of agreement with participating agencies through an MOU process, using the New Flood and Sea Level Rise District as the platform.

# 6 REFERENCES

AECOM. 2016. San Francisco Bay Tidal Datums and Extreme Tides Study.

Bay Conservation and Development Commission (BCDC). 2018. Adapting to Rising Tides Bay Shoreline Flood Explorer. https://explorer.adaptingtorisingtides.org

Cayan, D.R., M. D. Dettinger, D. Pierce, T. Das, N. Knowles, F. M. Ralph, and E. Sumargo. 2016. Natural Variability, Anthropogenic Climate Change, and Impacts on Water Availability and Flood Extremes in the Western United States. in 'Water Policy and Planning in a Variable and Changing Climate', eds. K. A. Miller, A. F. Hamlet, D. S. Kenney, and K. T. Redmond.

Dettinger, M.D. 2016. Historical and Future Relations Between Large Storms and Droughts in California. San Francisco Estuary and Watershed Science, 14(2). http://escholarship.org/uc/item/1hq3504j.

Environmental Science Associates (ESA). 2018. Edgerly Island and Ingersoll Tract Flood Management Plan and Adaptation Study. Prepared for Napa River Reclamation District and Napa County Flood Control and Water Conservation District.

Federal Emergency Management Agency (FEMA). 1981. Flood Insurance Study, City of South San Francisco, California.

FEMA. 2012. Flood Insurance Study, San Mateo County, California and Incorporated Areas.

FEMA. 2015. National Flood Insurance Program, Flood Insurance Rate Map, Preliminary 8/13/2015.

FEMA. 2016. Guidance for Flood Risk Analysis and Mapping – Hydraulics: One-Dimensional Analysis.

FEMA. 2017. Flood Insurance Study, San Mateo County, California and Incorporated Areas.

Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). 2017. Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust, April 2017.

Michael Baker International. 2016. South San Francisco Storm Drain Master Plan. Prepared for City of South San Francisco.

Moffat & Nichol and AGS Joint Venture. 2015. San Bruno Creek / Colma Creek Resiliency Study – Final Report. Prepared for California Coastal Conservancy and San Francisco International Airport.

Moffat & Nichol. 2016. San Bruno Creek Tidegates - Certification Feasibility. Prepared for County of San Mateo Department of Public Works.

National Oceanic and Atmospheric Administration (NOAA). 2018. U.S. Linear Relative Sea Level (RSL) Trends and 95% Confidence Intervals in mm/year and in ft/century for Station ID 9414290 San Francisco, California. https://tidesandcurrents.noaa.gov/sltrends/mslUSTrendsTable.html

Ocean Protection Council (OPC). 2018. State of California Sea-Level Rise Guidance, 2018 Update.

Santa Clara Valley Water District (SCVWD). 2009. Design Manual – Open Channel Hydraulics and Sediment Transport.

Schaaf & Wheeler. 2015. Hydrologic and Hydraulic Modeling for the SFO/San Bruno Creek/Colma Creek Resiliency Study. Appendix B in Moffat & Nichol 2015.

USACE. 1984.

WRECO. 2017. Draft Colma Creek Hydraulic Analysis Report. Prepared for County of San Mateo.

# 7 STUDY CONTRIBUTORS

Contributors to this study include the following people.

County of San Mateo, Department of Public Works

- Erika Powell, PE
- Ann Stillman, PE
- Julie Casagrande

City of South San Francisco

- Eunejune Kim, PE

City of San Bruno

- Jimmy Tan, PE

City of South San Francisco – San Bruno Water Quality Control Plant

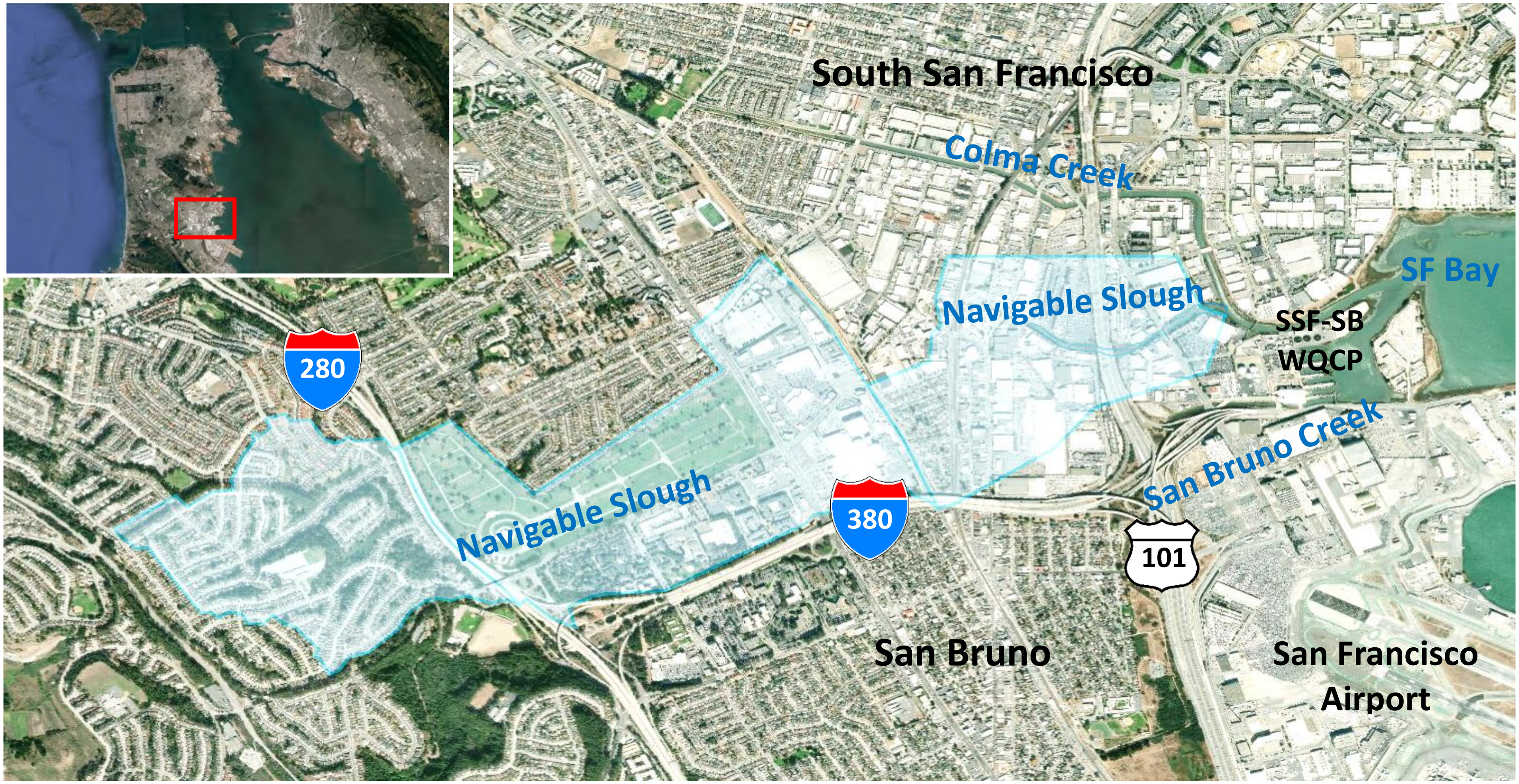
- Brian Schumacker, Plant Superintendent

ESA

- Matt Brennan, PE
- Christie Beeman, PE
- Tiffany Cheng, PE
- Alex Trahan, PE
- Jill Sunahara
- Erika Walther

and Joe DiDonato (independent consultant)

# 8 FIGURES

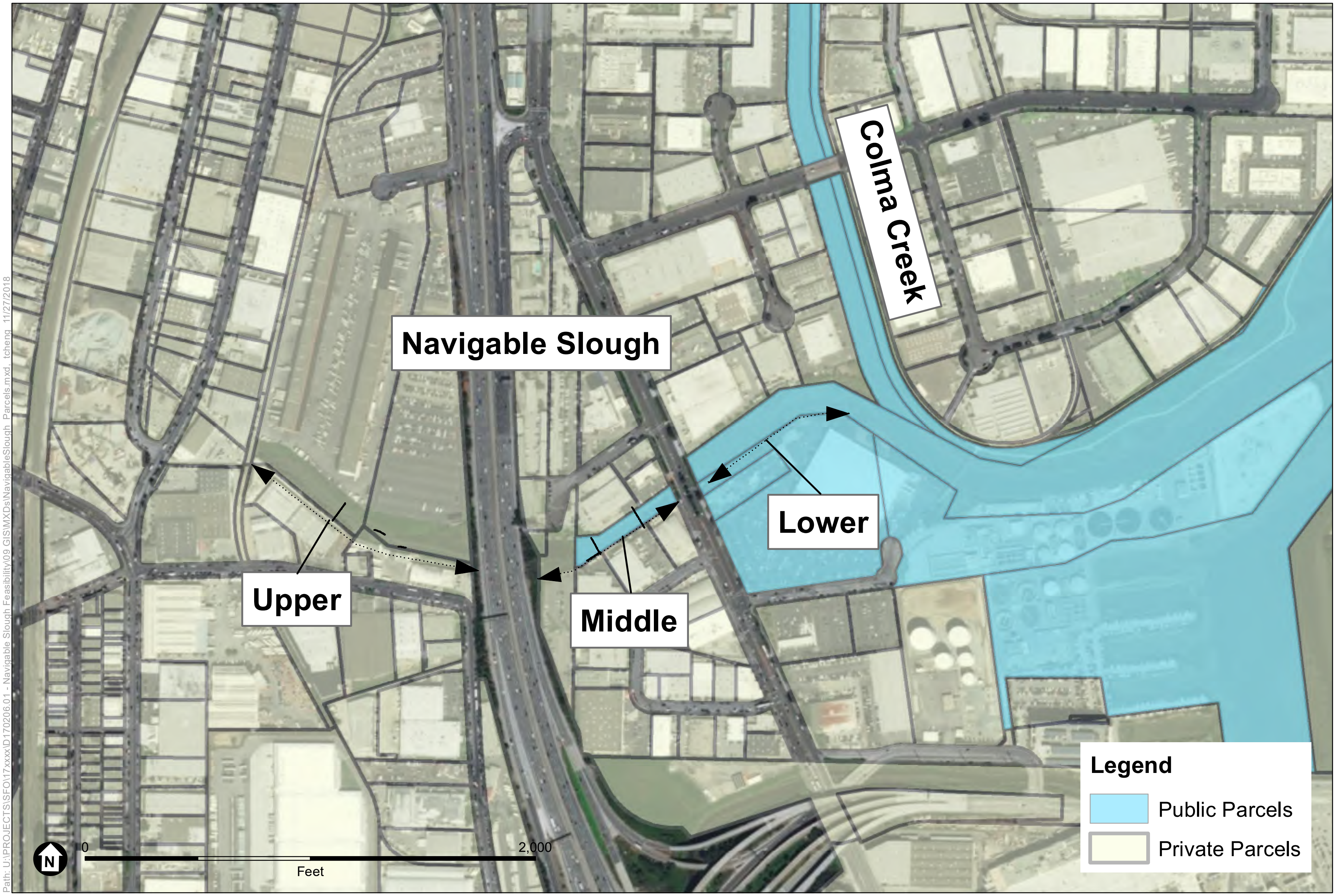



SOURCE: Google Earth

Navigable Slough Feasibility D170206.01

**Figure 1**

Navigable Slough and its Watershed




SOURCE: San Mateo County GIS

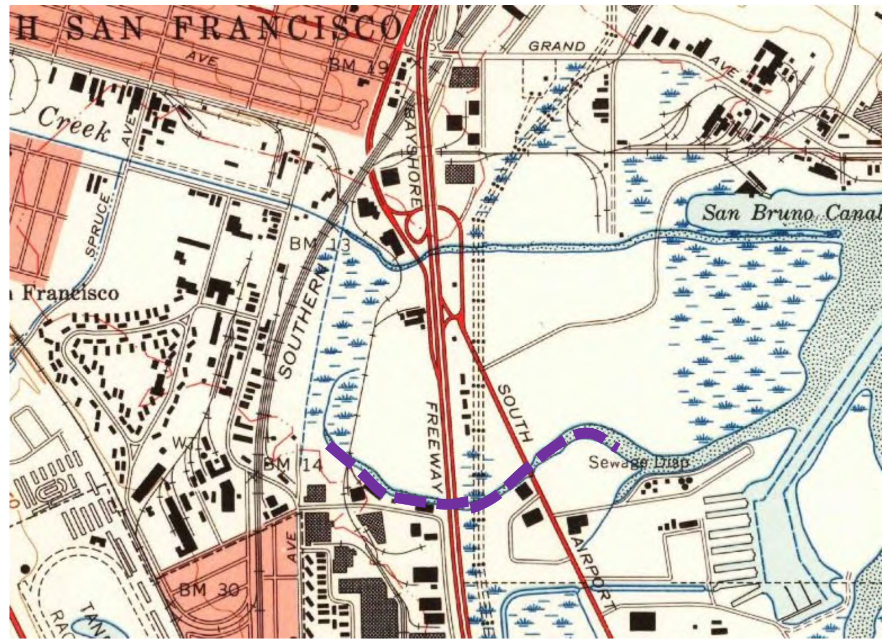
Navigable Slough Feasibility. D170206.01

**Figure 2**
Navigable Slough Reaches and Parcels

ESA

a) Historic marsh (1867)

b) 20th century development (1956)




Present-day extent of Navigable Slough

SOURCE: US Coast Survey, Register Number 1067 (1867); USGS San Francisco, South quadrangle (1956)

Navigable Slough Feasibility. D170206.01

**Figure 3**

Historic Land Use


SOURCE: ESA Survey (2018)



**Figure 4**
Field Data Locations

Middle Slough, looking west to HWY 101

Beacon Street, looking west to HWY 101

Parking area of 131 Beacon Street

Driveway of 454 Beacon Street

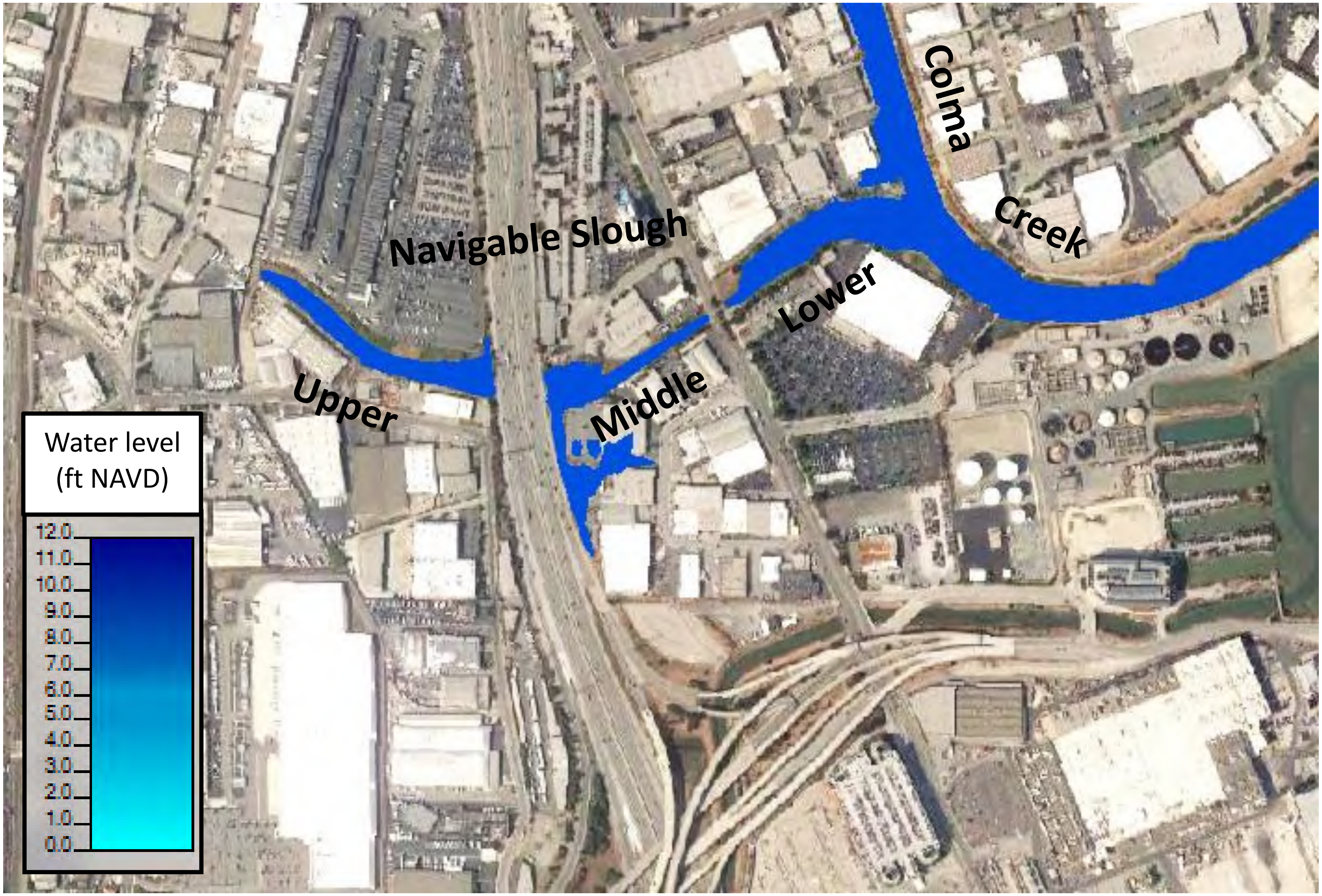
SOURCE: City of South San Francisco

Navigable Slough Feasibility D170206.01

**Figure 5**

Storm Drain Backwater Flooding

December 4, 2017




SOURCE: HEC-RAS Modeling (ESA, 2018)

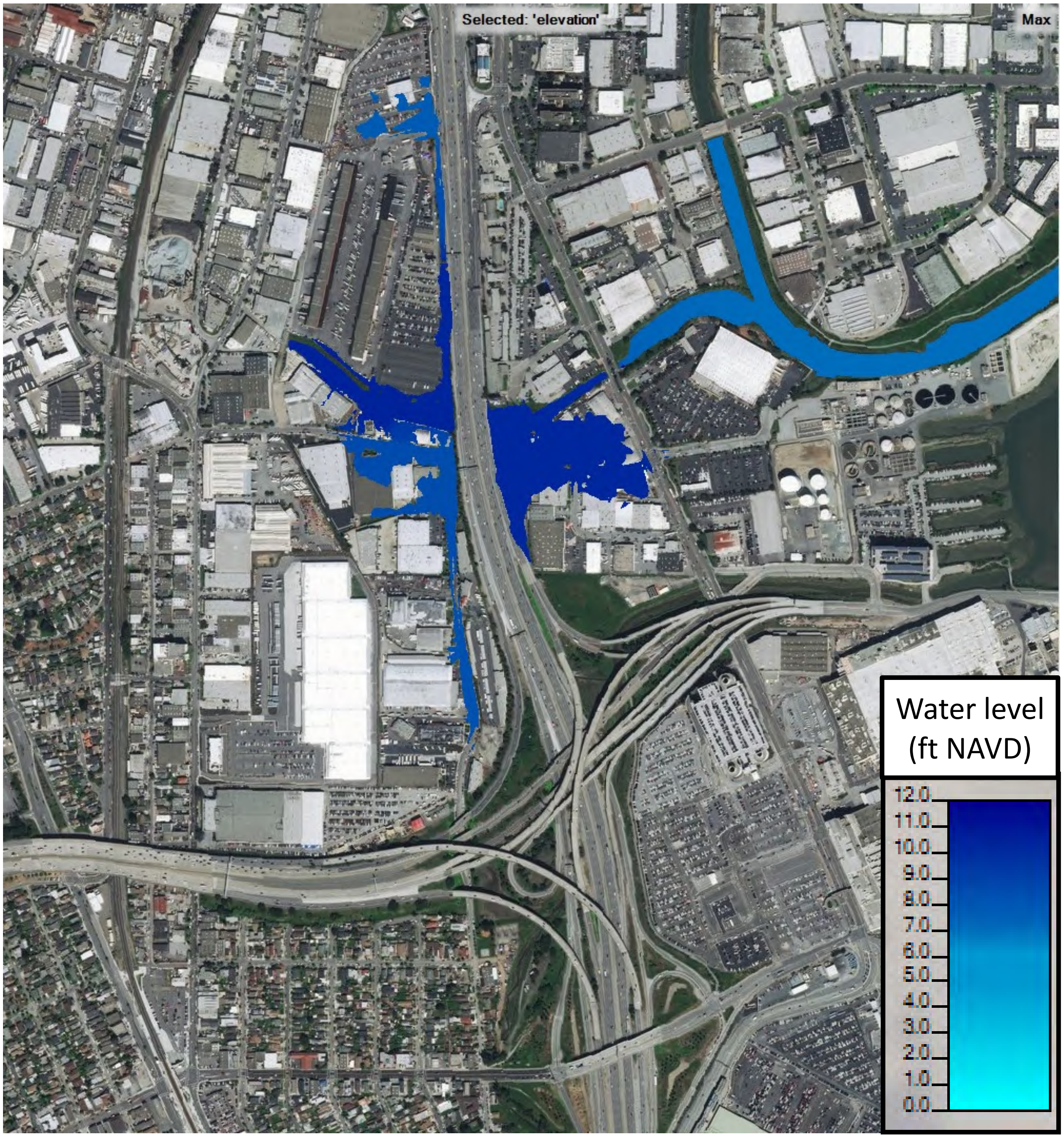
Navigable Slough Feasibility. D170206.01

**Figure 6**
Existing Conditions Flood Inundation
10-year Bay Water Level


SOURCE: HEC-RAS Modeling (ESA, 2018)



**Figure 7**
Existing Conditions Flood Inundation
100-year Bay Water Level



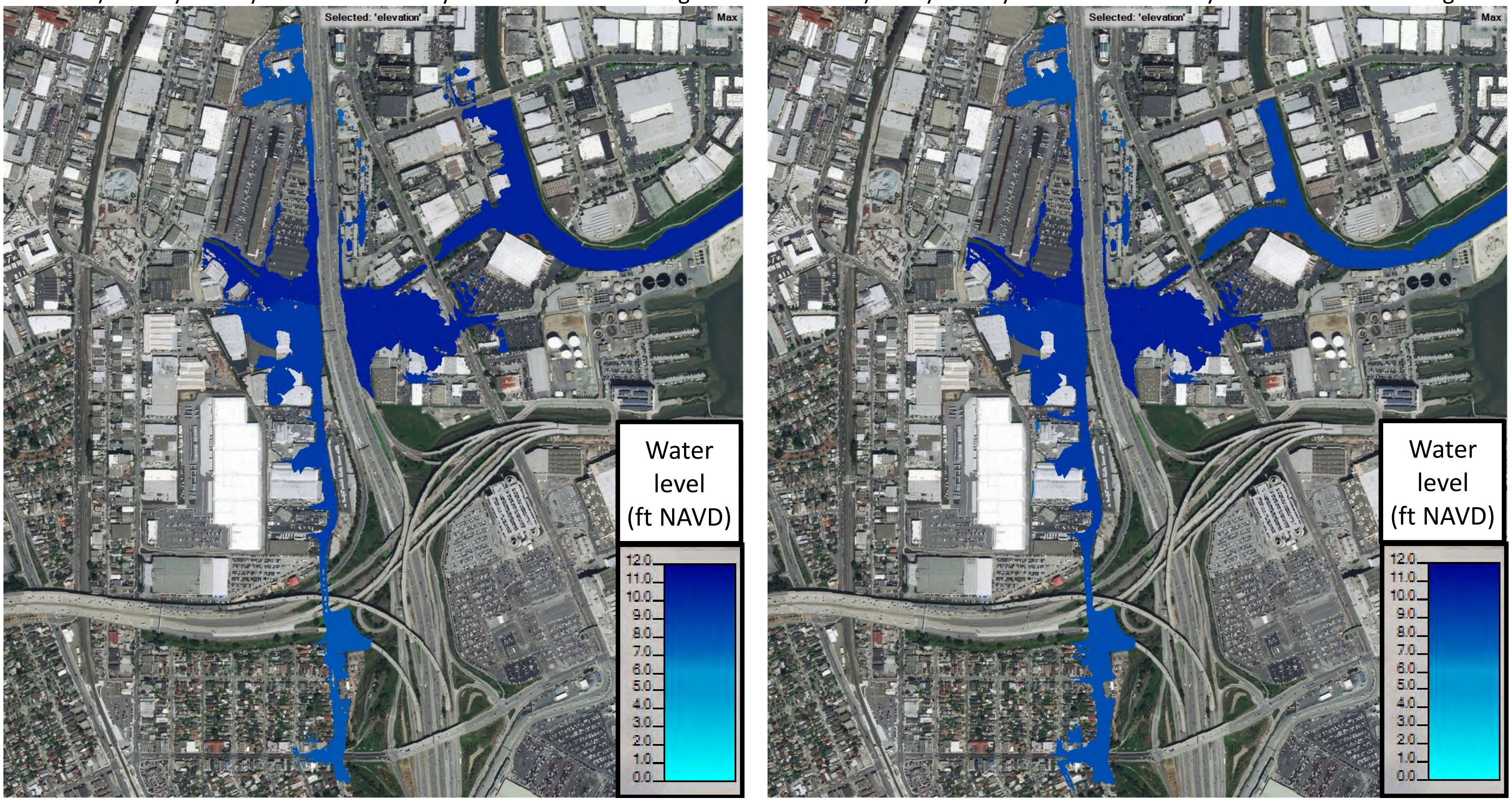



Source: HEC-RAS Modeling (ESA, 2018)

**Figure 8**
Existing Conditions Flood Inundation
MHHW Bay Water Level and 100-year Bay Water Level

a) 100-year Bay water level & 10-year watershed discharge

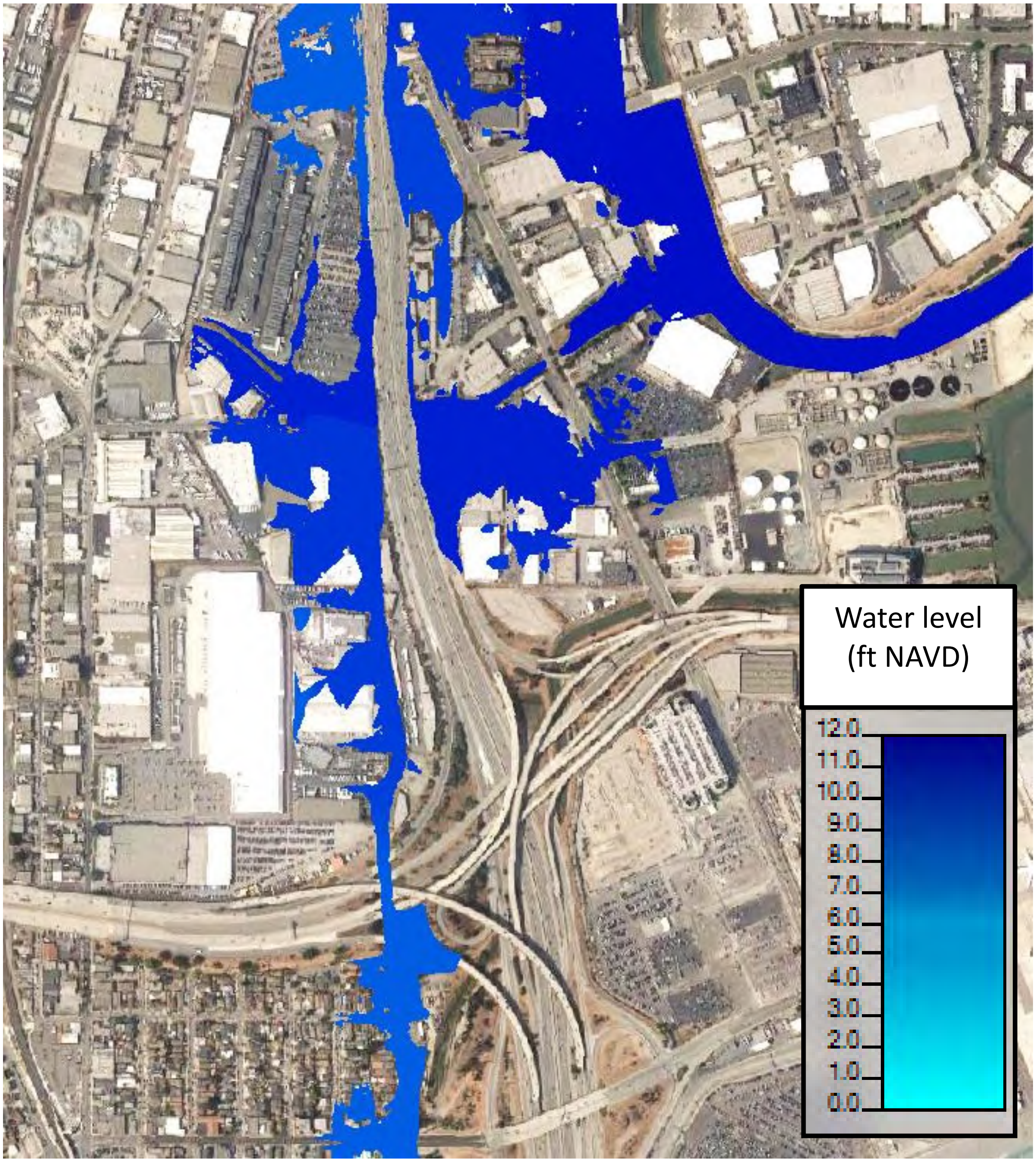
b) 10-year Bay water level & 100-year watershed discharge




SOURCE: HEC-RAS Modeling (ESA, 2018)

Navigable Slough Feasibility. D170206.01

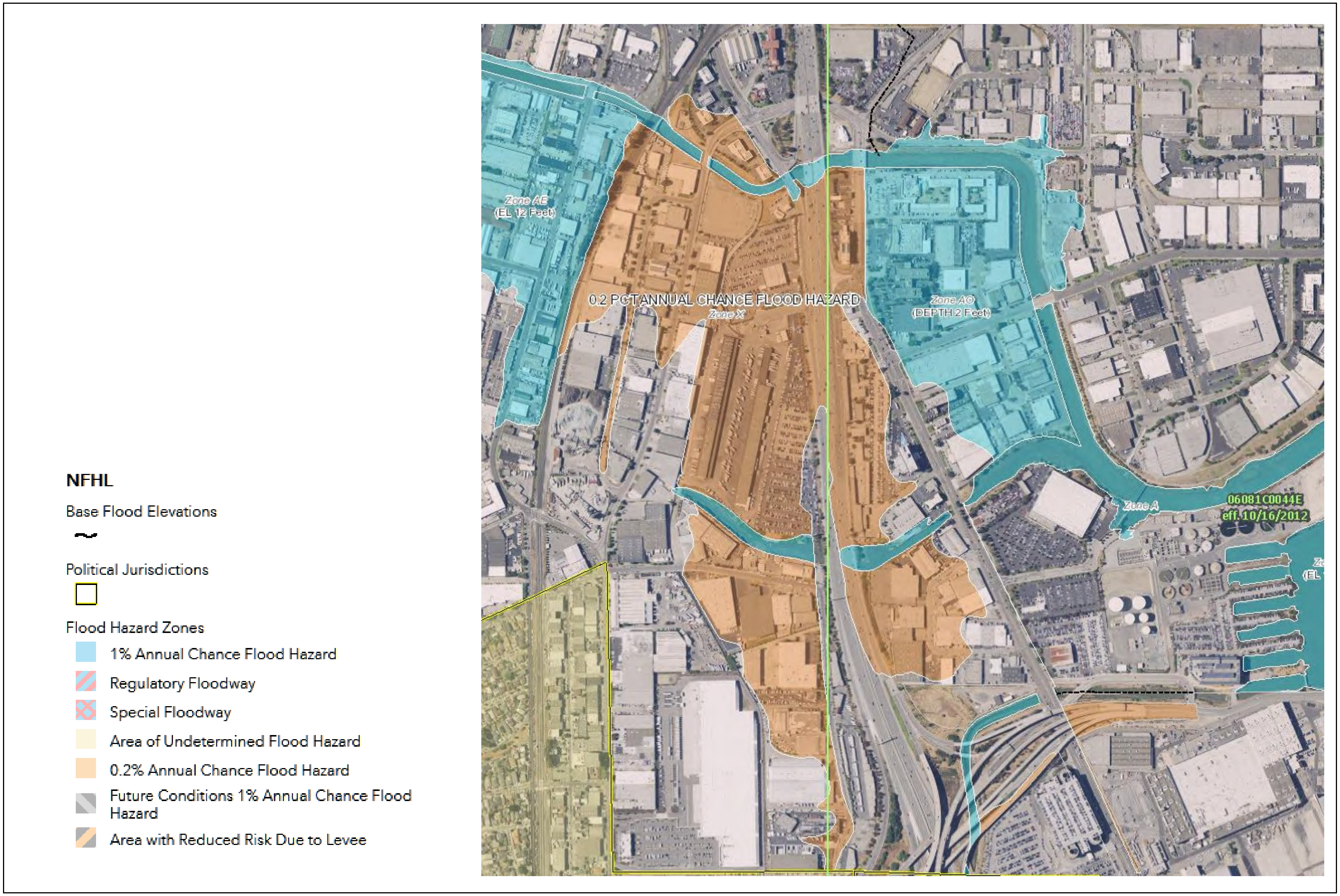
**Figure 9**
Existing Conditions Flood Inundation
Combined Bay Water Level and Watershed Discharge Events




Source: HEC-RAS Modeling (ESA, 2018)



**Figure 10**
Existing Conditions Flood Inundation
100-year Bay Water Level and 1ft Sea-Level Rise

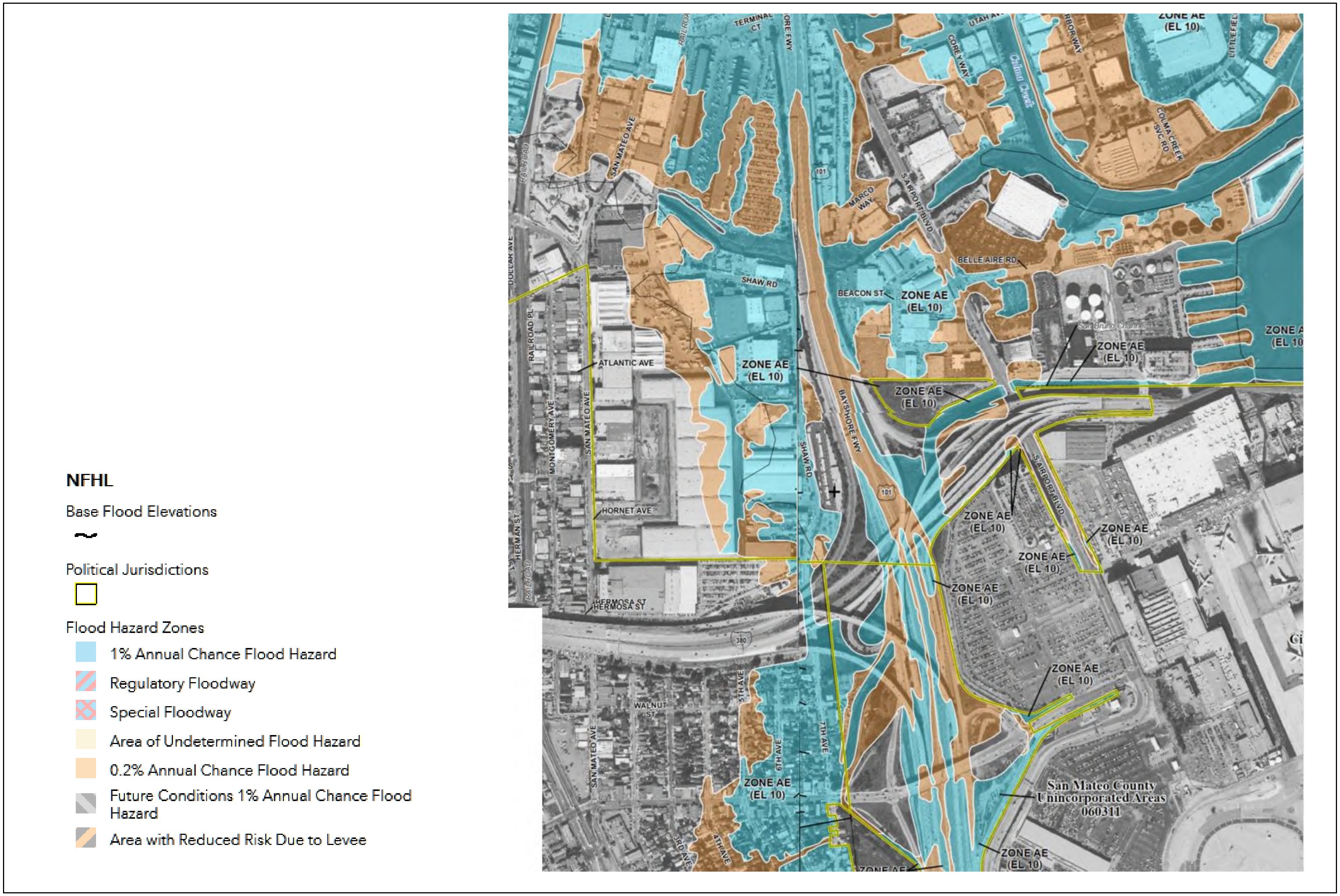



SOURCE: FEMA (2012)

Navigable Slough Feasibility. D170206.01

**Figure 11**

FEMA SFHA - Current

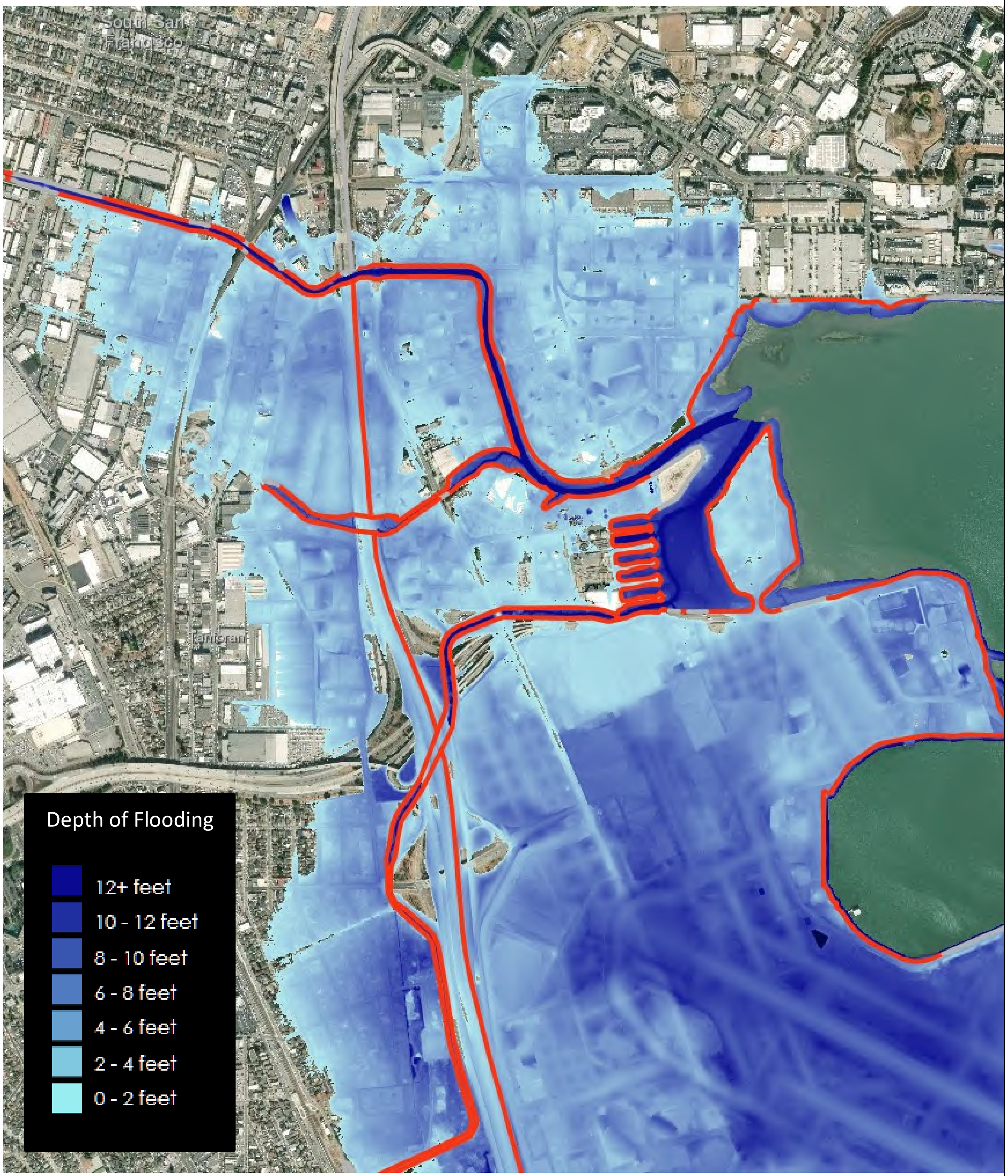



SOURCE: FEMA (2015)

Navigable Slough Feasibility. D170206.01

**Figure 12**

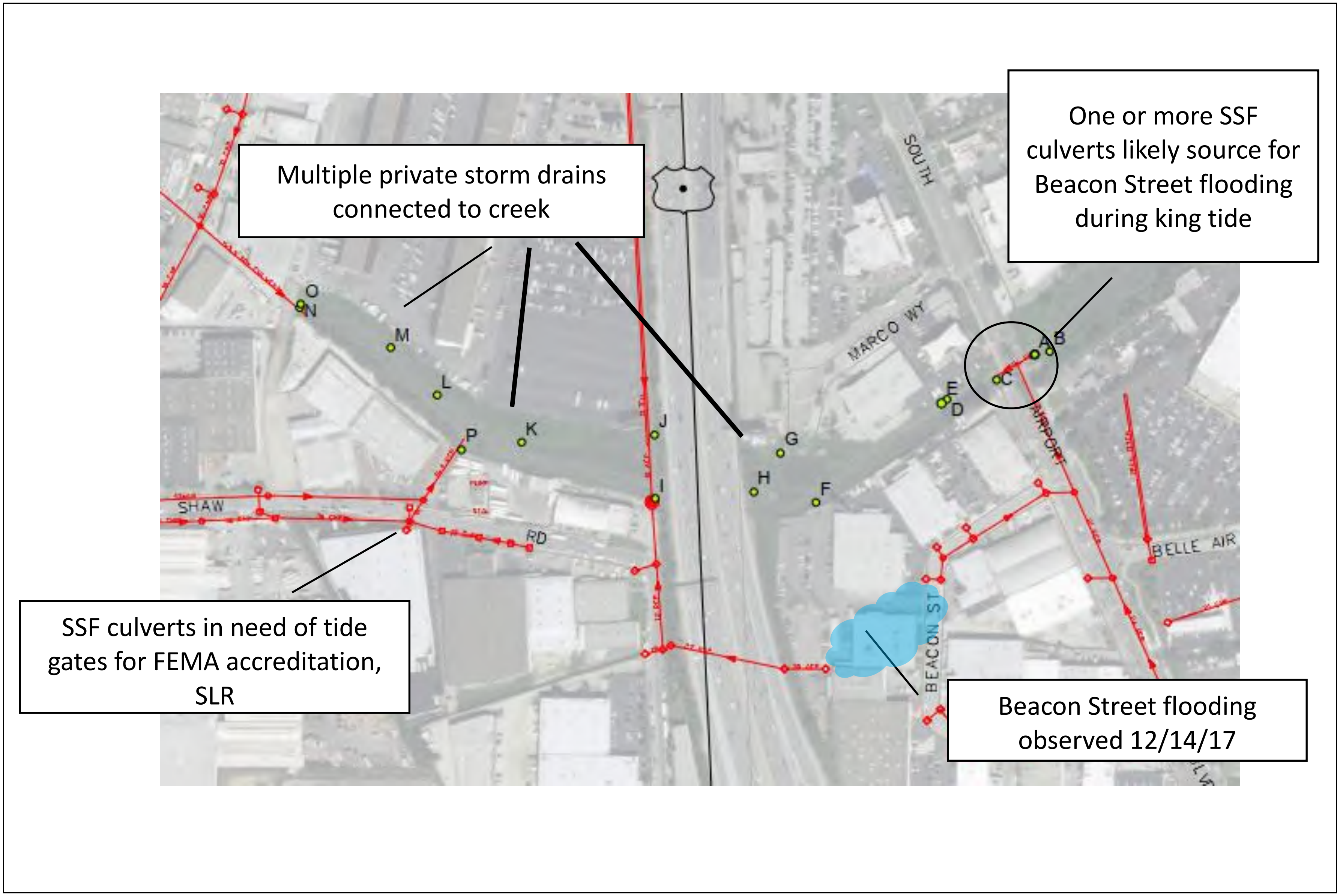
FEMA SFHA - Preliminary




Source: BCDC (2018), water level = 13.2 ft NAVD = MHHW (6.8 ft NAVD) + 77 inches (6.4 ft)



**Figure 13**
Projected Flooding –
100-year Bay Water Level & 3 ft Sea-level Rise




SOURCE: City of South San Francisco

Navigable Slough Feasibility. D170206.01

**Figure 14**

Storm Drain Pipe Network and Outfall Locations

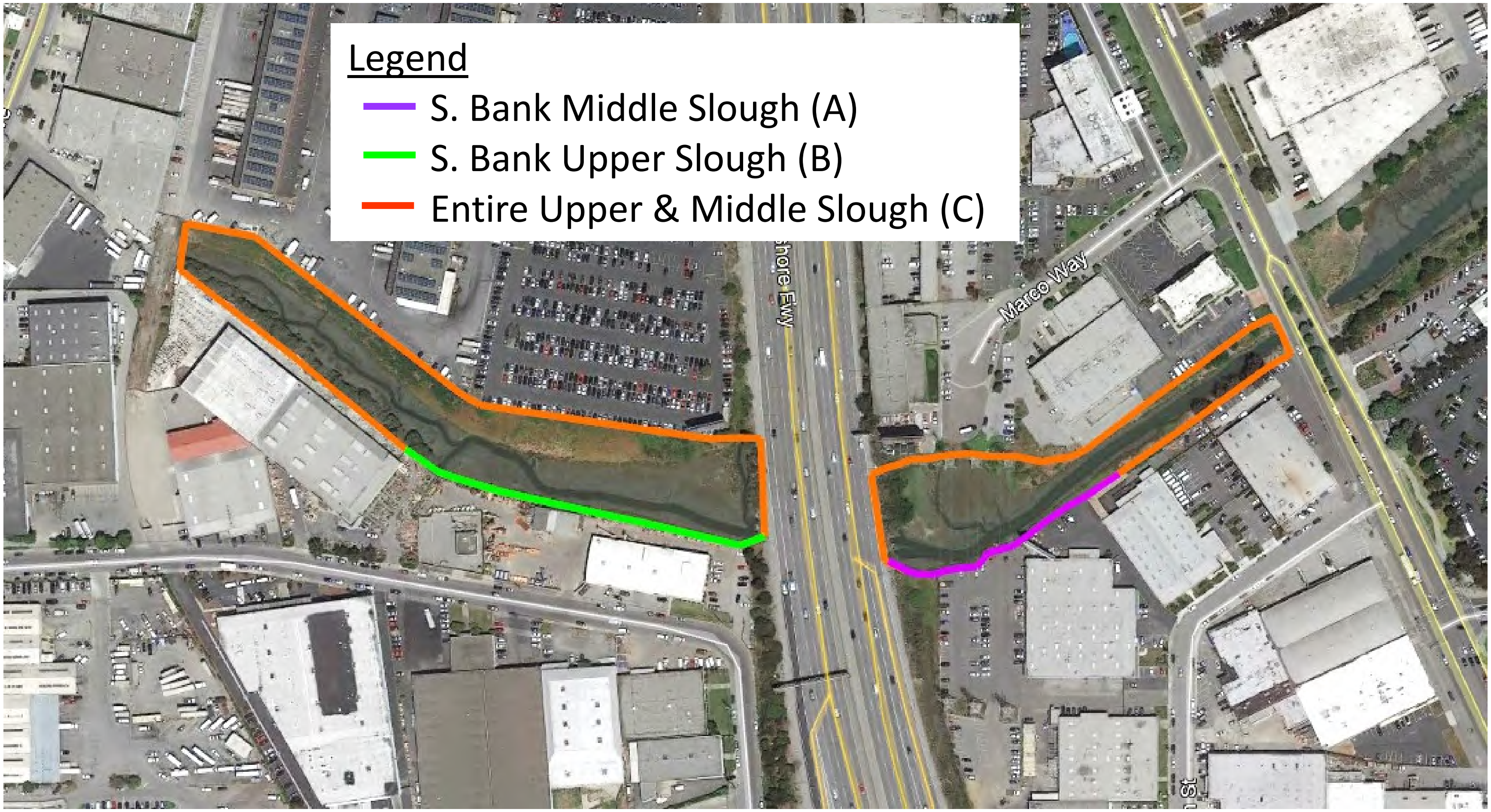


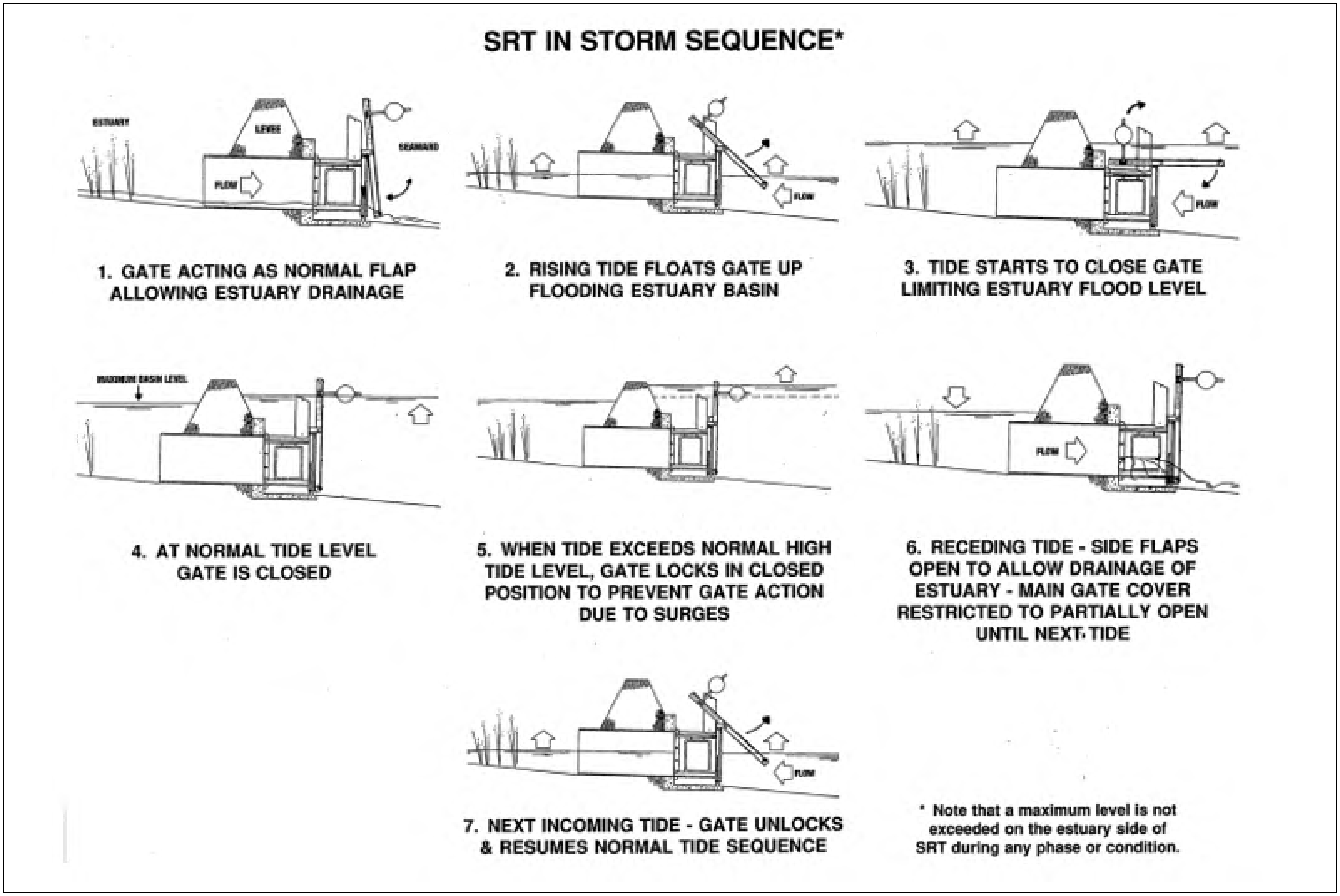



**Figure 15**
Floodwall Segments Option


Navigable Slough Feasibility. D170206.01

**Figure 16**
Self-Regulating Tide Gate Location

ESA



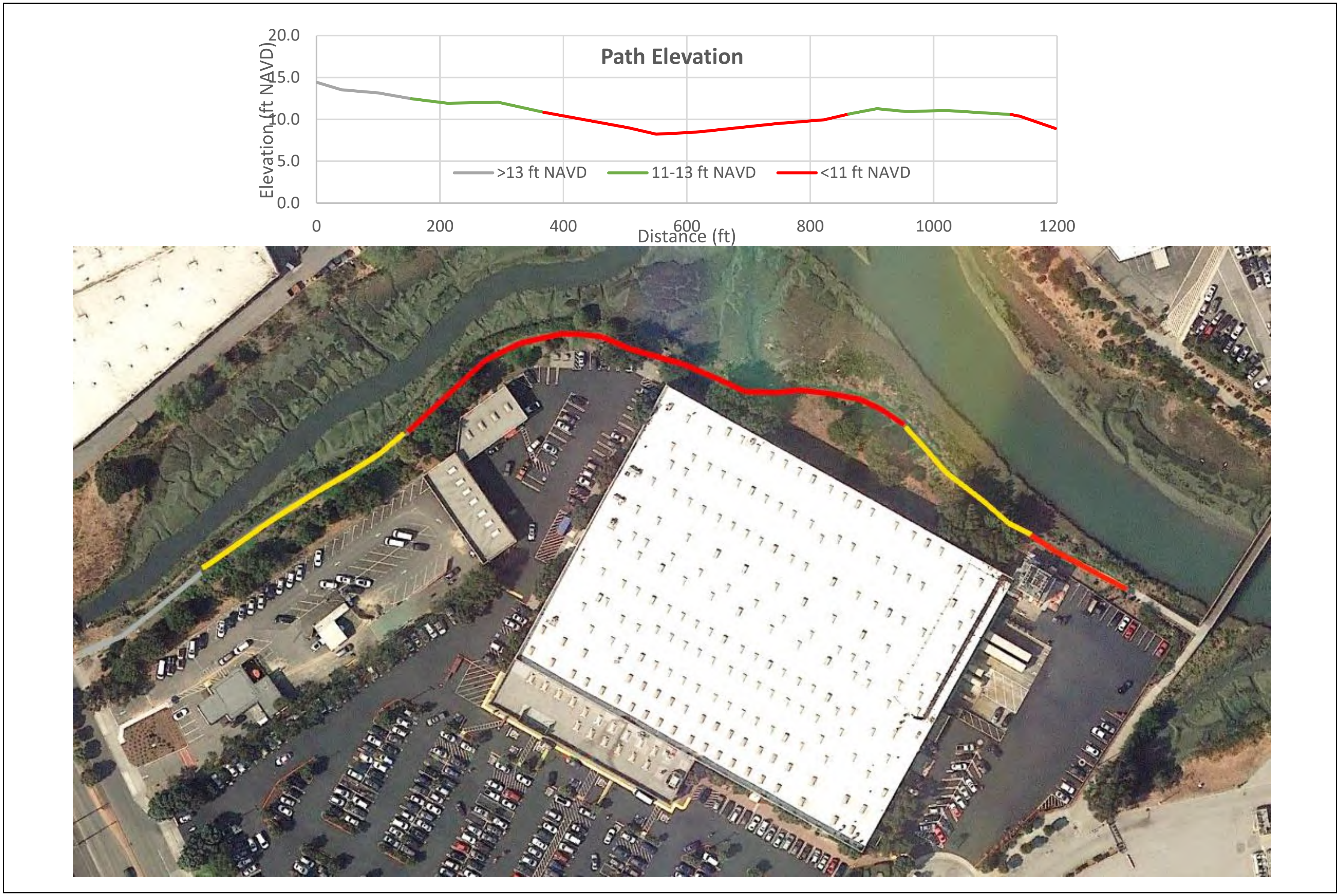

SOURCE: Waterman Industries



**Figure 17**
Self-Regulating Tide Gate Operations




**Figure 18**
Potential Ecotone Enhancement Locations




SOURCE: ESA survey data (2018)

Navigable Slough Feasibility. D170206.01

**Figure 19**

Bay Trail Alignment and Elevation

# Appendix A
## Field Data

# A. FIELD DATA

Several types of field data were collected in and adjacent to Navigable Slough. The purpose of the data collection was to quantify the slough's geometry, to record water levels, to observe stormwater discharge, and to inventory storm drain outfalls.

## A.1 Surveying

The slough geometry was surveyed with Leica Viva GS08plus Real-Time Kinematic GPS (RTK-GPS) rover units receiving real-time corrections through the Leica SmartNet base station network. Key elements which were surveyed include culvert/outfall elevations, representative cross-sections in each reach of the slough, a thalweg profile from the lower reach to the upper reach, and top-of-bank elevations. All measurements were taken in the horizontal datum California State Plane (CASP) Zone III, NAD83 (Epoch 2010.00, feet) and the vertical datum NAVD88 (Geoid 12B, feet).

ESA could not locate any known, reliable control points in or around the project area possibly as a result of roadwork since the previous survey. Coordinates were derived from the Leica SmartNet network and temporary control was established for QC protocol. All data was post-processed after the survey was completed.

## A.2 Water Level Data Collection

Three Solinst non-vented water levels gauges were deployed in each of Navigable Slough's reaches so the conveyance capacity of the culverts that separate the reaches could be characterized. Figure A-1 shows the gauge locations within the Upper, Middle and Lower reaches.

Since the water level gauges rely on pressure measurements, a barometric pressure gauge was also deployed at the project site to account for variations in atmospheric pressure. The data was post-processed and barometric compensation was applied to obtain true water pressure readings.

Figure A-2 shows the observed water levels at the gauge locations. Slough water levels are heavily influenced by Bay tides. The full tidal cycle is observed at the Lower gage location, while the gage data from the Middle and Upper reaches show a cutoff at the local thalweg elevations. Peak and trough water levels around 3/1/2018 and 4/6/2018 in the Middle and Upper reaches reflect the contribution of storm drain discharges from the precipitation events. To a lesser extent, the impact of discharge on slough water levels is visible as well for the precipitation event occurring around 3/21/2018.

# A.3 Discharge Data Collection

Discharge measurements were made in the slough's largest storm drain outfall, a 4-ft by 8-ft box culvert that drains a large fraction of the slough's watershed and discharges to the upper slough. Figure A-3 shows the observed discharge from the Upper reach and hourly precipitation data collected from the MesoWest station located at San Francisco International Airport (Station ID: KSFO) from February through April 2018. The two largest events, as indicated by the observed precipitation and discharge data, happen on or around 3/1/2018 and 4/6/2018.

# A.4 Storm Drain Outfall Inventory

All the storm drain outfalls which were visible at low tide, a total of fifteen outfalls, were photographed, surveyed, and measured for size (Figure A-8). The parameters of each storm drain outfall are summarized in Table A-1.

**Table A-1. Storm Drain Inventory**

| **Storm Drain ID** | **Shape** | **Diameter/Characteristic Dimension (ft)** | **Material** |
|---|---|---|---|
| A | Round | 1.5 | Unknown |
| B | Round | 2 | Steel |
| C | Round | 3 | Steel |
| D | Round | 2.5 | Unknown |
| E | Round | | Steel |
| F | Round | 3 | Steel |
| G | Round | 1.5 | Steel |
| H | Round | 2 | Unknown |
| I | Triangle | 2.5 | Unknown |
| J | Round | 4 | Concrete |
| K | Round | 2 | Steel |
| L | Round (Outlet Bent/Damaged) | 1.5 | Unknown |
| M | Unknown | 1.5 | Steel |
| N | Unknown | Unknown | Unknown |
| O | Unknown | Unknown | Unknown |
| P | Box | 4x8 | Concrete |

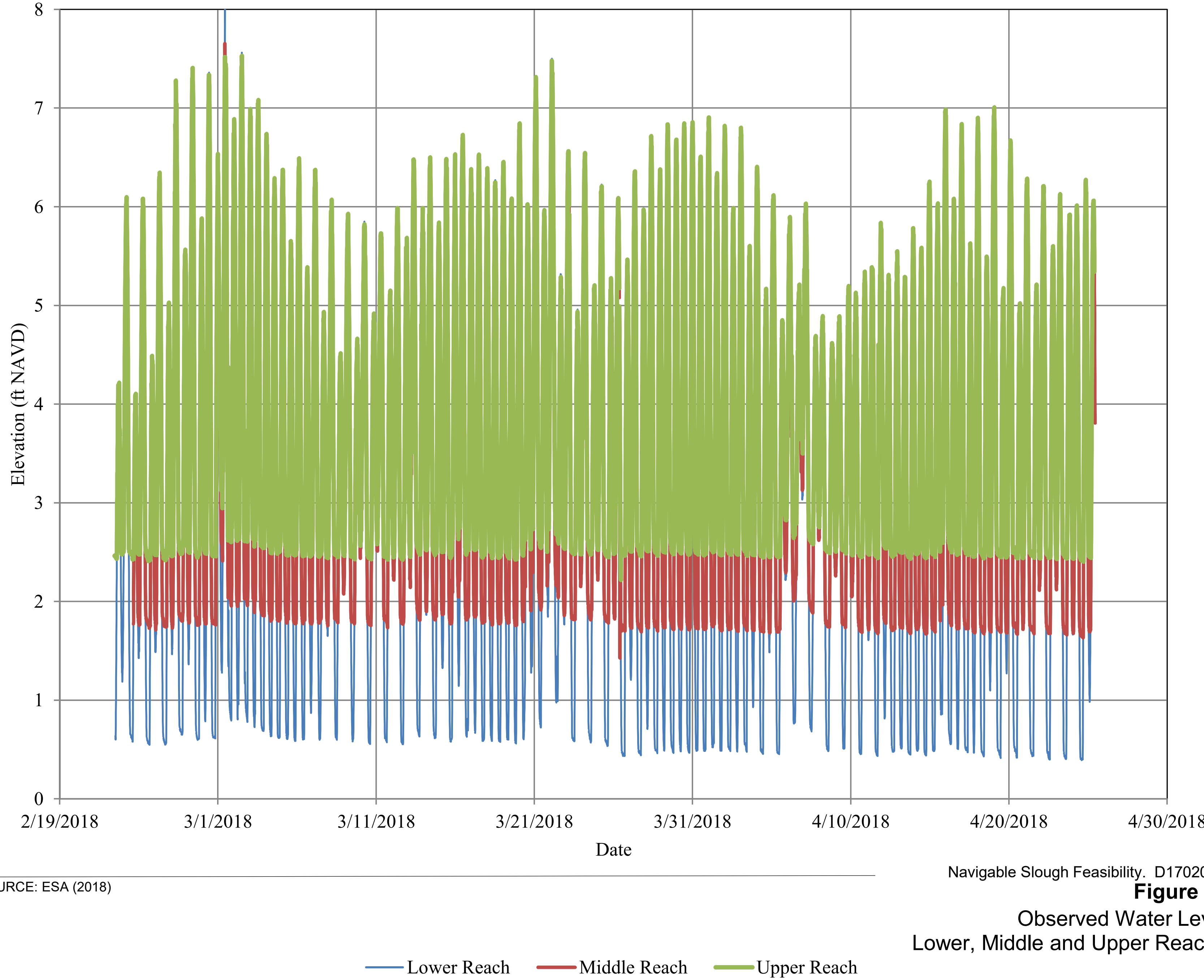
# A.5 Figures


SOURCE: ESRI (Aerial), ESA Survey (2018), City of South San Francisco

D170206.01 Navigable Slough Feasibility

ESA

**Figure A-1**
Gauge Locations

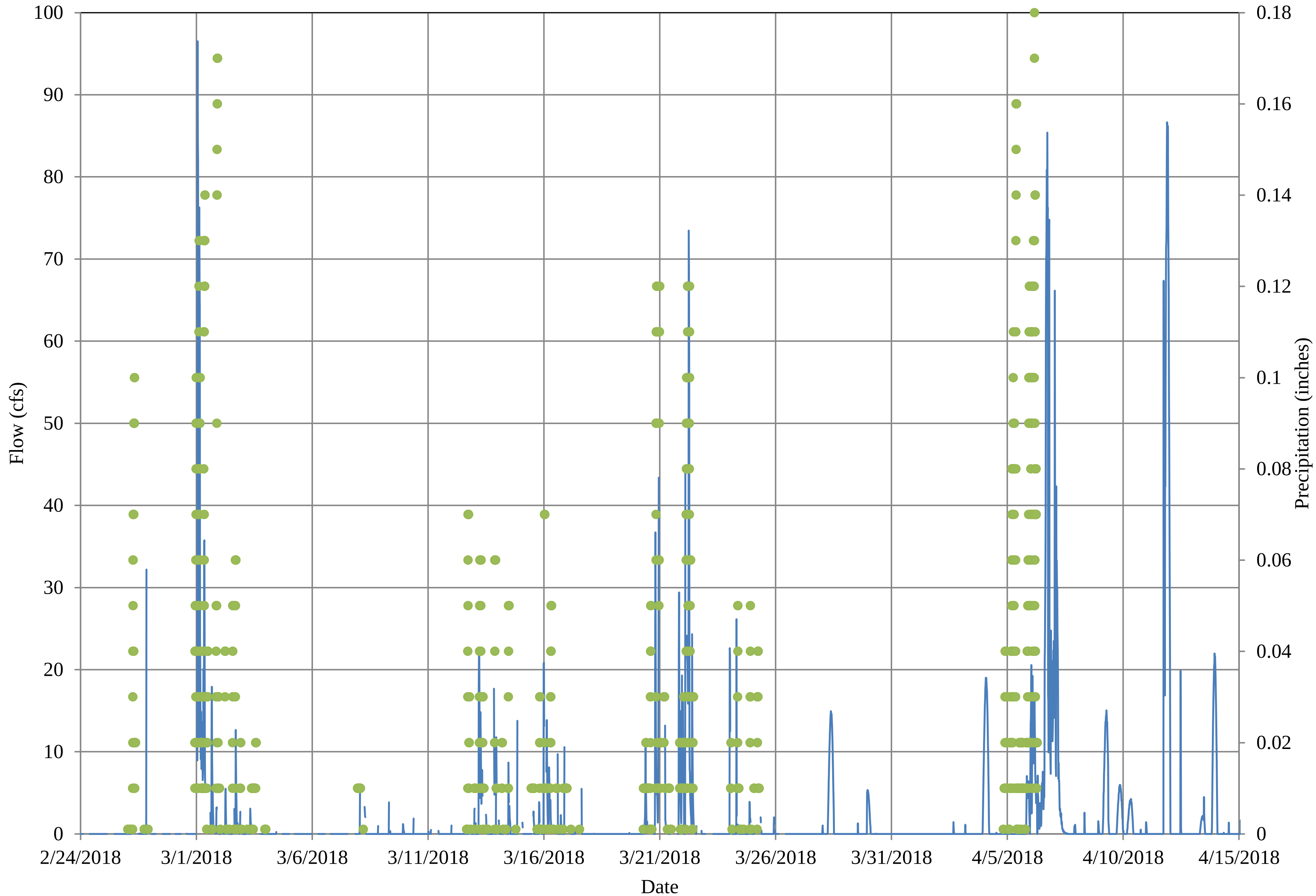



SOURCE: ESA (2018)

Navigable Slough Feasibility. D170206.01

**Figure A-2**

Observed Water Levels
Lower, Middle and Upper Reaches



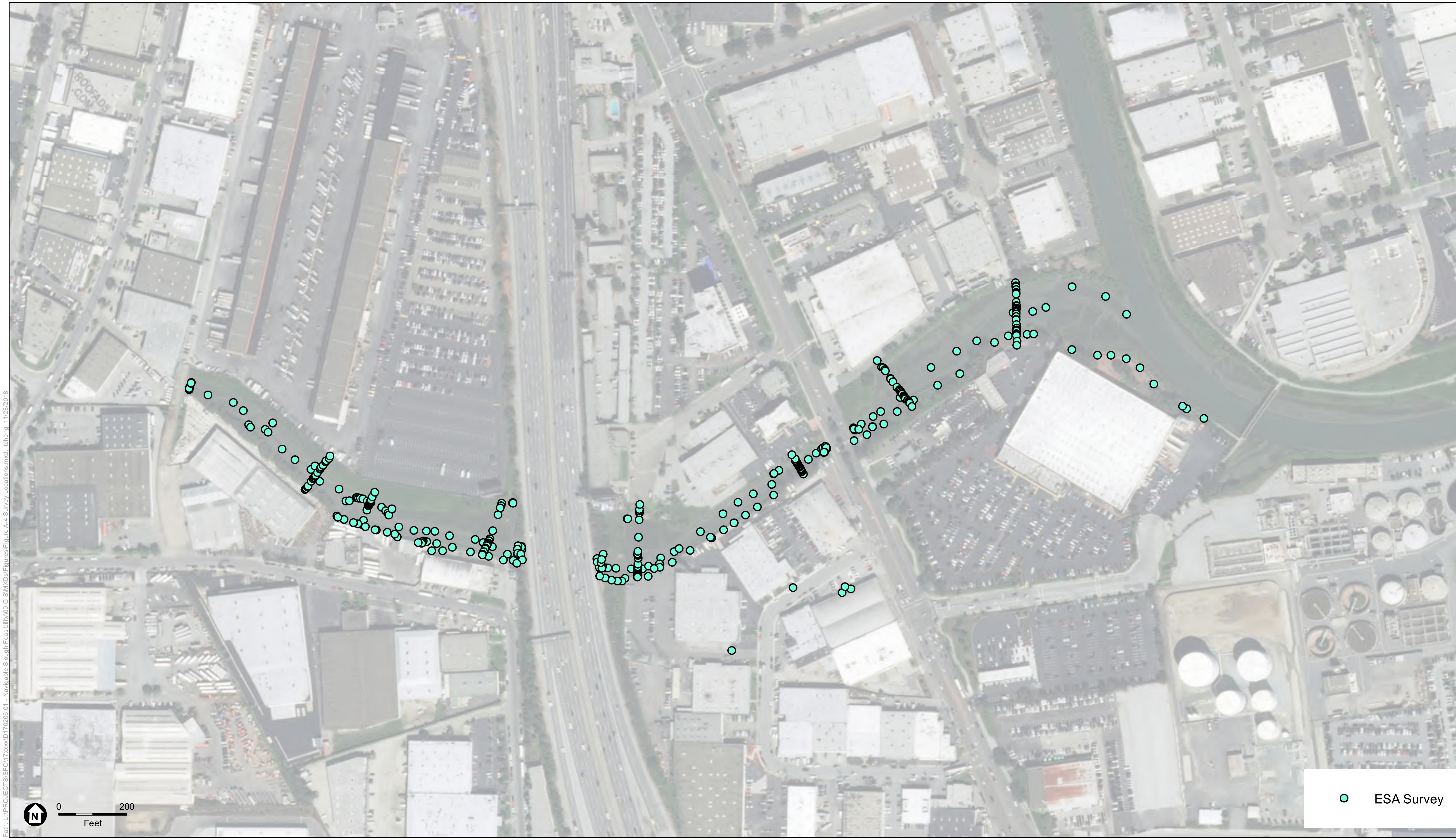

SOURCE: ESA (2018), MesoWest

Navigable Slough Feasibility. D170206.01

**Figure A-3**

Observed Discharge (Upper Slough) vs. Precipitation Data

Flow (cfs) Hourly precip

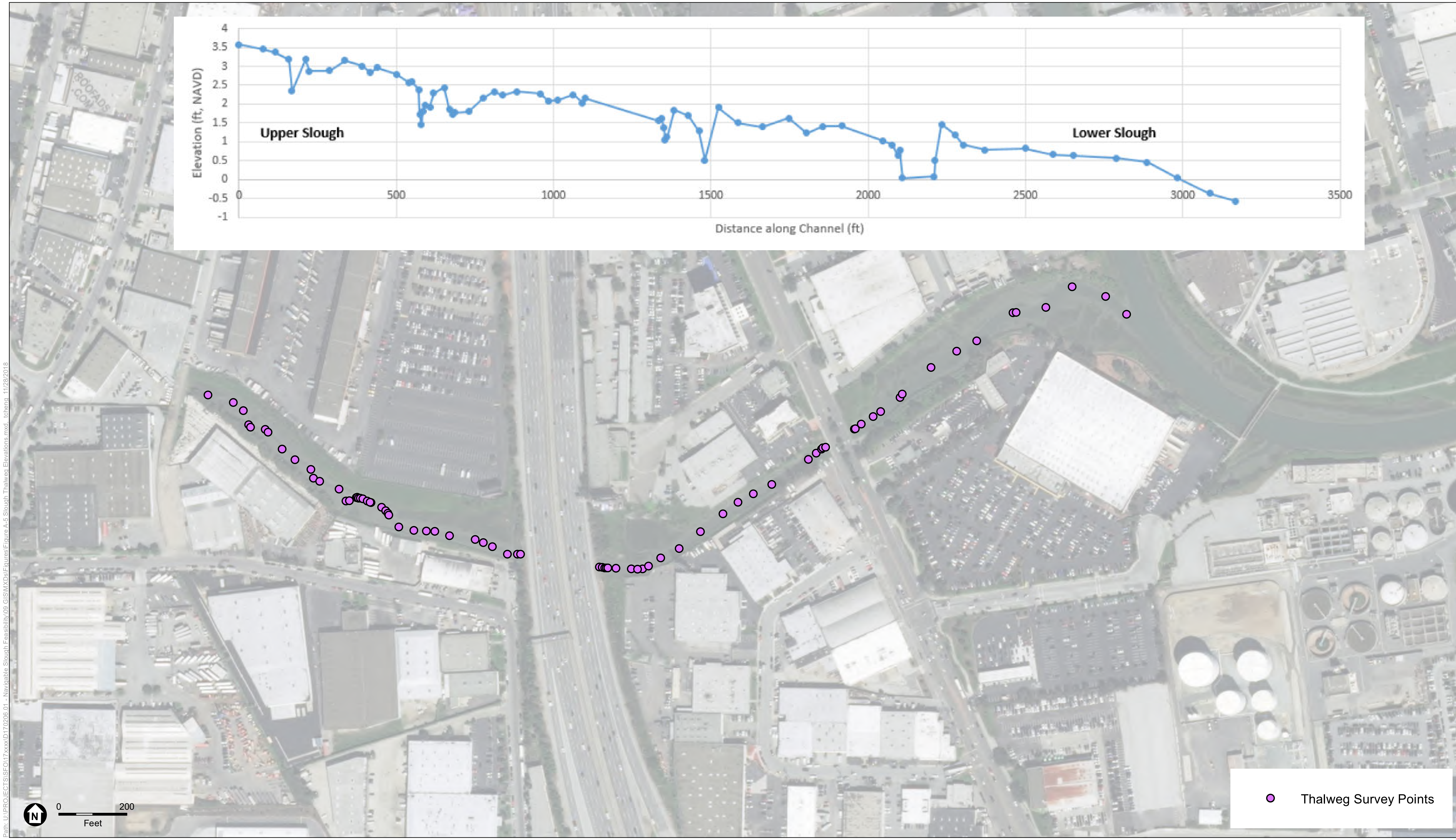



SOURCE: ESRI (Aerial), ESA Survey (2018), City of South San Francisco

D170206.01 Navigable Slough Feasibility

**Figure A-4**
Survey Locations

ESA

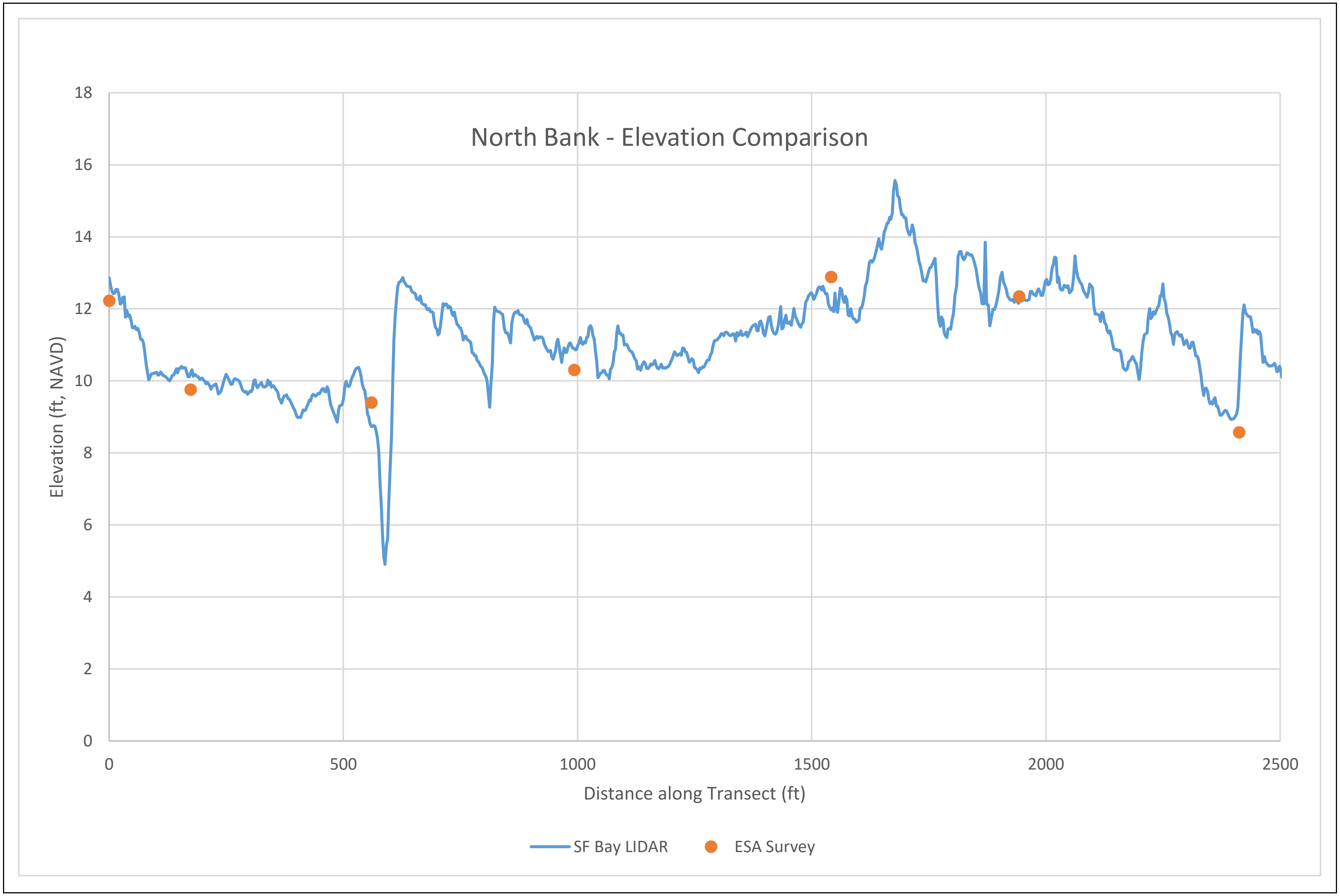



SOURCE: ESRI (Aerial), ESA Survey (2018), City of South San Francisco

D170206.01 Navigable Slough Feasibility

ESA

**Figure A-5**
Slough Thalweg Elevations

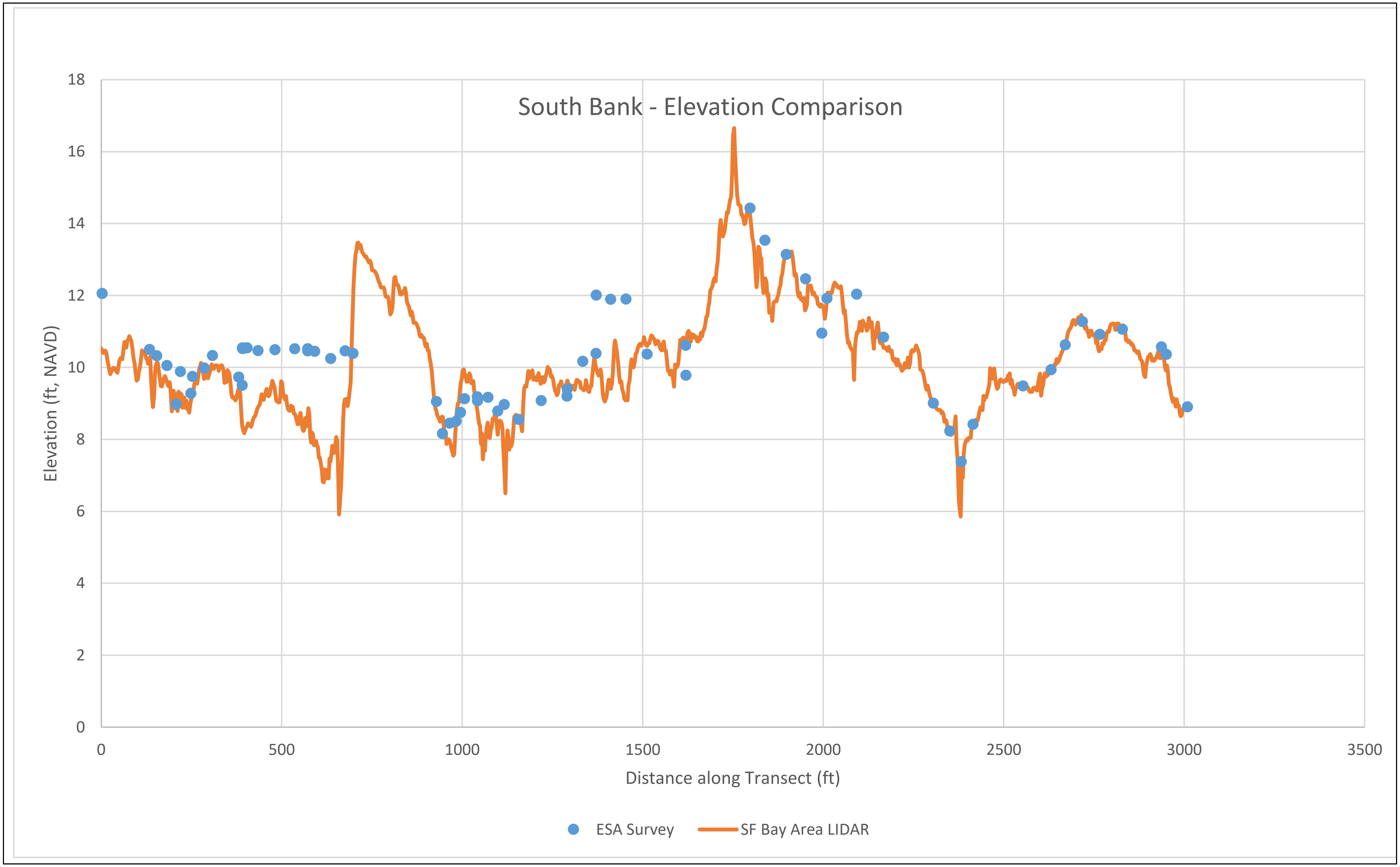



SOURCE: ESA Survey (2018), USGS San Francisco Bay Area LIDAR (2010)

Navigable Slough Feasibility. D170206.01

**Figure A-6**

North Bank Elevations




SOURCE: ESA Survey (2018), USGS San Francisco Bay Area LIDAR (2010)

Navigable Slough Feasibility. D170206.01

**Figure A-7**

South Bank Elevations


SOURCE: ESRI (Aerial), ESA Survey (2018), City of South San Francisco (Storm drain data)

D170206.01 Navigable Slough Feasibility

**Figure A-8**
Storm Drain Locations

ESA

# Appendix B
## Hydraulic Modeling

# B. HYDRAULIC MODELING

## B.1 Hydraulic Model Setup

### B.1.1 Ground Surface Elevations

The 2D HEC-RAS model requires terrain information in order to simulate flow. The ground surface elevation data sources used to inform the model topography/bathymetry were 2010 USGS San Francisco Bay Area LiDAR, a March 2018 ESA survey, and an existing 1D HEC-RAS model of Colma Creek. The ESA survey included culvert and storm drain locations and characteristics as well as thalweg, bank and floodwall elevations in Navigable Slough. Figure B-1 shows the model topography, mesh extents and key locations within the domain.

These data sets were aggregated in ArcMap 10.4 into a Triangular Irregular Network (TIN) format. The horizontal projection used was California State Plane Zone III. All elevation data used in model development were converted to North American Vertical Datum of 1988 (NAVD88). Subsequently, the TIN was converted into a single elevation raster with a cell resolution of 1 ft for import into HEC-RAS.

### B.1.2 Model Mesh

The HEC-RAS Geometry Editor was used to develop the model mesh (Figure 1), which extends from the edge of Colma Creek north of Navigable Slough to south of Lions Park in San Bruno. The railroad tracks approximate the westernmost edge of the model mesh. The bathymetry in the Colma Creek portion of the model mesh was adapted from the 1D Colma Creek model elevation data. The mesh extends up to the Utah Ave. bridge. Cell resolution within the mesh ranged from 50 ft in the flood plain to 5 ft within the channel.

To account for tidal influence within the slough, the downstream boundary condition was specified at the channel mouth entering the Bay. Three discharge locations (storm drains), one each in the Upper, Middle and Lower Sloughs, were defined as well.

## B.2 Model Calibration

A model calibration was run for two week-long time periods with precipitation/discharge events: 2/28/2018 – 3/5/2018 and 4/1/2018 – 4/10/2018. Water level observations from the tide gauge located in the Presidio (NOAA Station #9414290) were scaled to be the downstream tidal boundary condition for the model, using tidal amplification methods described by NOAA.

Additionally, water levels were lagged by 40 minutes, to account for the average time offset between the observed gage and modeled domain location. Observed discharges at the Upper Slough culvert were used as input to the calibration runs as well. Figure B-2 shows the comparison of modeled vs. observed water levels at the three gage locations within Navigable Slough. The timing of the storm drain discharge impact on slough water levels are reasonably captured by the model.

# B.3 Model Scenarios

A range of model runs were simulated to assess the hydrodynamic impact of extreme events for existing conditions and with project conditions. The following section provides a description of boundary condition and geometry development applicable for the alternatives.

## B.3.1 Watershed Discharge

HEC-HMS (Version 4.2.1) was used to evaluate the storm hydrographs for the Q1, Q10 and Q100 events. An approximate watershed area (1.58 sq. mi) was delineated from the South San Francisco (SSF) Storm Drain Master Plan (SDMP). The USGS StreamStats website was also used to support the watershed delineation. Figure B-3 shows the three watershed sub-areas, with distinct roughness and soil infiltration parameters.

For each sub-basin, the following parameters were calculated: area, average watershed slope, longest flow path, centroid and flow path to centroid. These parameters were used to evaluate basin lag time and peaking coefficient, which are inputs to the Snyder unit hydrograph method. The Snyder unit hydrograph method is a common unit hydrograph method used in hydrologic modeling and utilized by several agencies in California. The peaking coefficient was evaluated based on the average watershed slope and basin drainage area. The lag time is calculated based on the average watershed slope, length from outlet to the watershed centroid and the length of the longest flow path, determined from aerial imagery.

Curve number information for each sub-basin was determined from the NLCD 2011 dataset and SSURGO soil classification. Precipitation parameters for the sub-basins were based on NOAA Atlas 14. The soil infiltration and precipitation parameters were input into HEC-HMS watershed and meteorological modules.

Figure B-4 shows the predicted hydrographs associated with the three events, assuming a six-hour event duration. The peak flow values corresponding to the 1-yr, 10-yr and 100-yr events are defined in Table B-2 Since three discharge locations were specified in the RAS model, the storm hydrograph for each event was assumed to follow this distribution: 50% (Upper Slough), 25% (Middle Slough), and 25% (Lower Slough).

**Table B-2. Watershed Discharge Values**

| Event | Peak Discharge (cfs) |
|---|---|

| | |
|---|---|
| Q1 | 243 |
| Q10 | 430 |
| Q100 | 786 |

## B.3.2 Tidal Boundary Conditions

In addition to evaluating watershed discharge for different recurrence interval events, bay water levels corresponding to those events were calculated. Table B-3 summaries the tidal elevation values used in the model runs.

**Table B-3. Tidal Boundary Conditions**

| Event | Water Level (ft, NAVD) |
|---|---|
| Mean higher high water (MHHW) | 6.8 |
| 1-year water level(T1) | 8.1 |
| 10-year water level (T10) | 9.1 |
| 100-year water level (T100) | 10.4 |

## B.3.3 Floodwalls

A suite of alternatives featured the use of floodwalls in the Upper and Middle Sloughs. The floodwalls were both incorporated into the terrain surface and RAS geometry, using the Connection Data Editor window in the Geometry Editor. Floodwalls were specified at an elevation of 12.5’ NAVD. Runs FW-1 and FW-2 featured a floodwall in the southern upstream bank of both the Upper Slough and Middle reaches. Runs FW-3 and FW-4 featured a floodwall only in the southern upstream bank of the Upper reach. Run FW-5 had an idealized “ring wall” encapsulating the entirety of the Upper and Middle Sloughs, on both the northern and southern banks. Figure B-5 shows the proposed floodwall alignments simulated in the model runs.

## B.3.4 Self-Regulating Tide gate

Runs SRT-1 through SRT-4 entailed the use of a self-regulating tide gate located at the South Airport Boulevard culvert. The tide gate feature was implemented using the Connection Data Editor in HEC-RAS. An ‘Elevation Controlled Gates’ boundary condition was used for the gate in the unsteady flow file. This type of boundary condition allows the user to specify the water surface elevation at which the gate opens and closes, as well as the opening and closing rate and initial opening width.

## B.3.5 Model Runs Table

The geometries and model inputs developed for watershed discharge and tidal boundary conditions were used across a range of scenarios. A total of 16 model simulations were run and are summarized in Table B-4.

**Table B-4. Model Runs**

| Run # | Geometry | Bay water level boundary condition | Watershed discharge boundary conditions |
|---|---|---|---|
| EC-1 | Existing | T1 | None |
| EC-2 | Existing | T10 | None |
| EC-3 | Existing | T100 | None |
| EC-4 | Existing | T100 + 1 ft SLR | None |
| EC-5 | Existing | T10 | Q100 |
| EC-6 | Existing | T100 | Q10 |
| EC-7 | Existing | MHHW | Q100 |
| FW-1 | Existing & Floodwall A+B | T100 | Q10 |
| FW-2 | Existing & Floodwall A+B | T10 | Q100 |
| FW-3 | Existing & Floodwall B | T100 | Q10 |
| FW-4 | Existing & Floodwall B | T10 | Q100 |
| FW-5 | Existing & Floodwall C | MHHW | Q100 |
| SRT-1 | Existing & Self-Regulating Tide Gate<br>Gate closure at 9 ft NAVD | T100 | Q1 |
| SRT-2 | Existing & Self-Regulating Tide Gate<br>Gate closure at 7 ft NAVD | T100 | Q1 |
| SRT-3 | Existing & Self-Regulating Tide Gate<br>Gate closure at 9 ft NAVD | T100 | Q10 |
| SRT-4 | Existing & Self-Regulating Tide Gate<br>Gate closure at 7 ft NAVD | T100 | Q10 |

# B.4 Model Results

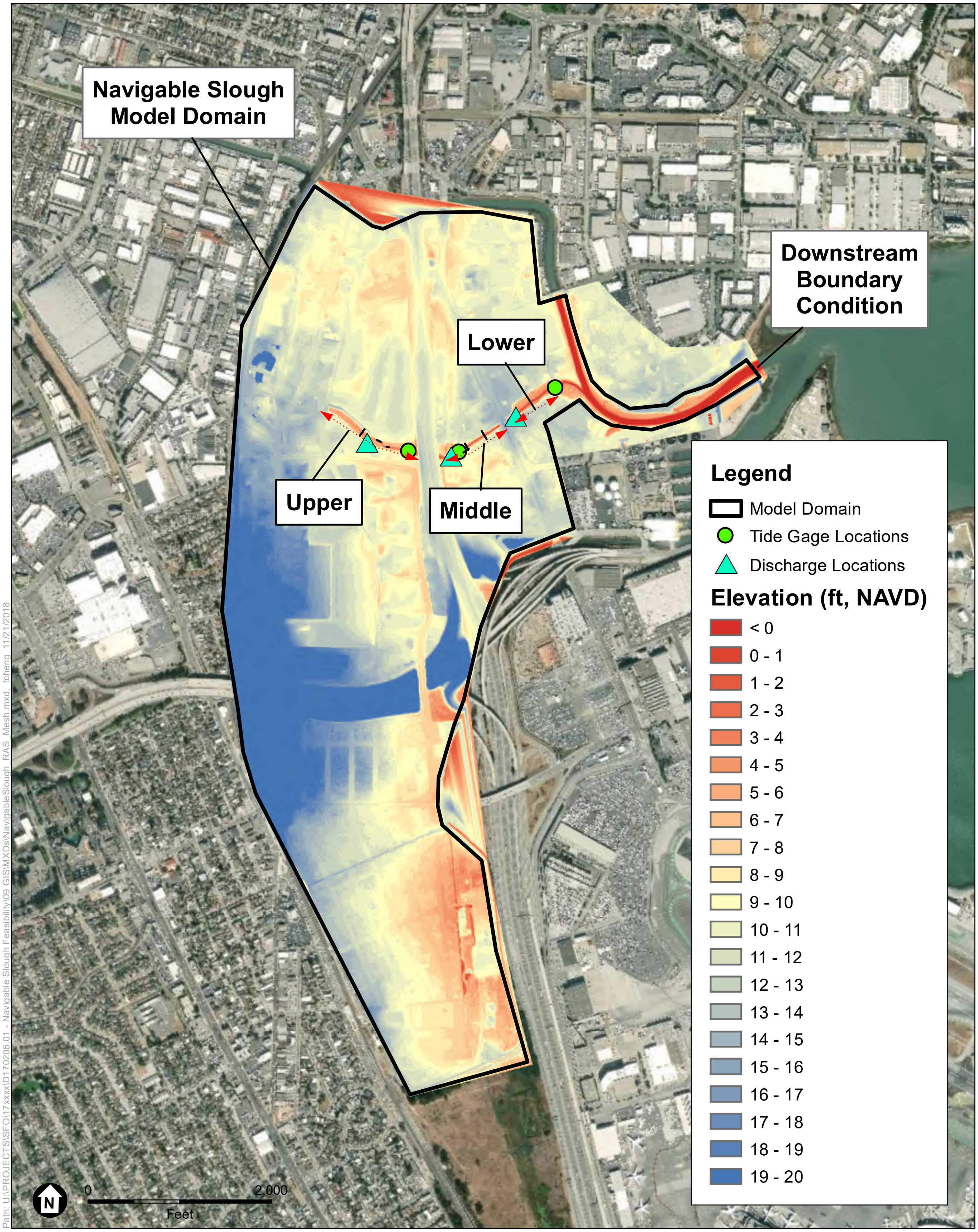
Model output extracted from RASMapper included peak flood extents and water level time series at the three gage locations. Figures B-6 through B-21 show the peak flood extents corresponding to the model run and Figures B-22 through B-26 show the water level time series in the Upper, Middle and Lower reaches.

Flooding is first observed south of the Middle reach for 1-year tidal water elevation for existing conditions. Overtopping in the Upper reach happens for the 100-year tidal water elevation along both northern and southern banks. The addition of 1 ft of SLR dramatically increases the extent of flooding in the vicinity of the slough, reaching as far south as San Bruno Ave and up north to Colma Creek. Differences in peak water elevations for Runs EC-5 through EC-7 were most noticeable in the Lower reach, with the influence of a 100-year tides contributing to nearly 1.5 ft more water level compared to 10-year tides. The Upper reach had approximately the same water levels in Runs EC-5 and EC-6.

Both Floodwall A+B and B alignments saw increased flood extents corresponding to a Q100 discharge event. The tidal water level associated with a 100-year event resulted in higher water elevations in the Middle and Lower reaches compared to that of the 10-year event, but did not result in overtopping. The presence of a ringwall in the Floodwall C alignment produced nearly a 1.5 ft increase in peak water surface elevation within the Upper and Middle reaches, when comparing time series between the floodwall alternative and existing conditions under MHHW tidal elevation and Q100 discharge.

Little to no difference was observed in the peak water elevation with variation in the closure depth for the tide gate scenarios. The time series output in Figure B-26 show the opening and closing of the tide gate at elevation 7' for Runs SRT-2 and SRT-4. Closure at elevation 9' is not immediately visible in the results; however, in both Runs SRT-1 and SRT-3, the gate closes for approximately 2 hours and traps water in the Middle and Upper sloughs. For Runs SRT-3 and SRT-4, flood extents were increased south of Interstate 380 for Runs SRT-3 and SRT-4, due to the increased watershed discharge.

# B.5 Figures




SOURCE: HEC-RAS Modeling (ESA, 2018)

Navigable Slough Feasibility. D170206.01

ESA

**Figure B-1**
Model Topography, Mesh and Key Locations

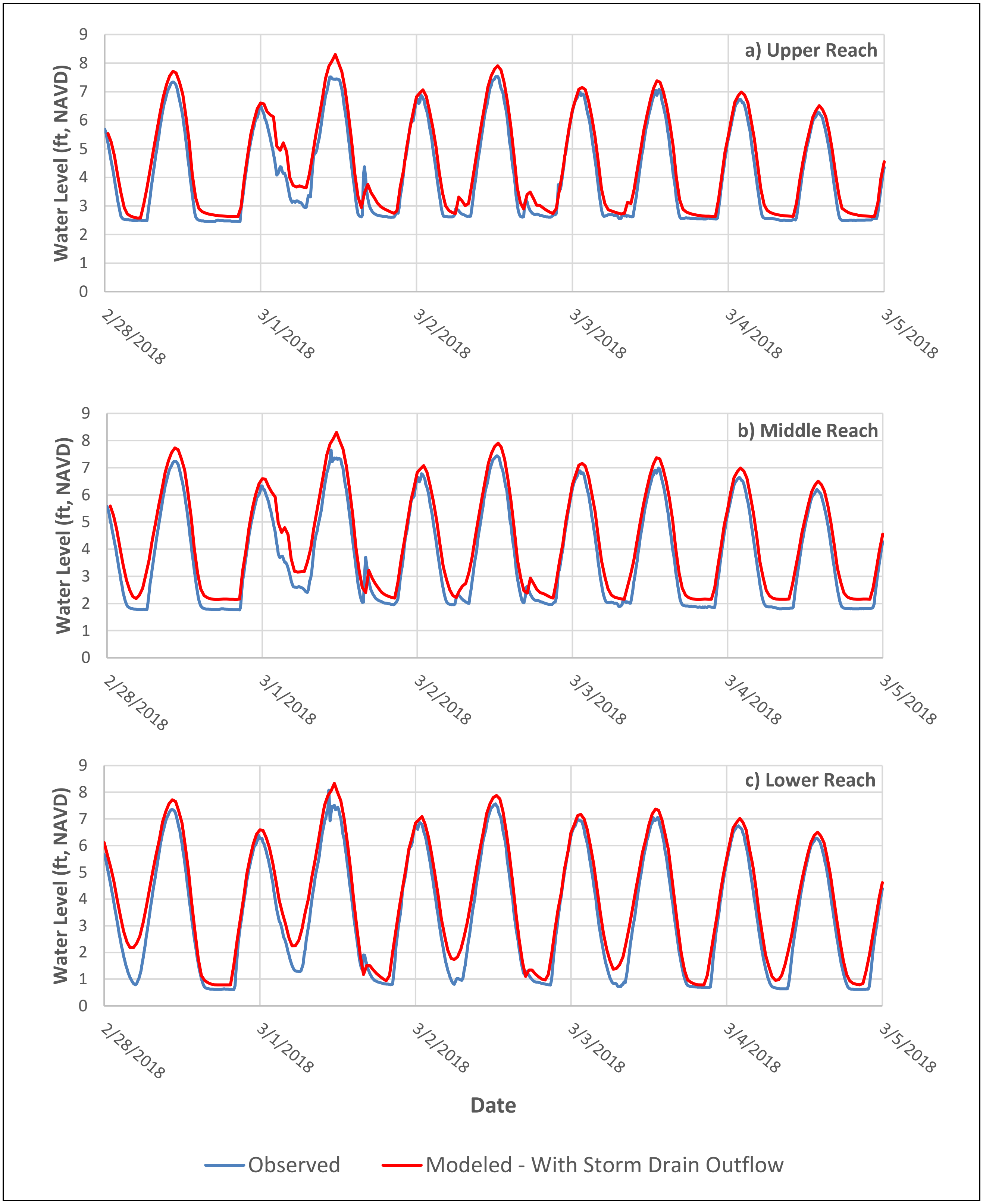
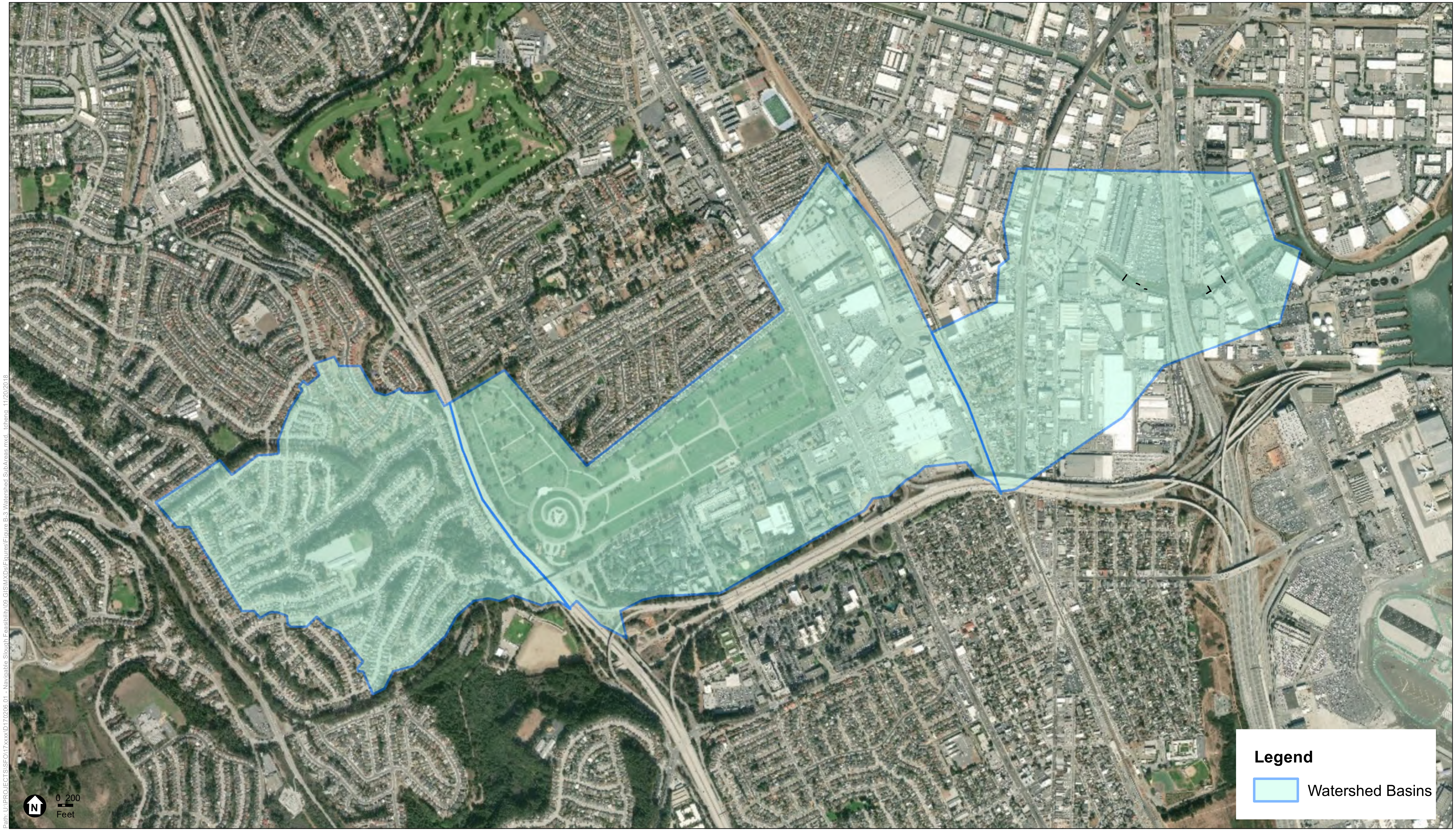





**Figure B-2**
Model Calibration
Upper, Middle and Lower Sloughs



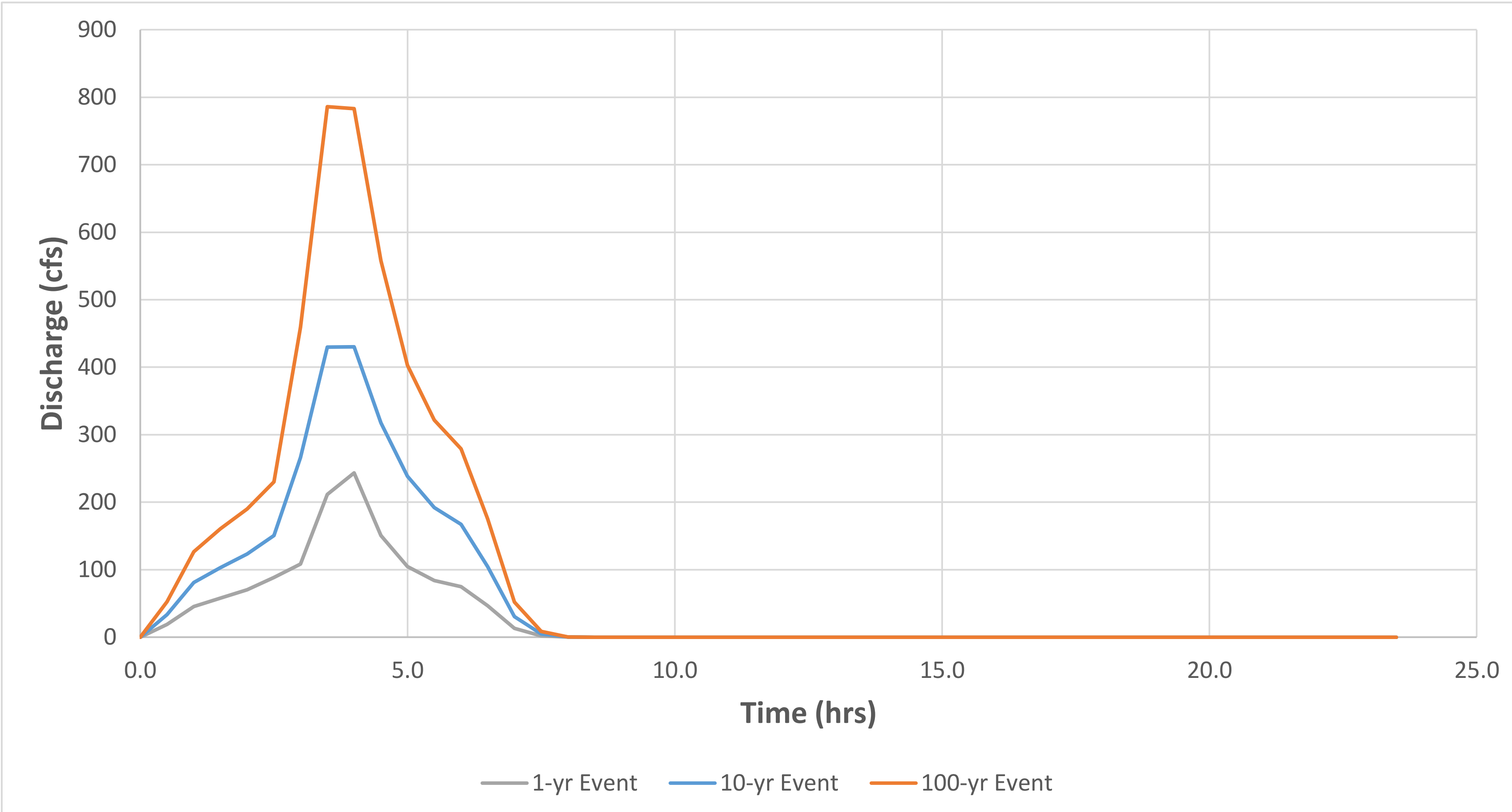

Path: U:\PROJECTS\SFO\17xxxx\D170206.01 - Navigable Slough Feasibility\09 GIS\MXDs\Figures\Figure B-3 Watershed SubAreas.mxd, tcheng 11/20/2018

SOURCE: South San Francisco (SSF) Storm Drain Master Plan (SDMP)

D170206.01 Navigable Slough Feasability

**Figure B-3**
Watershed SubAreas

ESA




SOURCE: HEC-HMS Modeling

Navigable Slough Feasibility. D170206.01

**Figure B-4**

Predicted Watershed Hydrographs

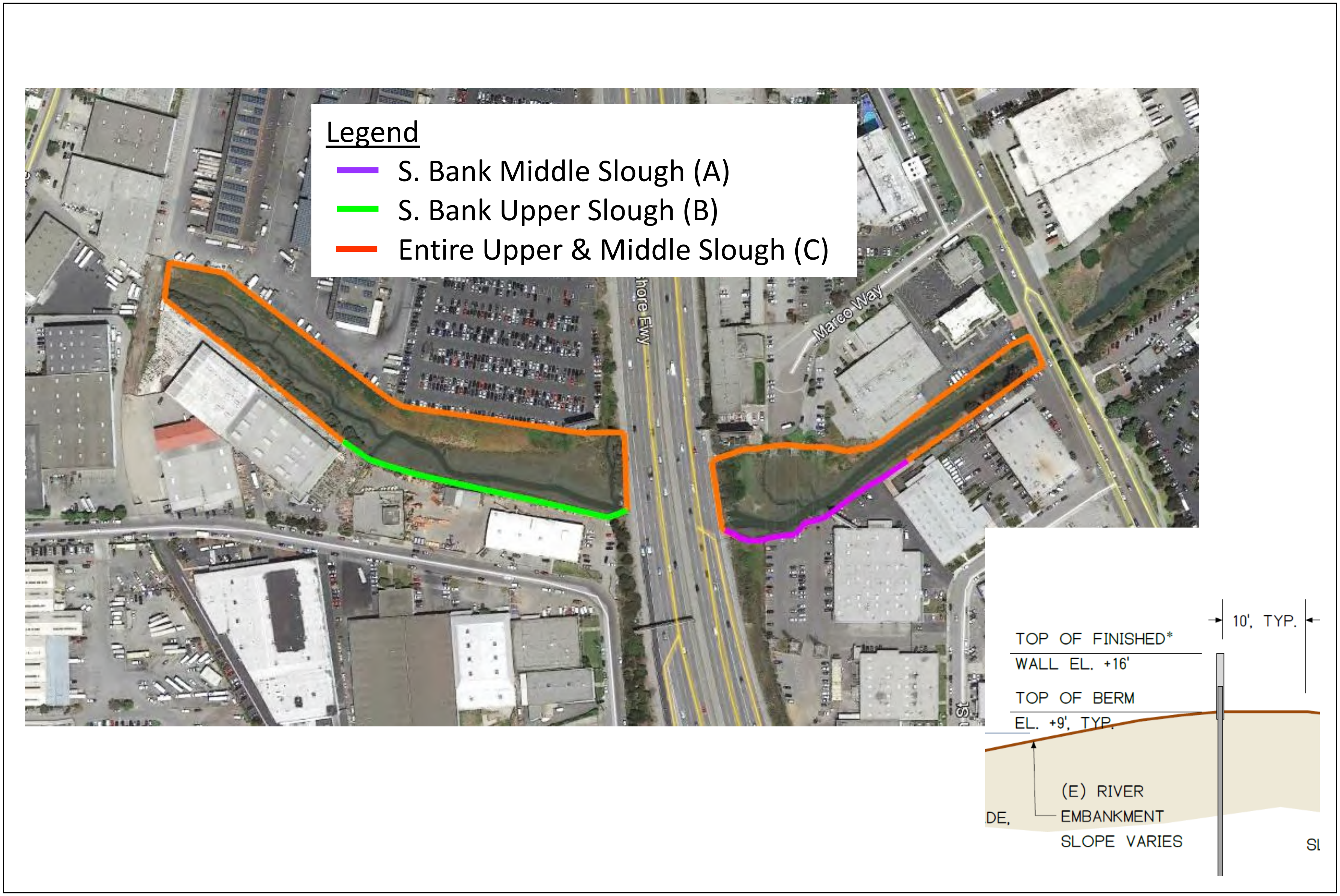





**Figure B-5**
Proposed Floodwall Alignment



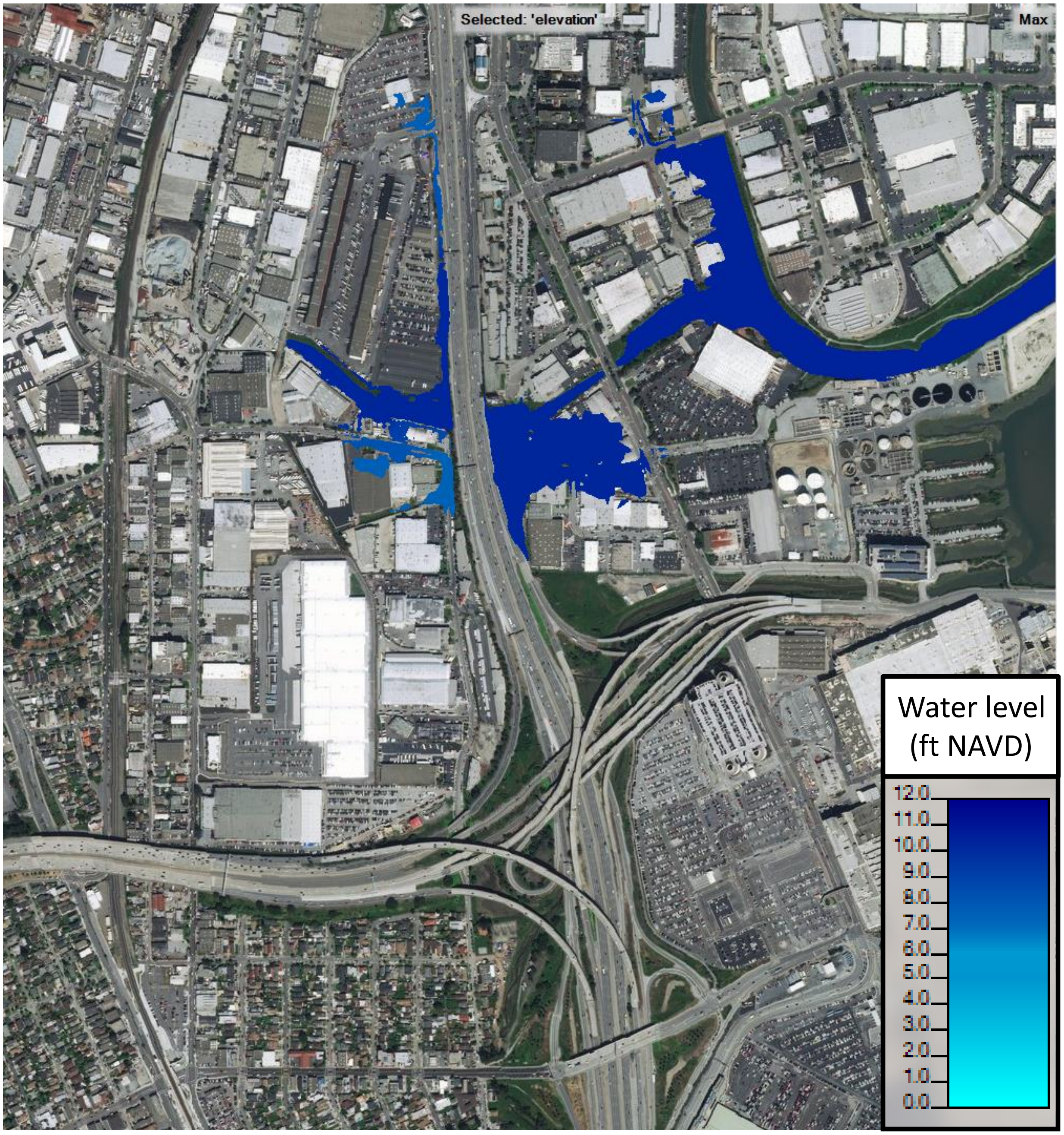

**Figure B-6**
Run EC-1
Peak Flood Extents

Source: HEC-RAS Modeling (ESA, 2018)


Source: HEC-RAS Modeling (ESA, 2018)



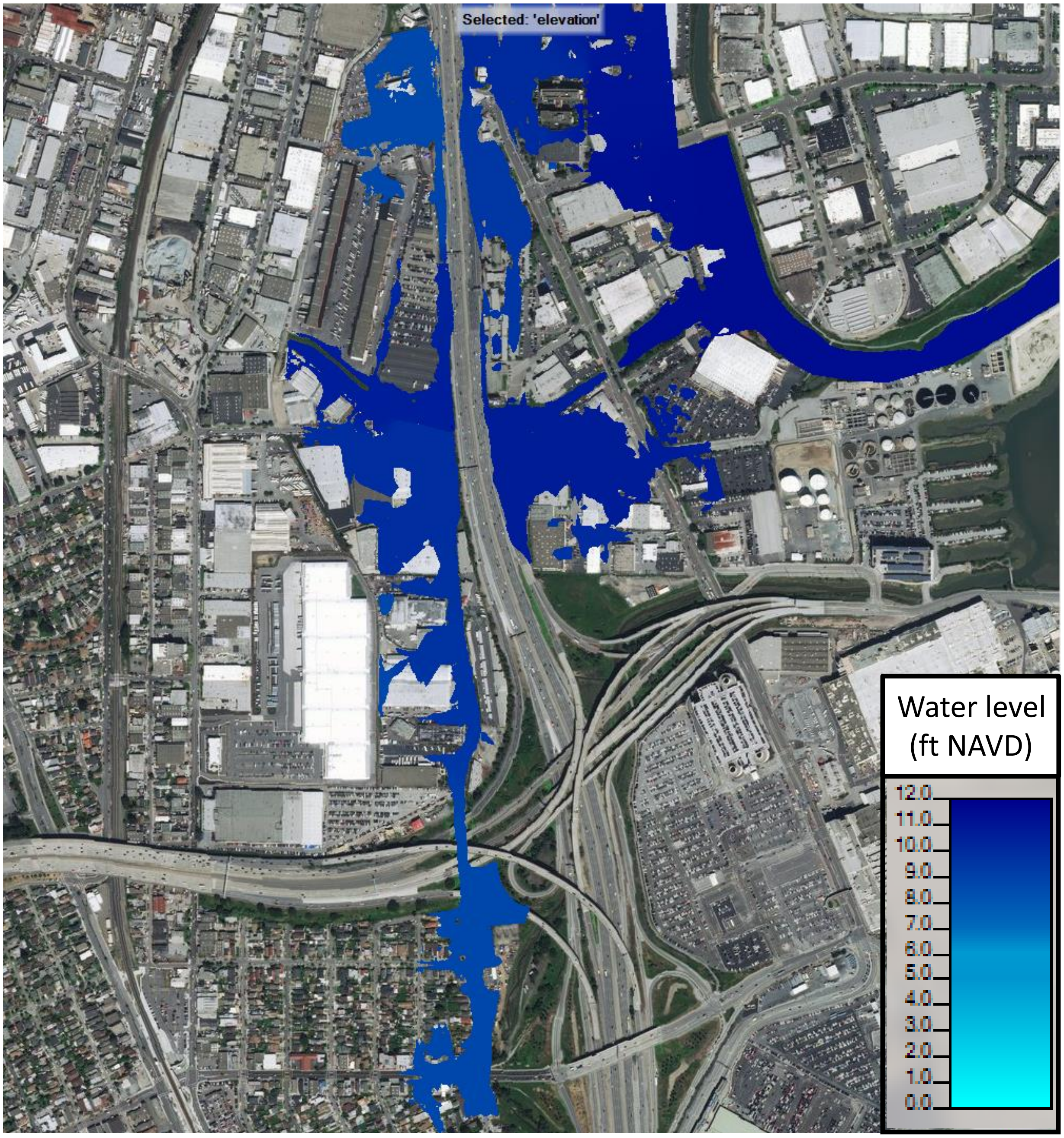
**Figure B-7**
Run EC-2
Peak Flood Extents






Source: HEC-RAS Modeling (ESA, 2018)

**Figure B-8**
Run EC-3
Peak Flood Extents




Source: HEC-RAS Modeling (ESA, 2018)



**Figure B-9**
Run EC-4
Peak Flood Extents

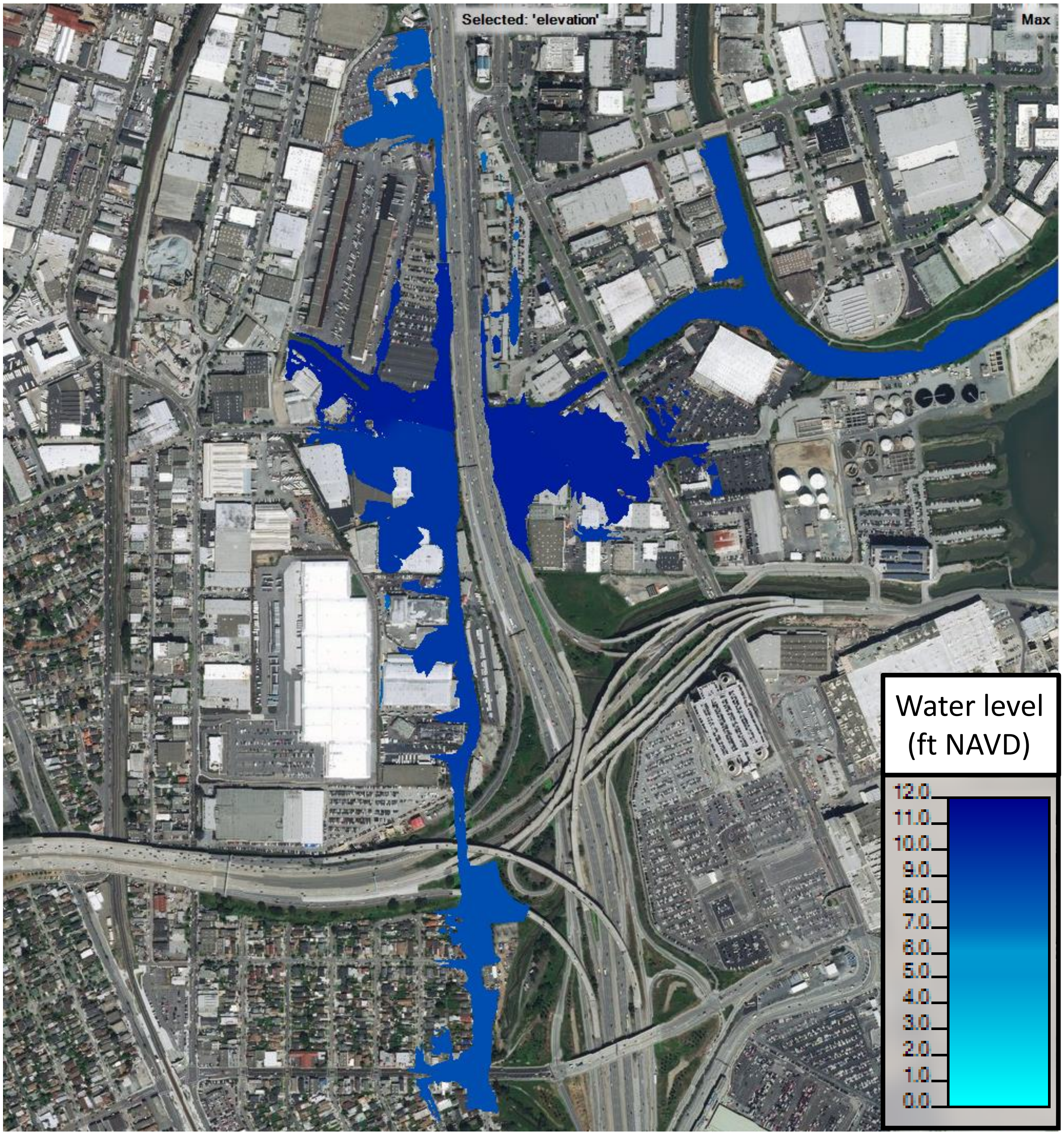





**Figure B-10**
Run EC-5
Peak Flood Extents

Source: HEC-RAS Modeling (ESA, 2018)

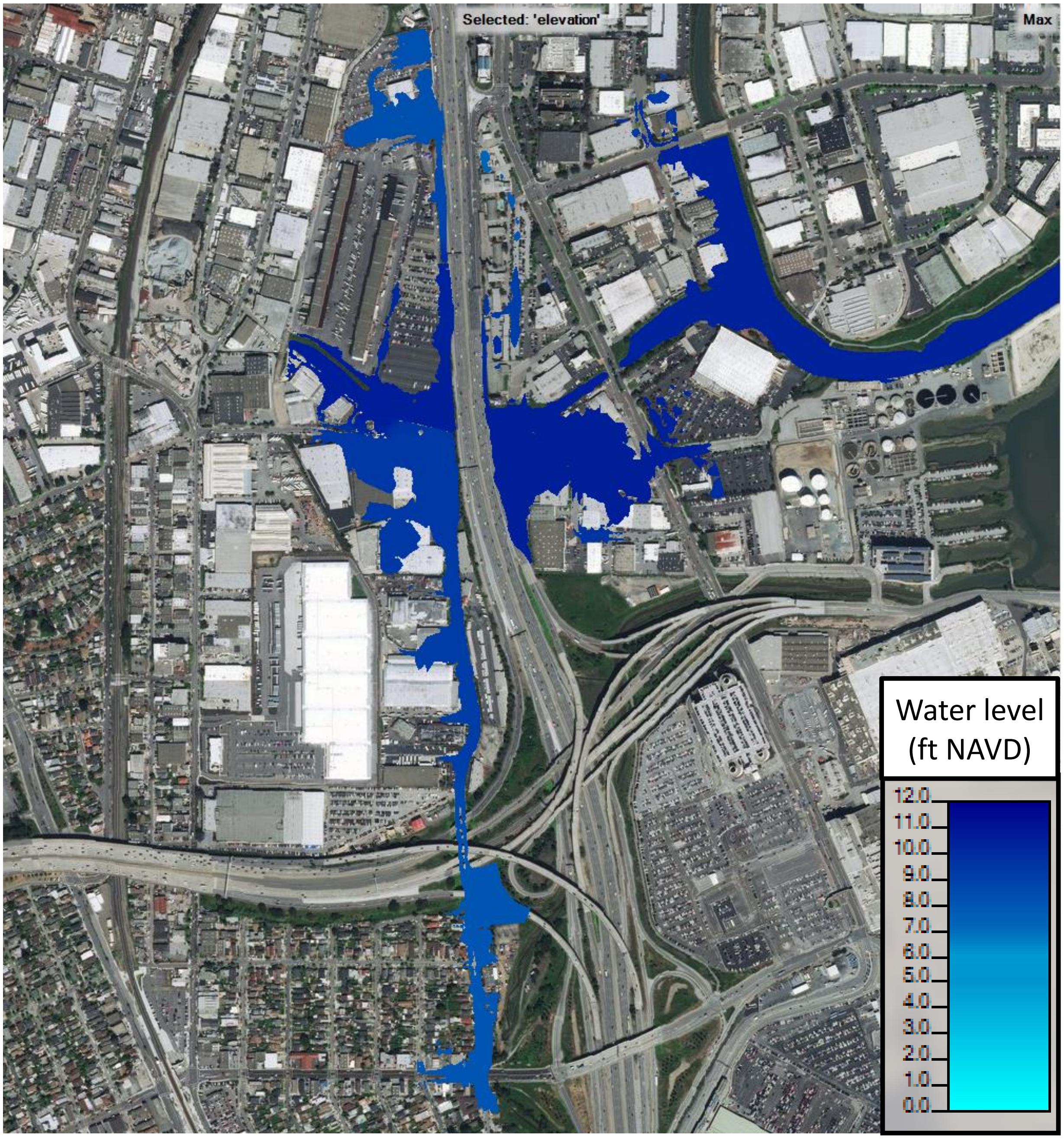
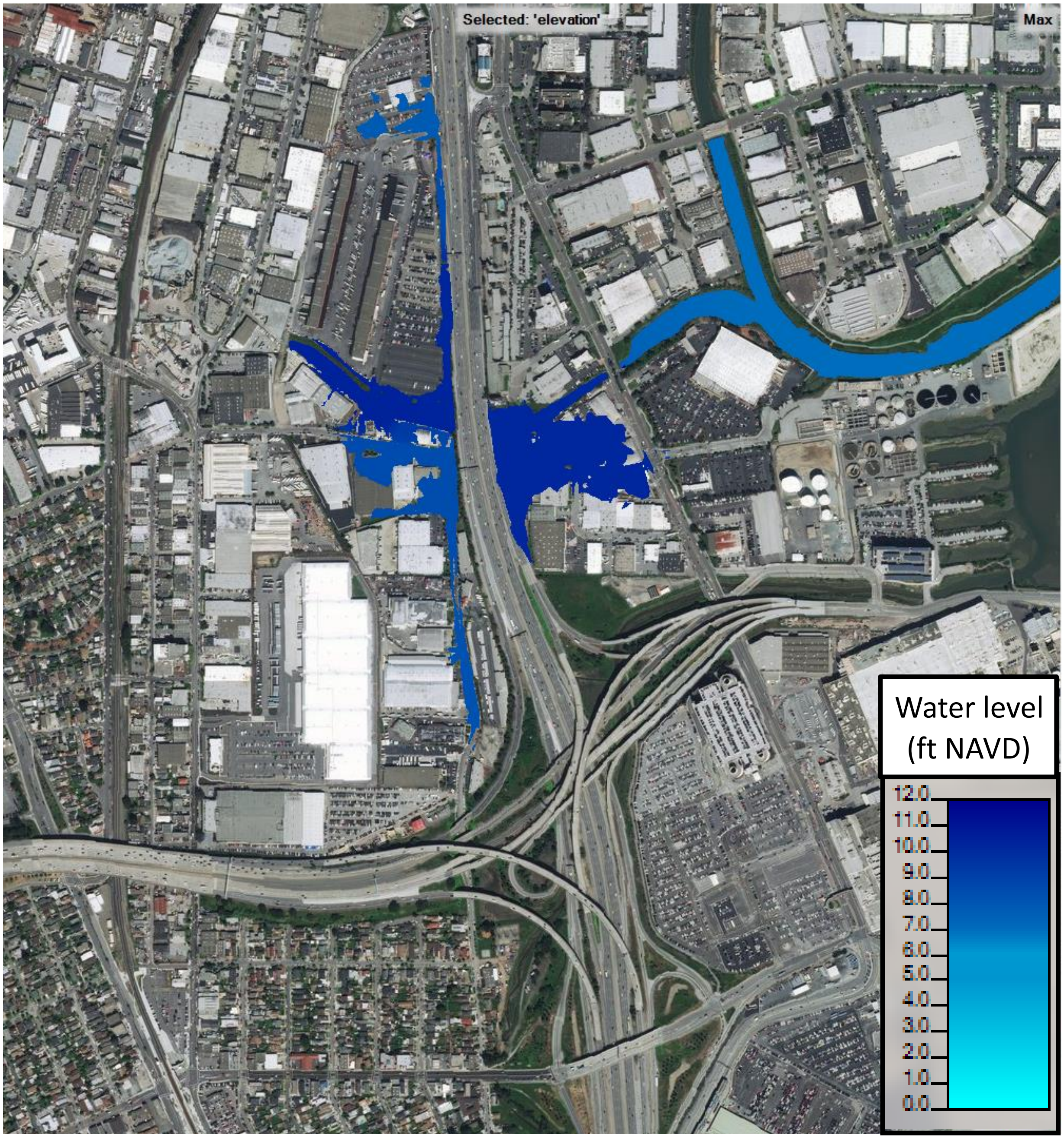





**Figure B-11**
Run EC-6
Peak Flood Extents

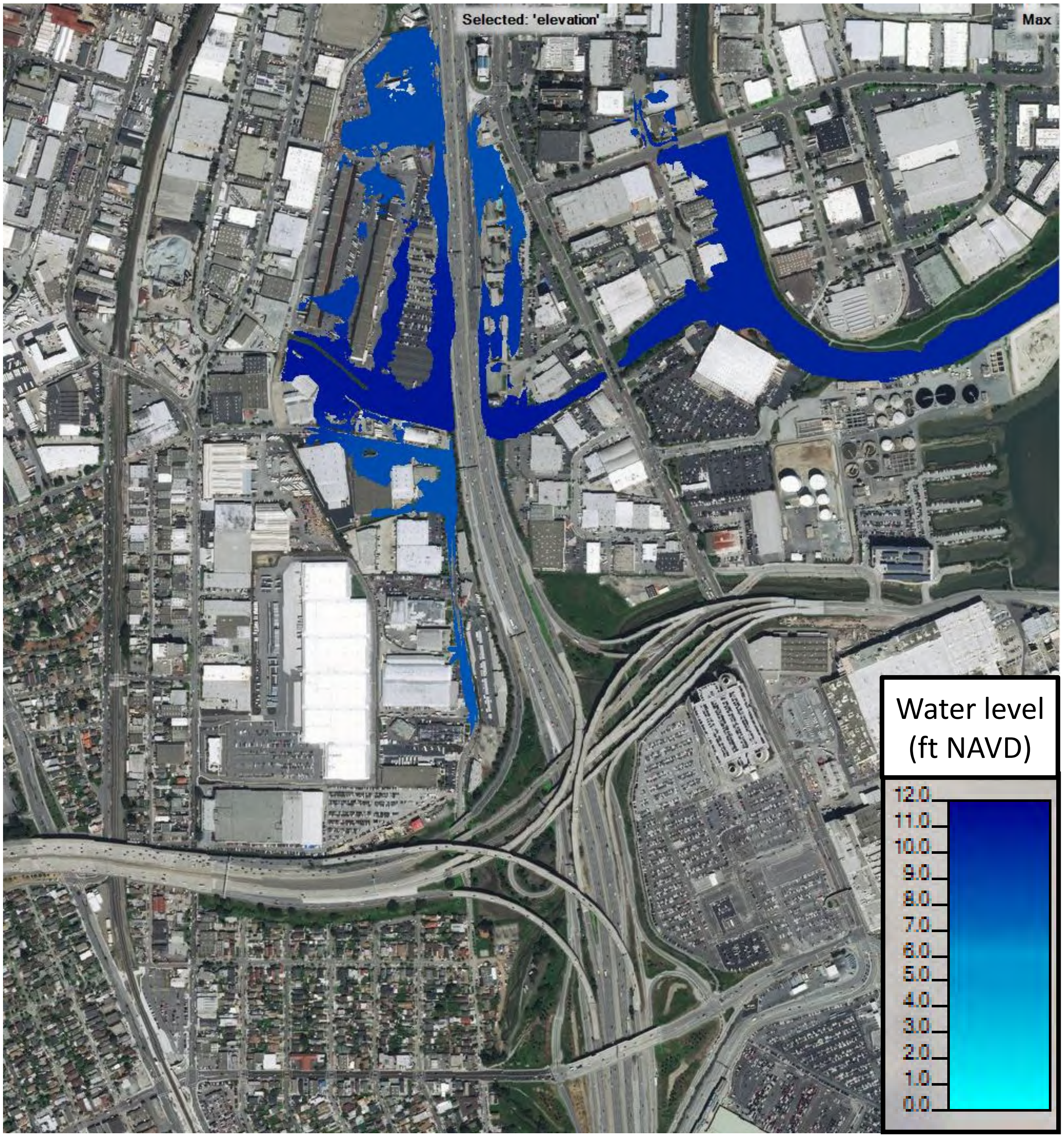
Source: HEC-RAS Modeling (ESA, 2018)




Source: HEC-RAS Modeling (ESA, 2018)



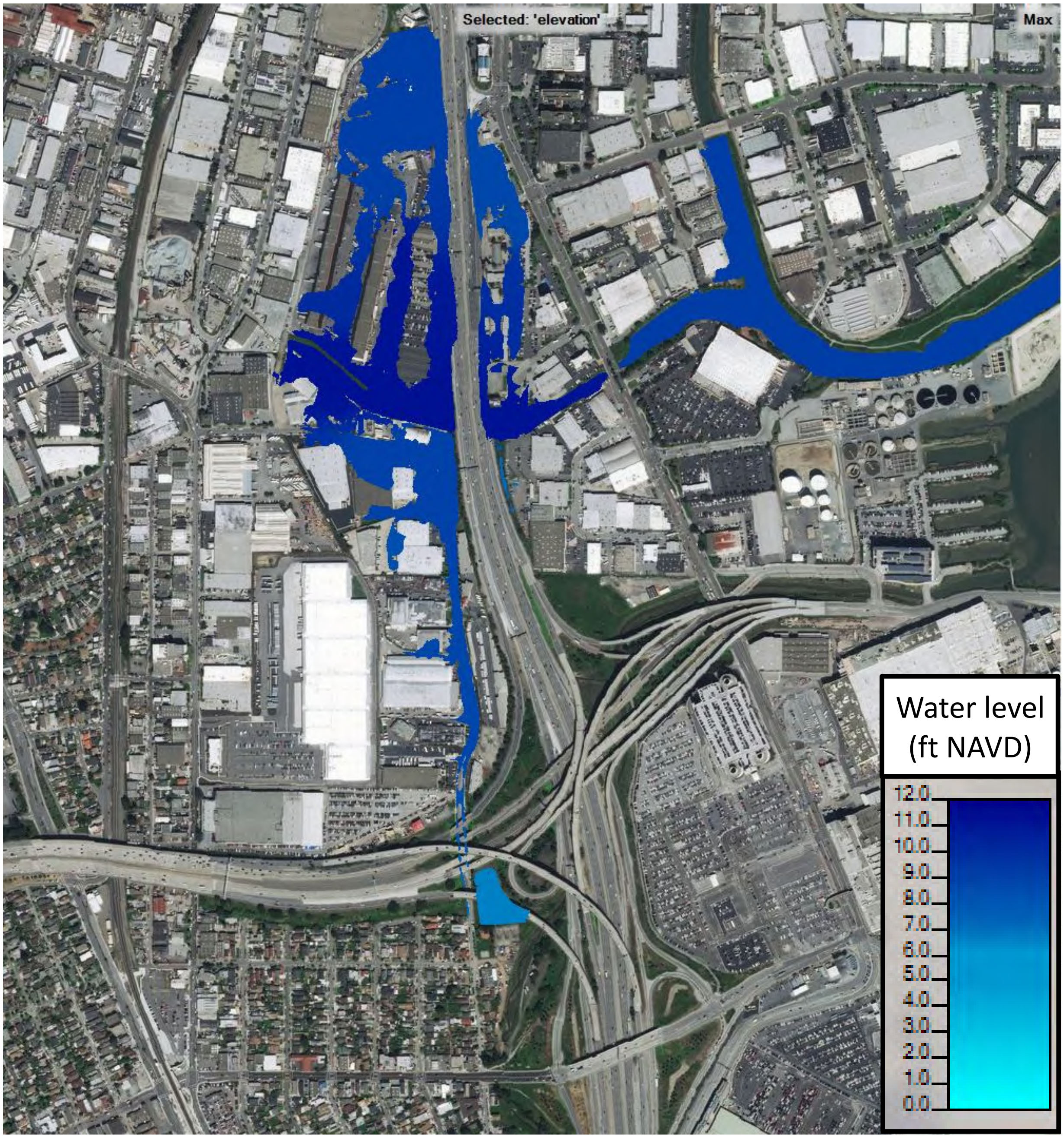
**Figure B-12**
Run EC-7
Peak Flood Extents






Source: HEC-RAS Modeling (ESA, 2018)

**Figure B-13**
Run FW-1
Peak Flood Extents






Source: HEC-RAS Modeling (ESA, 2018)

**Figure B-14**
Run FW-2
Peak Flood Extents

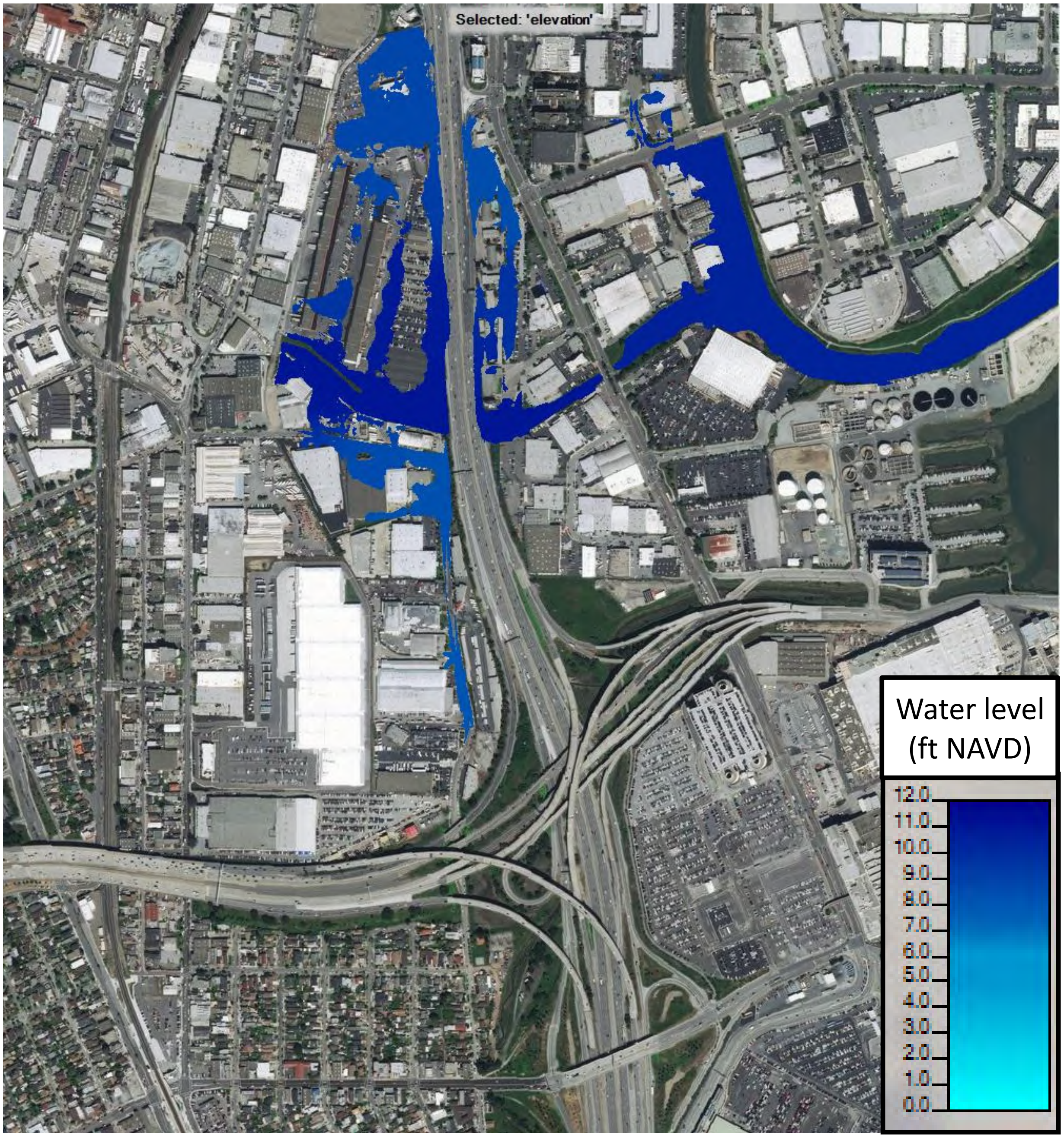
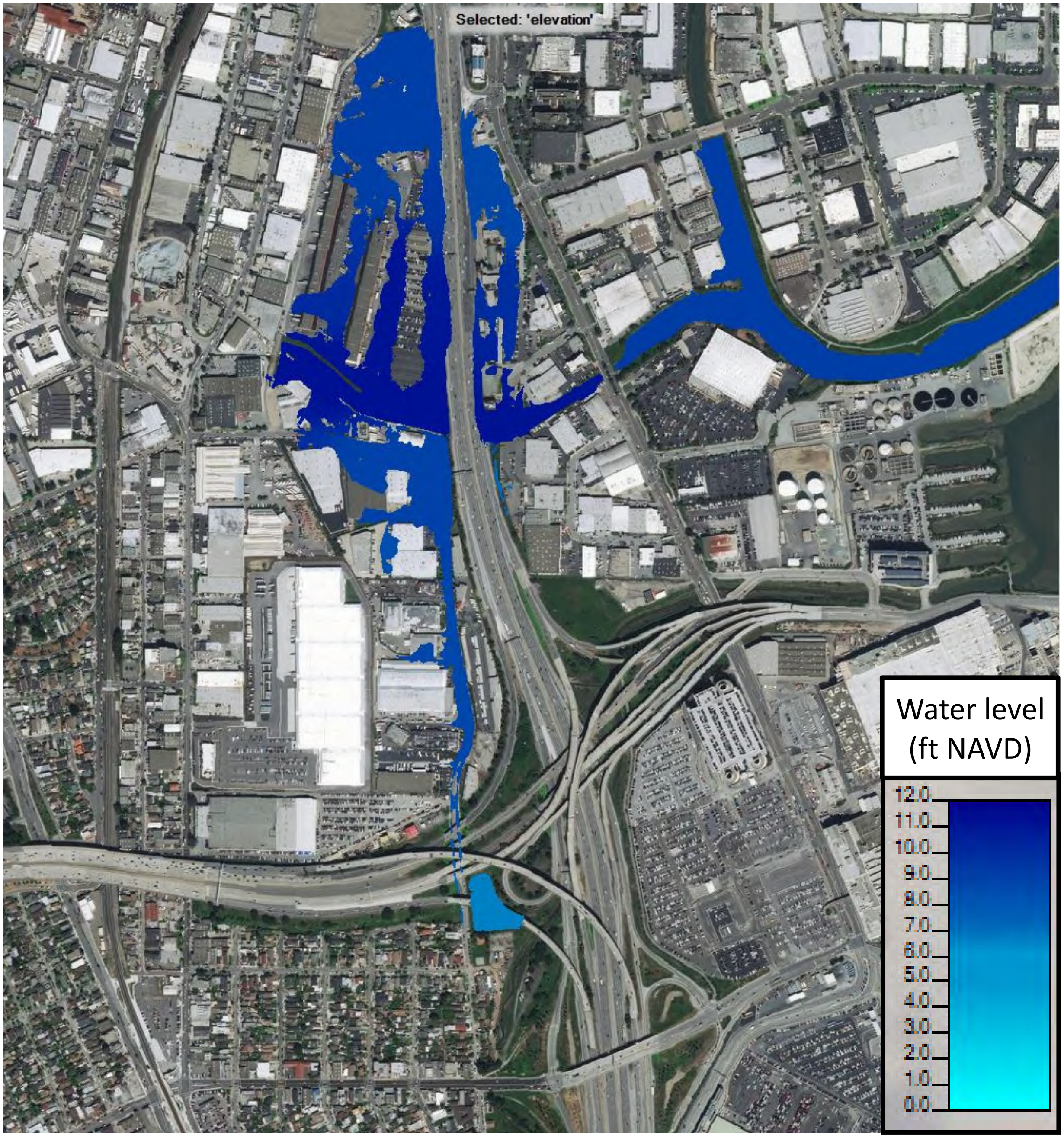





**Figure B-15**
Run FW-3
Peak Flood Extents

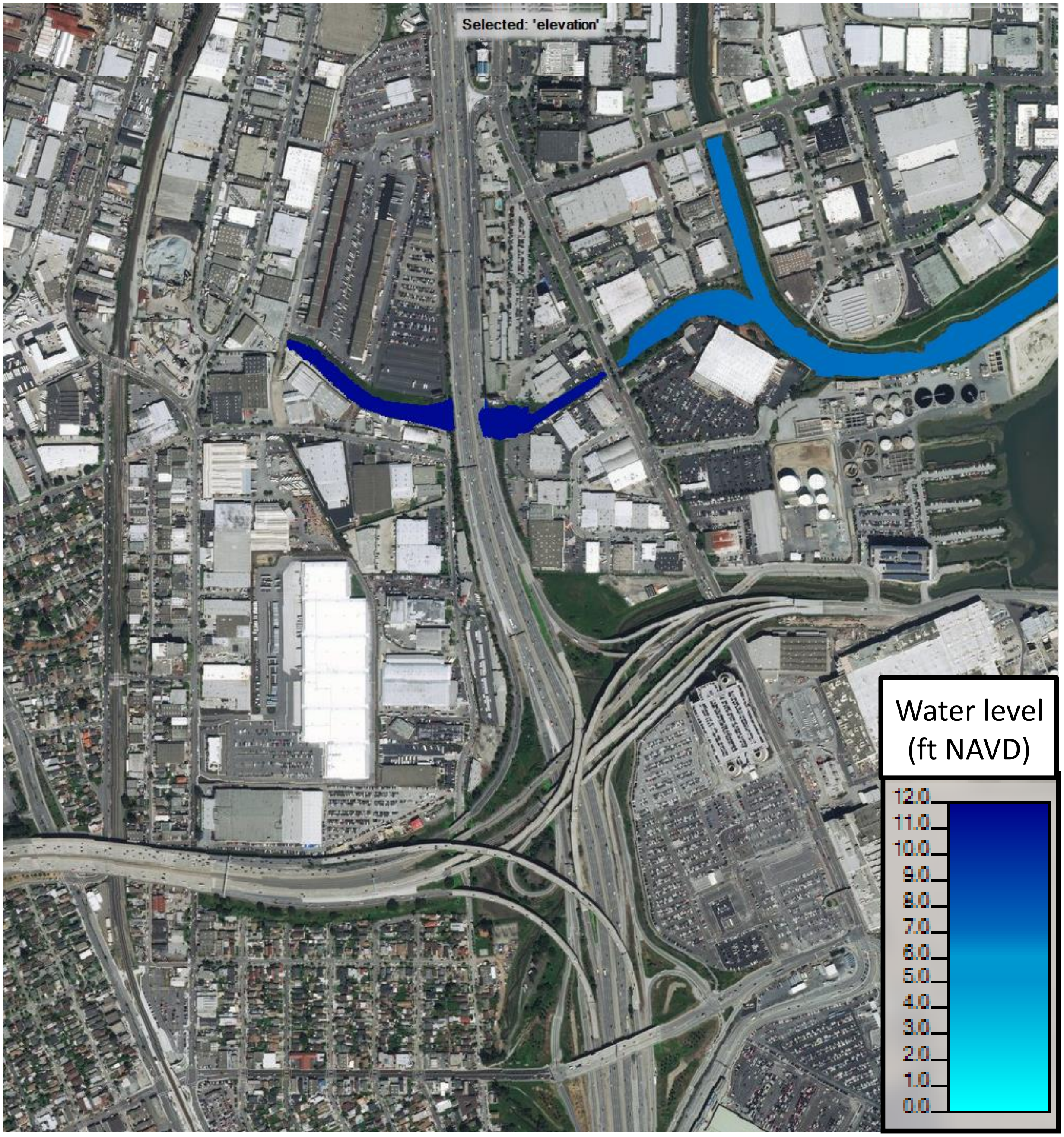
Source: HEC-RAS Modeling (ESA, 2018)




Source: HEC-RAS Modeling (ESA, 2018)



**Figure B-16**
Run FW-4
Peak Flood Extents






Source: HEC-RAS Modeling (ESA, 2018)

**Figure B-17**
Run FW-5
Peak Flood Extents

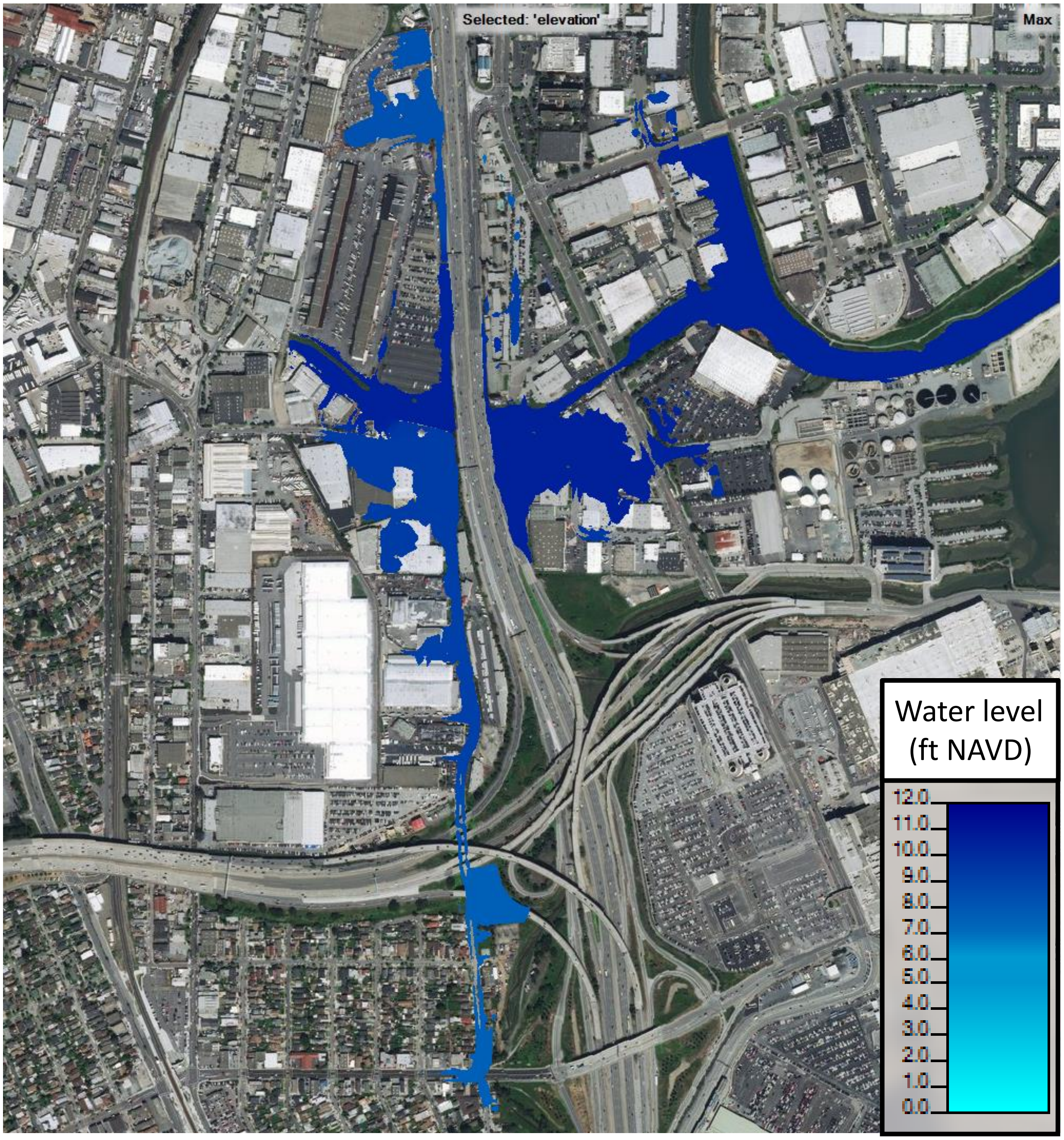
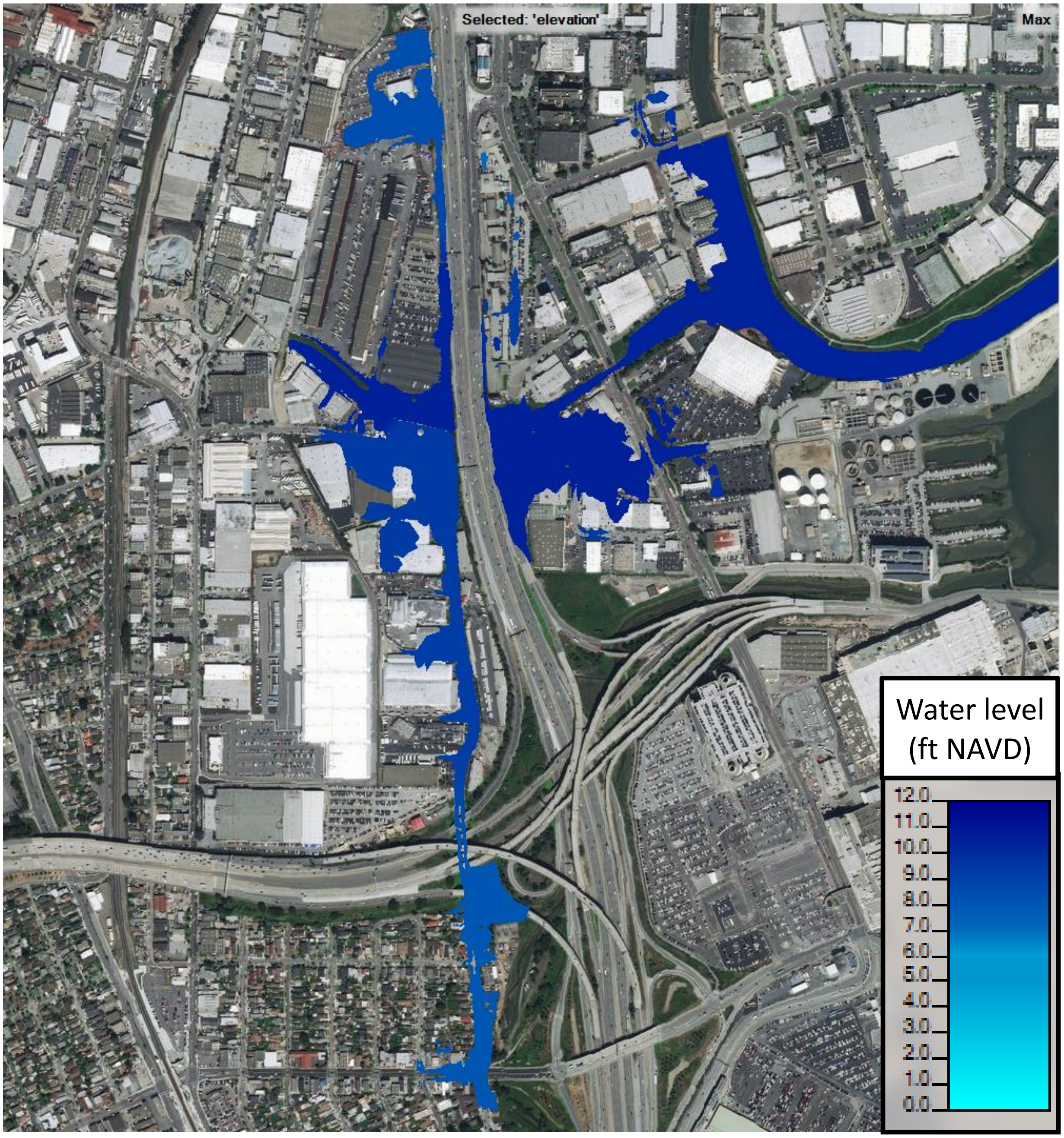





**Figure B-18**
Run SRT-1
Peak Flood Extents

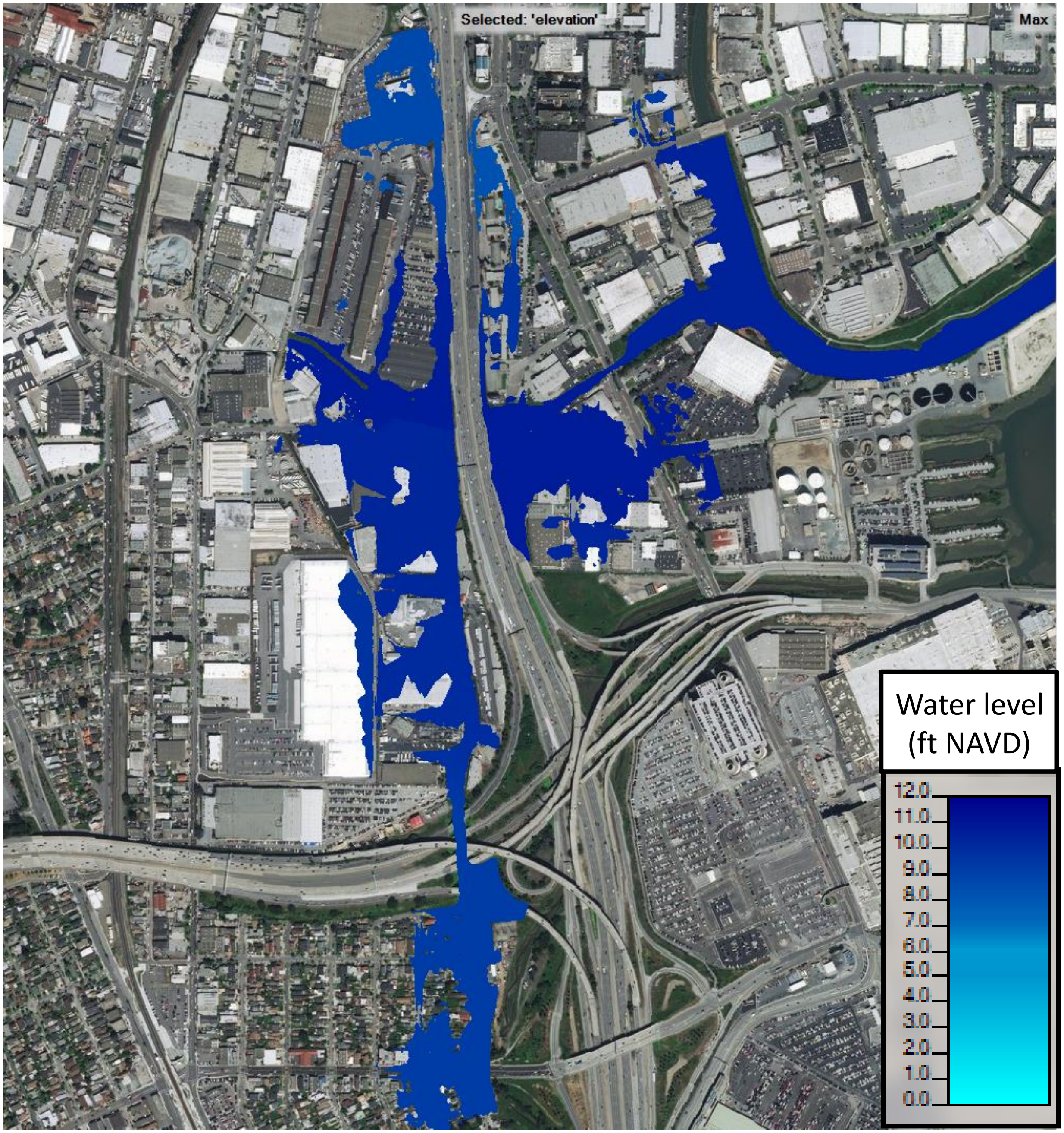
Source: HEC-RAS Modeling (ESA, 2018)




Source: HEC-RAS Modeling (ESA, 2018)



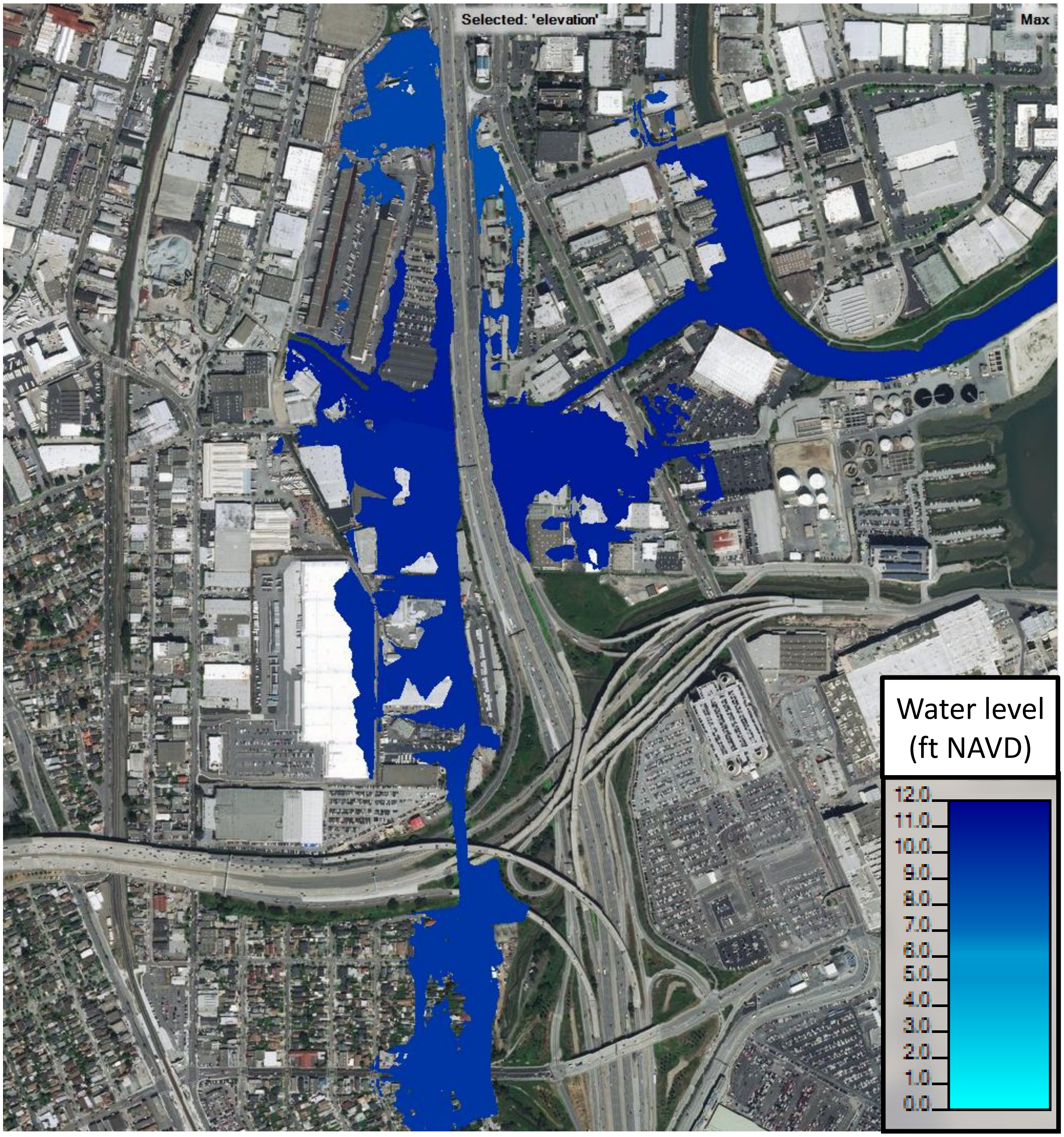
**Figure B-19**
Run SRT-2
Peak Flood Extents






Source: HEC-RAS Modeling (ESA, 2018)

**Figure B-20**
Run SRT-3
Peak Flood Extents




Source: HEC-RAS Modeling (ESA, 2018)



**Figure B-21**
Run SRT-4
Peak Flood Extents

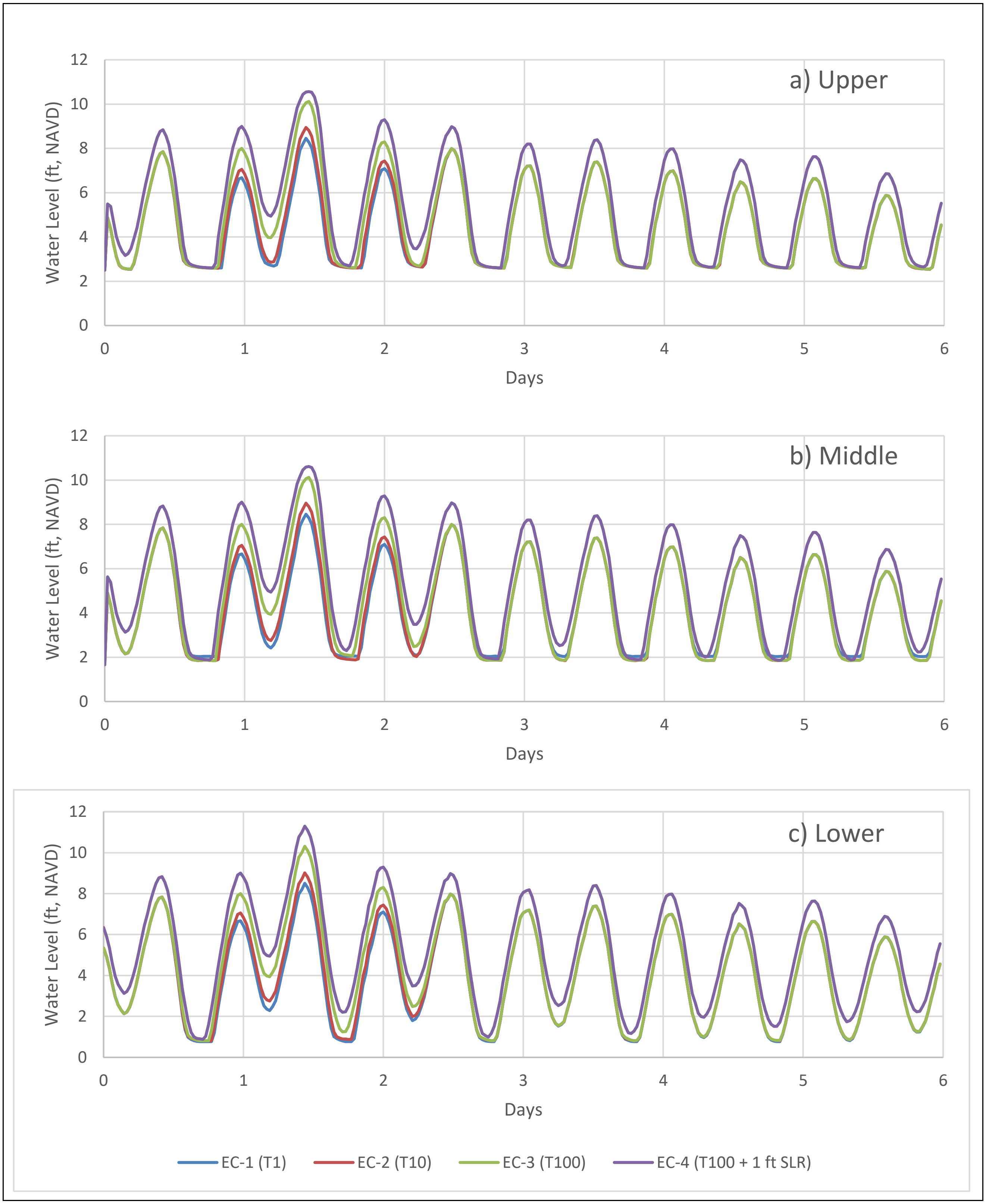





**Figure B-22**
Water Level Time Series
Runs EC-1, EC-2, EC-3 and EC-4

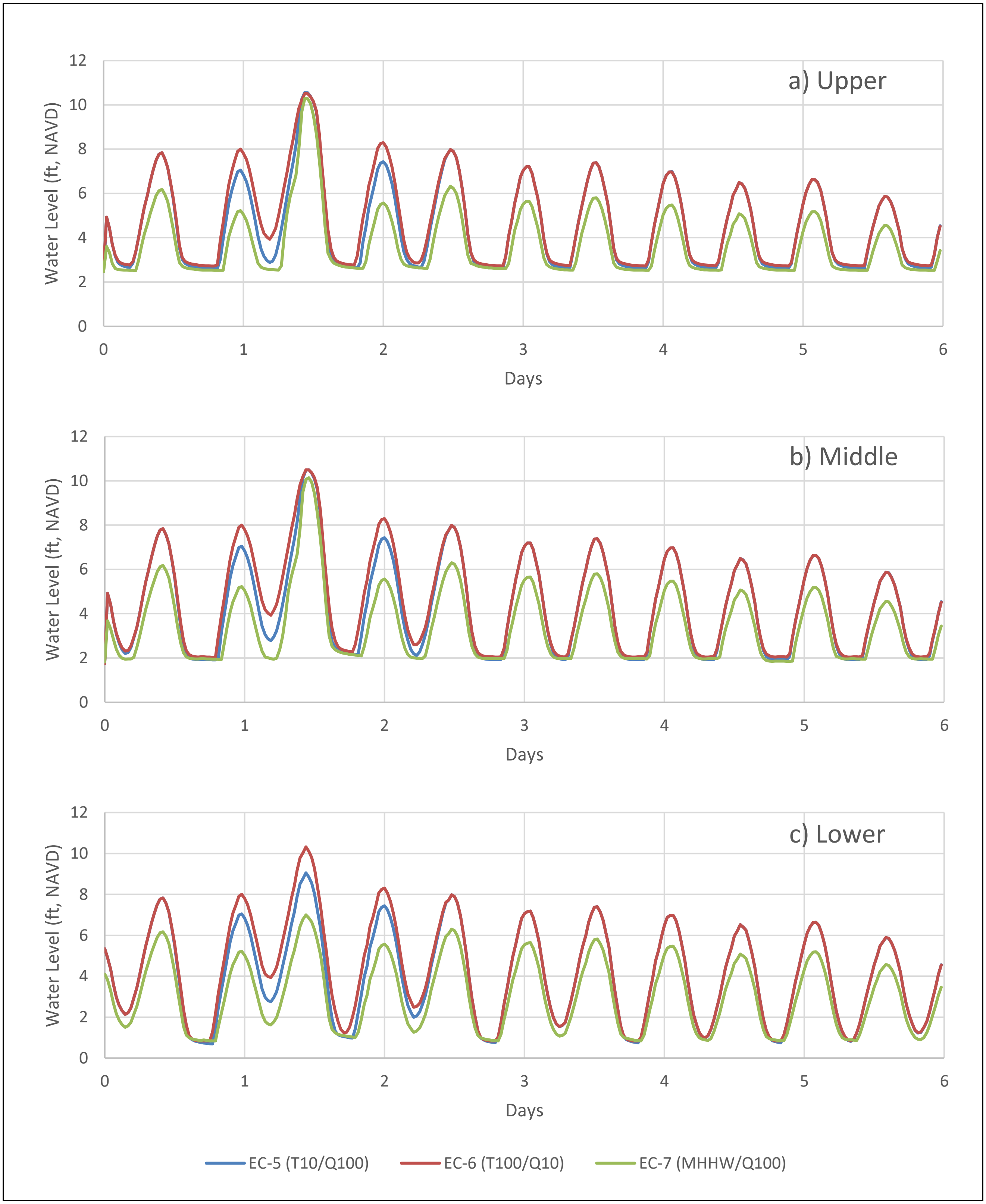





**Figure B-23**
Water Level Time Series
Runs EC-5, EC-6 and EC-7

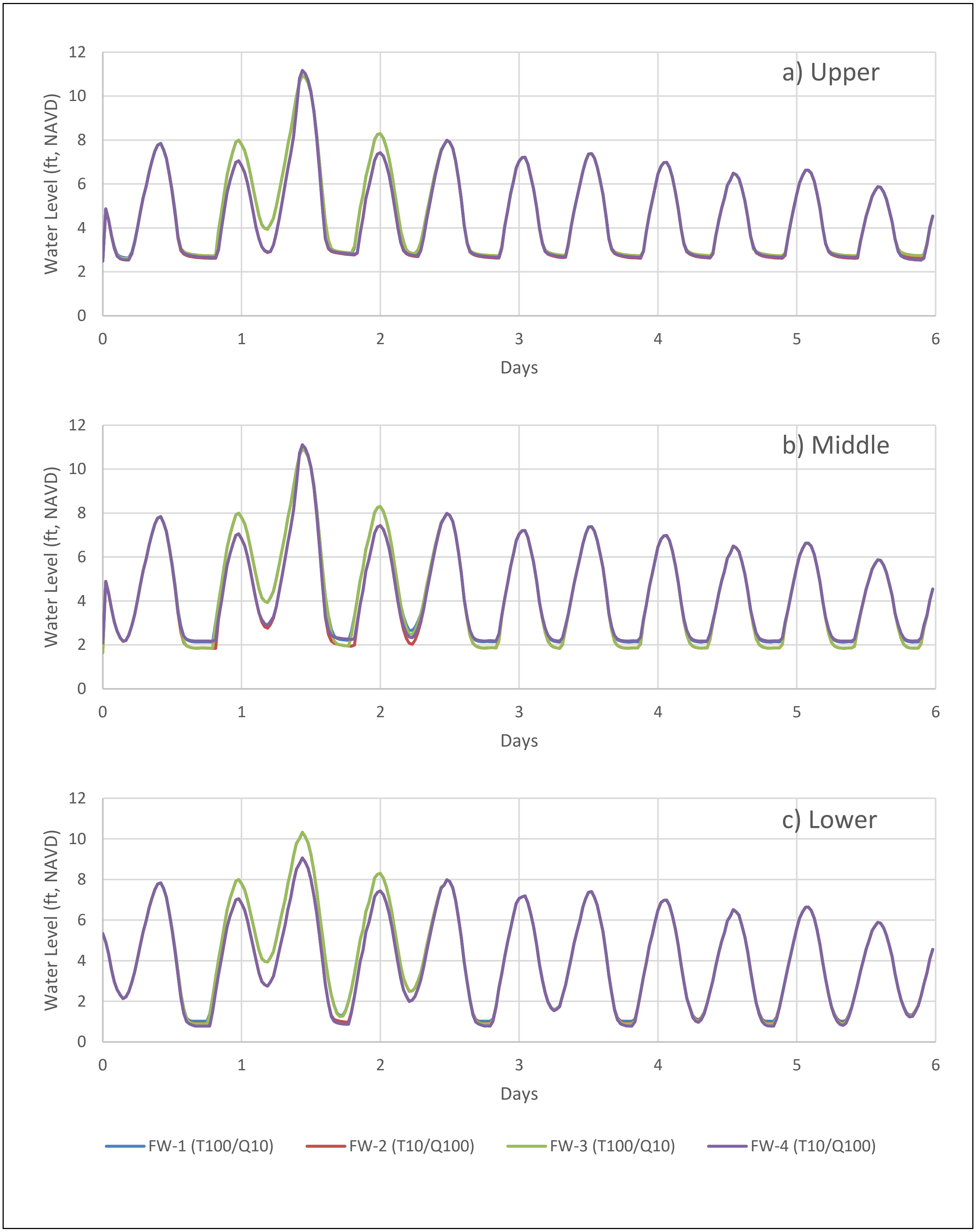





**Figure B-24**
Water Level Time Series
Runs FW-1, FW-2, FW-3 and FW-4

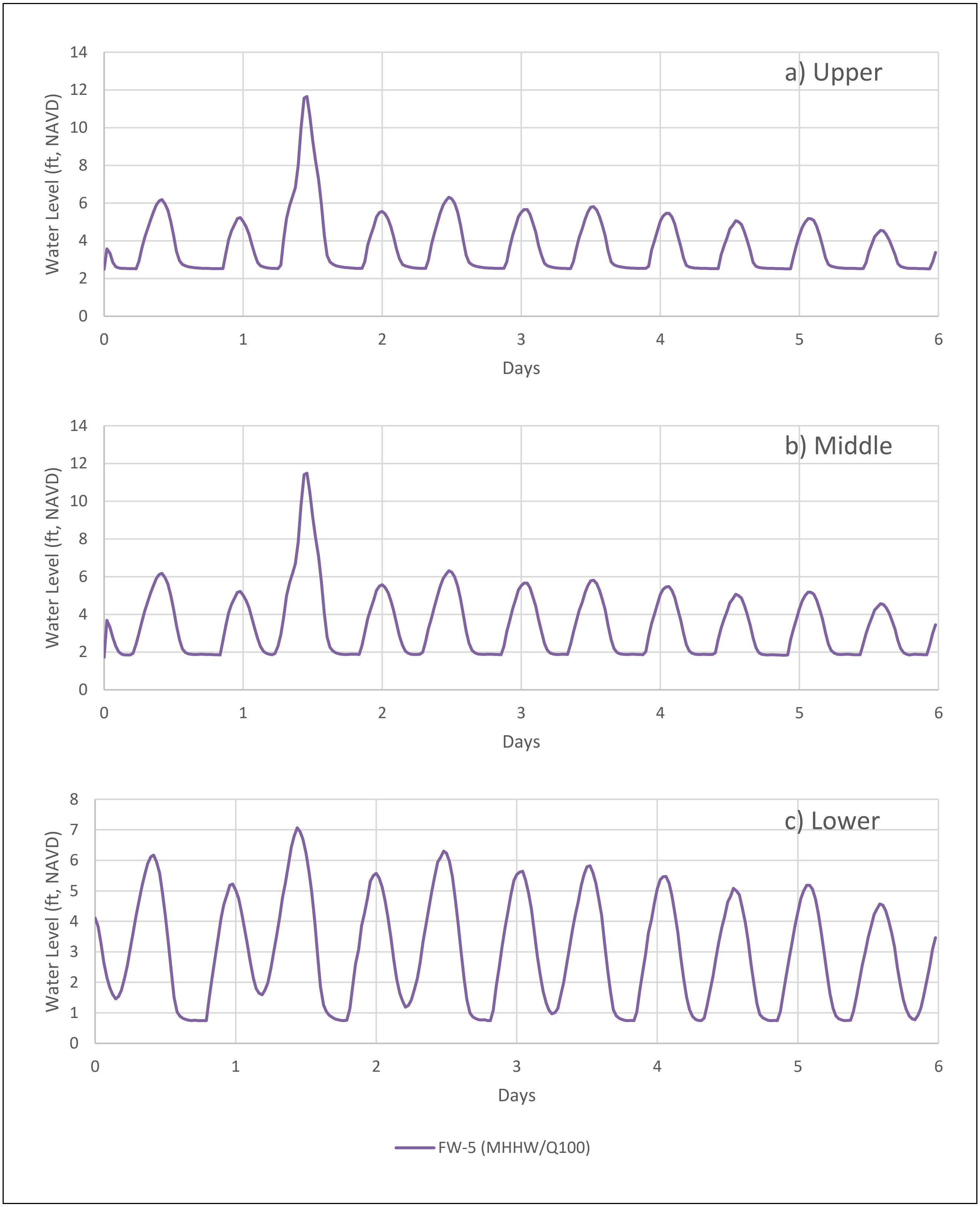





**Figure B-25**
Water Level Time Series
Runs FW-5

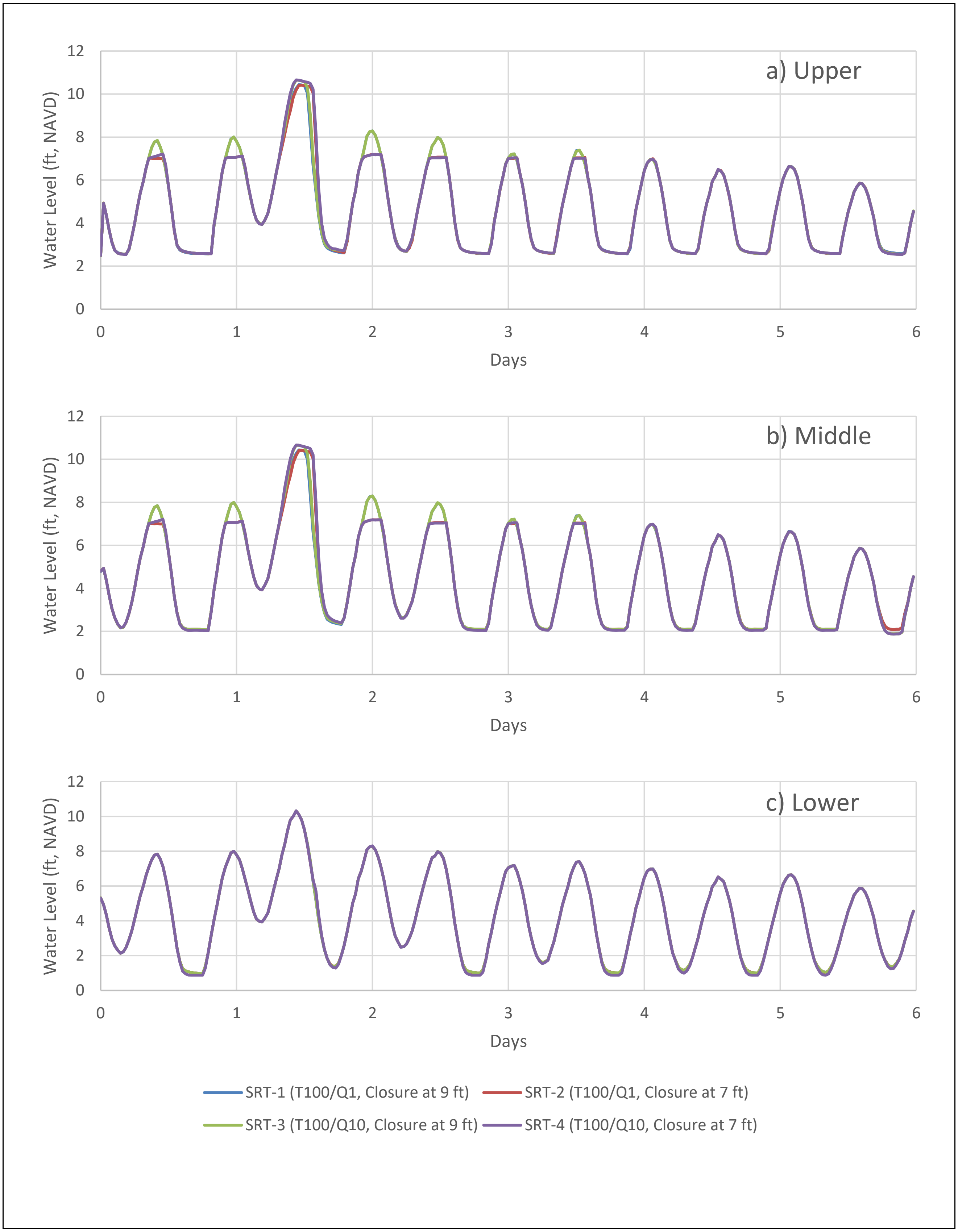





**Figure B-26**
Water Level Time Series
Runs SRT-1, SRT-2, SRT-3 and SRT-4

# Appendix C
## Biological and Cultural Assessments

ESA

180 Grand Avenue
Suite 1050
Oakland, CA 94612
510.839.5066 phone
510.839.5825 fax

www.esassoc.com

# memorandum

date February 9, 2018

to Erika Powell, Flood Resilience Program Manager

from Matt Brennan, P.E., Alex Trahan, P.E., Jill Sunahara, Erika Walther, Heidi Koenig

subject Navigable Slough Flood Study: Data Inventory and Data Gaps Analysis (Task 1)

The purpose of this memorandum is to document available studies and reports related to flooding conditions at Navigable Slough and adjacent areas, as well as identify questions and potential data gaps that need to be resolved before project alternatives can be identified and evaluated. To inform this evaluation, this memorandum reviews existing biological and cultural resources after first discussing flooding.

Navigable Slough is a tidal channel and tributary to Colma Creek, which drains to San Francisco Bay. For the purposes of this assessment, the Slough is divided into three reaches: the lower reach, from the confluence with Colma Creek to the culvert under South Airport Boulevard; the middle reach, between South Airport Boulevard and the culvert under Highway 101; and the upper reach from Highway 101 to the terminus of the daylighted portion east of San Mateo Avenue (Figure 1). The Slough receives stormwater drainage from surrounding development in San Bruno and is prone to flooding, especially during high Bay water levels.

## Existing Flood Hazards and Management

### *Existing Studies*

Four reports concerning the Navigable Slough watershed were reviewed in considering flood risks at the site:

1. Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) (FEMA, 2017)
2. San Bruno Creek / Colma Creek Resiliency Study (Moffatt & Nichol and AGS, 2015)
3. Colma Creek Flood Control Channel Improvement Project (WRECO, 2017)
4. South San Francisco Storm Drain Master Plan (Michael Baker International, 2016)
5. San Bruno Creek Tidegates Certification Feasibility study (Moffat & Nichol, 2016)

(1) The San Mateo County FIS (FEMA, 2017) in the area is a combination of coastal and fluvial analyses. The effective (i.e. currently accepted) FIRMs date from 2012 and map Navigable Slough and surrounding neighborhoods and infrastructure in Zone X, meaning they are exposed to flood hazards between the 100-year and 500-year return interval. In 2015, a preliminary set of revised coastal FIRMs were generated, and these map

Navigable Slough and the surrounding area in the Zone AE hazard zone with a 100-year flood base flood elevation (BFE) of 10 feet NAVD. These preliminary maps are still being discussed by the City, County, and FEMA. The FIS does consider Navigable Slough's watershed, reporting a drainage area (0.4 square miles) and flowrates at different return periods (200 cfs at the 10-year level and 300 cfs at the 100-year level).

(2) The San Bruno Creek / Colma Creek Resiliency Study (Moffatt & Nichol and AGS, 2015) was completed in 2015 for San Francisco International Airport. The resiliency study focuses on the vulnerability of the airport and other assets adjacent to the downstream reaches of San Bruno Creek and Colma Creek, including Navigable Slough and associated flood risk. First, the study reports that the reach of Colma Creek downstream of the Utah Avenue bridge has its highest flood water levels determined by extreme Bay water levels. This reach includes the area where Navigable Slough joins Colma Creek, so the reach of Navigable Slough from the South Airport Drive culverts to the junction is also expected to be determined by extreme Bay water levels as well. Second, the resiliency study uses BFEs from FEMA's preliminary FIRMs to assess flood hazard in Navigable Slough from the mouth to upstream of the Hwy 101 culverts. The report warns that the south bank of Navigable Slough is lower than the preliminary FEMA BFE (10.4 feet NAVD) for approximately 550 feet west of the Hwy 101culverts, and this could lead to overtopping and flood the industrial park south of the Slough. The industrial park is connected to the residential area surrounding 7$^{th}$ Ave and Walnut Street in San Bruno to the south and the San Bruno BART station to the west, and there is concern that flooding at these locations would be exacerbated by overflow at Navigable Slough. The resiliency study also reviewed discharges along Colma Creek and estimates Navigable Slough flowrates at different return periods (215 cfs at the 10-year level and 360 cfs at the 100-year level). These flowrates were estimated in 2012.

(3) The Colma Creek Flood Control Channel Improvement Project Hydraulic Analysis Report (analysis report) was prepared for San Mateo (WRECO, 2017). The analysis report supports the County proposal to install floodwalls along Colma Creek to address flood hazards based on FEMA's preliminary revisions of 100-year flooding. These walls would extend on both banks of Colma Creek from the Utah Avenue bridge to the Navigable Slough junction. The analysis report documents the development of and results from a HEC-RAS model with and without the proposed floodwalls, focusing on the 100-year water surface elevation (WSE), including sea-level rise (3 feet by 2100, as estimated in NRC (2012) and reported in Moffatt & Nichol and AGS (2015). The model includes a transect directly upstream of the Colma Creek junction with Navigable Slough (considered representative of Navigable Slough's lower reach), and at this transect, the model predicts a 100-year WSE of 13.5 feet NAVD, commensurate with the water level from the resiliency study (10.4 feet NAVD) plus sea-level rise (3 feet). The model also predicts that the floodwall project will generate no change in 100-year WSE with sea-level rise at the Navigable Slough junction. The analysis report performed a separate analysis of discharges in the Colma Creek and Navigable Slough watershed, but found it approximately 45% lower than those reported by FEMA, and so decided to use the more conservative FEMA flowrates. This would correspond to 200 cfs at the 10-year level and 300 cfs at the 100-year level on Navigable Slough.

(4) The South San Francisco Storm Drain Master Plan (SDMP) was prepared for the City of South San Francisco (Michael Baker International, 2016). The SDMP investigates existing storm drain facilities, looking to support long-term planning for improvements to and maintenance of the storm drain system. The SDMP modeled the existing storm drain system and proposed improvements using XPSWMM, a variant of the US Environmental Protection Agency (EPA) stormwater management model (SWMM). To capture the smaller-scale stormwater behavior in the city, the SDMP divides the area into watersheds and subwatersheds, each draining into a major storm drain line, and proposes improvements for those lines. The improvements along the line feeding Navigable

Slough include an additional 66-inch pipe from the San Bruno BART Station and expansions to the collector pipes feeding the existing (and expanded) lines from south of Shaw Road. The discharge estimates for existing drainage into Navigable Slough are significantly smaller in the SDMP than those provided by the other three sources, and they are very similar between the 10-year level and the 100-year level. This is likely because the SDMP focuses on water conveyed by the drain network, and this appears to be capacity-limited around the 10-year level, in which case additional runoff would be conveyed overland to the Slough. The report does not appear to specify potential change in discharge rate and timing to Navigable Slough that could result from the additional 66-inch pipe.

(5) The San Bruno Creek Tidegates Certification Feasibility study (Moffat & Nichol, 2016) was prepared for San Mateo County. The assessment included hydraulic modeling to see if obtaining FEMA accreditation for the tide gates could remove a portion of San Bruno's Belle Air neighborhood from the FEMA floodplain. The hydraulic modeling evaluated a range of scenarios which varied the tide gate configuration, the Bay water levels, and watershed runoff. The assessment concluded that the tide gates configuration, nor their accreditation for the tide gates affect the floodplain mapping in Belle Air. The modeling also found that water overtopping the south bank of Navigable Slough and flowing down Shaw Road and under I-380 is a potential flood hazard in Belle Air. In addition, the modeling indicates that watershed runoff can also cause flooding in Belle Air.

### *Conditions at Navigable Slough and Its Watershed*

Currently, Navigable Slough is a tributary of Colma Creek that begins at its confluence with Colma Creek about 1,000 feet downstream of the Utah Avenue bridge and extends upstream approximately 3,000 feet. Historically, Colma Creek and Navigable Slough were the same channel through a tidal marsh (U. S. Coast Survey, 1954). Colma Creek was then straightened and disconnected from a meander that used to connect to the upper end of Navigable Slough. The Slough has three reaches (see Figure 1) separated by two banks of culverts, one crossing under South Airport Boulevard and another crossing under Highway 101. Downstream of South Airport Boulevard, the lower reach's extreme water levels are controlled by extreme water levels in the San Francisco Bay, which propagate up Colma Creek. The culverts under the boulevard and highway may constrict flow when Bay water levels rise rapidly and/or during high discharge from the Slough's watershed. Under most conditions, the culverts exchange tidal flows with the middle reach (upstream of South Airport Blvd) and upper reach (upstream of Hwy 101) of the Slough. Upstream of the culverts, water levels in the Slough are also influenced by stormwater runoff, including a storm drain outfall from the line connecting San Bruno BART station to Tanforan Ave and Shaw Rd. The balance of tidal and fluvial contributions to extreme water levels in the upper two reaches is not yet clear. A better understanding of the size and capacity of the culverts, as well as hydraulic modeling of unsteady flow conditions in the Slough, would lead to more understanding as to the flooding contribution from stormwater backwatering in the middle and upper reaches, particularly when tidal water levels are elevated.

Figure 2 presents the topography surrounding Navigable Slough. Elevations above 10 feet NAVD, the preliminary FEMA BFE, have been faded out to emphasize the lower areas near the Slough. Except for some fringing wetlands along the Slough's edge, the developed areas along the downstream reach are above 10 feet NAVD and also subject to flooding from Colma Creek. The industrial park south of the Slough's middle reach, however, is low and connected and could see flooding from Navigable Slough. In fact, during December 4$^{th}$, 2017 king tides (the highest astronomic tides of the year), these low areas experienced inundation. This inundation probably occurred via storm drain backups, since water levels appeared too low to overtop the Slough's banks. Finally, the south bank of the upper reach is 8-9 feet NAVD high, but the area south of that, along Shaw Road, is only 6-7 feet NAVD high. Shaw Road could provide conveyance for floodwaters from Navigable Slough to proceed south into San Bruno (off map).

Figure 3 is an annotated adaptation of the hydrology and drainage map for the watershed surrounding Navigable Slough from the South San Francisco Stormwater Drainage Master Plan (Michael Baker International, 2016). The annotations indicate areas where drainage and storm drain connectivity or flow direction were not immediately evident, and discussion with local government staff will be needed to clarify.

### *Nearby Flood Management Planning and Projects*

In addition to this study, there are several studies and projects in the region that may have an influence on Navigable Slough. Descriptions of these projects, including jurisdiction and current status are listed in Table 1.

#### Table 1. Flood management planning and projects in the Navigable Slough region

| Name | Jurisdiction | Description | Timeline |
|---|---|---|---|
| Sea Change San Mateo County | San Mateo County | County-wide vulnerability assessment of flooding exacerbated by sea-level rise. The study initiated a long-term resilience strategy that will identify phased adaptations, develop governance structures, and implement pilot projects. | Draft vulnerability assessment completed 4/2017; adaptation planning in progress |
| San Francisco Airport Shoreline Protection Project | City/County of San Francisco | SFO completed an Airport Shoreline Protection Feasibility Study to better understand the deficiencies in its existing shoreline protection system. The study also provides recommendations on improvements needed to protect the Airport from a 100-year flood and sea level rise. Started working on developing concept design. | Completed study 3/2015; started concept design 6/2016 |
| San Francisco Airport, Colma and San Bruno Creek Resilience Study | SFO, Colma, San Bruno, South San Francisco | Vulnerability assessment of flooding from creek and sea level rise in area plus identification of a suite of adaptation options. Funded by Coastal Conservancy Grant. Now working to implement some of recommendations. (2: Moffatt & Nichol and AGS, 2015) | Completed 6/2015 |
| San Bruno Tidegates Certification Feasibility | San Mateo County, San Bruno | SMC evaluated the feasibility of certifying the San Bruno tide gate to revise FEMA flood mapping in the Belle Air | Completed 10/16 |

| | | | |
|---|---|---|---|
| | | neighborhood.. Although the tide gate was found to not affect mapping, the study identified overtopping from Navigable Slough and San Bruno Creek as flood hazards. | |
| Colma Creek Sheetpile Floodwall Project | San Mateo County | SMC is designing floodwalls on Colma Creek from Utah Avenue downstream to the pedestrian bridge (3: WRECO, 2017) | In progress |
| Orange Memorial Park Detention Basin | South San Francisco | SSF has engaged in a Cooperative agreement with Caltrans to design and build a 7 Ac feet stormwater Detention Basin | In progress |
| In Lieu-wetlands restoration agreement | San Francisco Airport | SFO is working on a potential agreement to pay in lieu fees for wetlands mitigation associated with the airport's construction of projects. | In progress |
| San Bruno Water Quality Control Plant | South San Francisco | 9 MGD to 60 MGD Water Quality Control Plant - Master Plan | In progress |
| South San Francisco Storm Drain Master Plan | South San Francisco | Among other improvements, the Master Plan proposes adding an additional 66-inch stormwater line from the San Bruno BART Station to Navigable Slough (4: Michael Baker International, 2016) | Conceptual |
| Resilience By Design – South San Francisco | South San Francisco | As part of Bay Area-wide effort to improve resilience, this high level planning seeks to integrate transit infrastructure with waterfront access and flood management. | In progress |

### *Summary of questions and data gaps*

A summary of the questions and data gaps directly mentioned or alluded to in the preceding sections are collected below, to inform follow-on discussion with the County and other stakeholders that will shape the Navigable Slough flood study.

Hydrologic analysis

1. Verify ground surface elevations, Slough geometry, and existing water control structures.
2. Consider wet-season water level observations to characterize existing conditions and to calibrate hydraulic model.
3. Verify Navigable Slough's watershed flow pathways (e.g. questions on Figure 3) and corresponding discharge to the Slough.
4. Assess the relative contribution of watershed discharge and Bay water levels, particularly during storm events which cause coincident high discharge and elevated Bay water levels. Anticipated approach would consist of unsteady hydraulic modeling for a range of hydrologic scenarios.

Flood management planning

1. What is this project's area of focus for flood management issues to improve? At a minimum, we assume the focus area includes:
    - flooding that originates in Navigable Slough due to elevated Bay water levels alone
    - flooding that occurs due to backwatering of the stormdrain system by Navigable Slough
2. We assume that this project's focus area does not include flooding within Navigable Slough's watershed due to stormwater exceeding capacity of stormdrain system, independent of Navigable Slough water levels.
3. We ask to continue to be informed about regional flood management planning such as developing a continuous line of coastal flood protection and Resilient by Design.
4. What are the design criteria for improvements to Navigable Slough? For the Navigable Slough stormdrain system? What future climate change scenarios, including sea-level rise and precipitation shifts, should be evaluated?
5. Which existing flood management planning and projects should be evaluated as part of this study? At a minimum, we recommend considering those projects which may affect coastal flooding in Navigable Slough and the amount and/or timing of watershed discharge to Navigable Slough.

## Existing Environmental Conditions

This section discusses existing biological and cultural resources in and around Navigable Slough based on existing data and a reconnaissance-level field survey.

### *Biological Resources*

ESA reviewed aerial photographs and California Natural Diversity Database (CNDDB) records of special-status species occurrences within a 3-mile study area surrounding Navigable Slough, and conducted a field survey on December 13, 2017. Figures 4 and 5 illustrate the CNDDB record search results for wildlife and plant species, respectively.

San Francisco Bay, Colma Creek, and Navigable Slough are all considered jurisdictional “waters of the United States,” as defined in the Code of Federal Regulations (33 CFR § 328.3[a]; 40 CFR § 230.3[s]).

Navigable Slough supports several acres of tidal salt marsh across the three reaches. These marshes are part of a marsh complex at the confluence of Colma Creek and San Bruno Creek, one of the larger marsh complexes on the San Francisco Peninsula north of the San Mateo Bridge (Invasive Spartina Project, 2014). The marshes in Navigable Slough are composed primarily of pickleweed (*Salicornia pacifica*). Upland vegetation bordering the Slough is primarily ruderal. In the lower reach, upland vegetation is comprised of sweet fennel (*Foeniculum vulgare*), wild radish (*Raphanus sativus*), slender oat (*Avena barbata*), and coyote brush (*Baccharis pilularis*), as well as limited patches of coastal gumweed (*Grindelia stricta*). In the middle reach, upland vegetation is comprised of iceplant (*Carpobrotus edulis*), Himalayan blackberry (*Rubus armeniacus*), sweet fennel, and Bermuda buttercup (*Oxalis pes-caprae*), and limited patches of coastal gumweed and alkali heath (*Frankenia salina*). Upland vegetation in the upper reach includes iceplant, Himalayan blackberry, sweet fennel, coastal gumweed, as well as a few eucalyptus and poplar trees.

Special-status terrestrial wildlife species commonly associated with tidal marsh habitat include the California Ridgway’s rail (*Rallus obsoletus; FE/SE*), salt-marsh wandering shrew (*Sorex vagrans halicoetes; state species of concern*), and the salt marsh harvest mouse (*Reithrodontomys raviventris; FE/SE*). Tidal salt marsh habitat also supports special-status plant species, such as California seablight (*Suaeda californica; FE*).

**Ridgway’s Rail.** There are three occurrences for Ridgway’s rail in the CNDDB, including two from 2006 that are within 0.5 mile of the study area, and that are located in small, isolated tidal salt marshes. In 2011, a Ridgway’s rail was detected during surveys conducted at Navigable Slough in support of the Invasive Spartina Project (ISP) (Olofson Environmental, 2012). Ridgeway’s rail was not detected in Navigable Slough in 2013 or 2014 (Olofson Environmental, 2014a). The ISP did not conduct Ridgway’s rail surveys in Navigable Slough in 2015 and 2016 (Olofson Environmental, 2015a; 2016), presumably because the Slough was treated for invasive cordgrass in 2014 and was reported in the same year to already have a >99% decline in invasive cordgrass since its peak in 2006 (Olofson Environmental, 2014b). Ridgeway’s rails are commonly associated with native (*Spartina foliosa*), non-native invasive and hybrid cordgrass (*S. foliosa* x *S. alterniflora*), which provide tall vegetative cover for nesting and at high tide (USFWS, 2013). Field surveys of Navigable Slough confirmed that there is minimal tall vegetative cover at Navigable Slough. Coastal gumplant is present in small patches along the lower, middle and upper reaches of the Slough, but not enough to provide cover or nesting habitat for rails. The ISP noted in 2014 that there was near eradication of invasive cordgrass in the Colma/San Bruno marshes (Olofson Environmental, 2015b). The removal of *Spartina* on the San Francisco Peninsula has likely reduced the number of Ridgway’s rail in the region and habitat enhancement efforts to increase their populations in the region have been limited. In 2011, a pilot project was launched to reintroduce the native cordgrass along Colma Creek and in San Bruno Marsh and, by 2014, showed some potential for creating Ridgway’s rail habitat. In addition, San Mateo County has planted native cordgrass along the upland transition zone within the Colma Creek Complex (Olofson, 2014b). In summary, Ridgway’s rail is not expected in Navigable Slough, but may be present in other areas of the Colma Creek-San Bruno Creek complex where suitable cover in the form of cordgrass or other tall vegetation is present.

**Salt marsh harvest mouse and salt marsh wandering shrew.** Preferred habitat for salt marsh harvest mouse includes the middle and upper elevations of dense, tidal salt marshes; they will move into adjacent grasslands in spring and summer when the grasslands provide maximum cover (Goals Project, 2000). They will also use similar habitat in diked wetlands adjacent to the Bay. Recent research has identified salt marsh harvest mouse in marshes dominated by alkali bulrush (*Schoenoplectus maritimus*) (Shellhammer, et al., 2010) and in mixed vegetation not dominated by pickleweed, including Baltic rush (*Juncus balticus*), prickly lettuce (*Lactuca serriola*), and sow thistle (*Sonchus asper*). The tidal salt marshes in the lower, middle and upper reaches of Navigable Slough provide suitable habitat for salt marsh harvest mouse. No CNDDB records exist for salt marsh harvest mouse within 3 miles of Navigable Slough; however, due to the presence of suitable habitat, salt marsh harvest mouse should be presumed to occur here unless presence/absence surveys are conducted to confirm otherwise.

Salt marsh wandering shrew is a California species of special concern. According to the *Life Histories and Environmental Requirements of Key Plants, Fish, and Wildlife* (Goals Project, 2000), this species appears to have some of the most restrictive food and habitat requirements of any mammal inhabiting the marshes of the greater San Francisco Bay Region, exceeding those of the salt marsh harvest mouse. Suitable habitat includes wet, medium high salt marshes in the 6- to 8-foot elevation zone characterized by abundant driftwood and other debris scattered among 1- to 2-foot high pickleweed (Collins, 1998). They are not thought to occur in diked marshes. The tidal salt marsh in Navigable Slough is approximately 5-7 feet above mean sea level (USGS, 2010) and contains pickleweed less than 1-foot high. The salt marsh wandering shrew is currently confined to small remnant stands of salt marsh found in South San Francisco Bay, specifically San Mateo, Santa Clara, Alameda and Contra Costa Counties. No CNDDB records exist for salt marsh wandering shrew within 3 miles of Navigable Slough, however, this species is not well studied and the marshes present in Navigable Slough have suitable pickleweed habitat for this species at an elevation believed to be utilized by salt marsh wandering shrew. This species has a moderate potential to occur here. Any measures taken to protect salt marsh harvest mouse would also protect the salt marsh wandering shrew.

**Special-status Fish Species.** San Francisco Bay supports several listed species of fish, including green sturgeon (*Acipenser medirostris*), which is federally threatened and a state species of concern, the federally threatened (*FT*) steelhead (Central California Coast DPS) (*Oncorhynchus mykiss iridius*), and longfin smelt (*Spirinchus thaleichthys*), a candidate for federal listing and a state threatened species. In addition, longfin smelt is documented to be in the Bay and to approximately the mouth of Navigable Slough, but not in the Slough itself. Longfin smelt are a pelagic species, that, with the exception of spawning events, tend to be confined to the open water habitat of the San Francisco Bay and Delta (Moyle, 2002). Green sturgeon are exceedingly rare within South San Francisco Bay, only venturing into South Bay waters when deviating from their migratory pathway between the Pacific Ocean and the upper reaches of the Sacramento River watershed. While Central California Coast (CCC) steelhead do spawn within South Bay tributaries, no present or historical spawning habitat exists within the vicinity of Navigable Slough. The nearest stream that is known to currently support CCC steelhead is San Mateo Creek, approximately 7 miles to the south (Leidy et al., 2005).

The current distribution and life history requirements of the three species above makes occurrence within Navigable Slough unlikely. Furthermore, the degradation of the available aquatic Slough habitat makes their presence especially improbable. While hydrologically connected to San Francisco Bay and subject to some amount of tidal flushing, the developed setting within which the Slough resides has resulted in significant amounts of garbage and urban runoff that empty into the Slough. Additionally, two culverts, beneath Highway 101 and South Airport Drive, may prevent fish from accessing upstream habitat at low tides. The poor quality of aquatic habitat within the Slough, coupled with the life history requirements of the special-status fish species that occur within the Bay, makes it unlikely that any protected fish species would be present within Navigable Slough.

**Additional Special-status Wildlife.** Additional listed and special-status species are documented in the CNDDB within 3 miles of the project area. Mission blue butterfly (*Icaricia icarioides missionensis; FE*), Bay checkerspot butterfly (*Euphydryas editha bayensis; FT*) and callippe silverspot butterfly (*Speyeria callippe; FE*) are documented only at San Bruno Mountain, approximately 2 miles from the project area, and they are not likely to be in the vicinity of the project area due to the lack of suitable host and nectaring plants. Similarly, California red-legged frog is documented within 3 miles of the project area, but is not expected due to the lack of freshwater habitat at the project site. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) is documented as a non-specific occurrence that covers the entire 3-mile study area around the project site. This species is present only in San Mateo County, including at San Francisco International Airport; utilizes a wide range of habitats, including sloughs; and feeds primarily on amphibians found in freshwater ponds (Stebbins and McGinnis, 2012). Due to the lack of freshwater habitat, there is a low potential for the San Francisco garter snake to occur in or around Navigable Slough. Alameda song sparrow (*Melospiza melodia pusillula*), American peregrine falcon (*Falco peregrinus*), and saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*) have also been documented within 3 miles of the project area. A large stand of sweet fennel in the uplands of the upper reach of Navigable Slough could provide nesting habitat for Alameda song sparrow and saltmarsh common yellowthroat. This upland vegetation, as well as trees, could provide nesting and foraging habitat to other birds protected by the Migratory Bird Treaty Act. There is no suitable nesting habitat for American peregrine falcon in the vicinity of the Slough. Peregrine falcons are aerial hunters that could enter the airspace over the Slough to prey on ducks, shorebirds and rock pigeons, but would not otherwise forage in the project area. Mallard ducks (*Anas platyrhynchos*) and Canada geese (*Branta canadensis*), both observed using Navigable Slough, could nest in the uplands around the Slough.

**Special-status Plants.** California seablight (*Suaeda californica*) is a perennial forb in the Chenopodiaceae family. This species is found in a narrow zone at the upper edge of tidal marshes. Habitat includes coarse marsh sediments or sheltered estuarine beaches (USFWS, 2013). Historically, California seablight occurred in high tidal marsh in parts of San Francisco Bay, where it was extirpated due to habitat loss. California seablight is now known only in a few reintroduced locations (Baye, 2006; USFWS 2013). The nearest of these, at Pier 98 in San Francisco, is over 6 miles from Navigable Slough, where it was reintroduced onto beach habitat. In the absence of beaches within the Navigable Slough study area, and without efforts to reintroduce it, the potential for this species to occur is very low.

Several federal or state listed plants are documented in the CNDDB within 3 miles of the project area, including Pacific manzanita (*Arctosaphylos pacifica*), San Bruno manzanita (*Arctostaphylos imbricata*), beach layia (*Layia camosa*), robust spineflower (*Chorizanthe robusta* var. *robusta*), two-fork clover (*Trifolium amoenum*) and white-rayed pentachaeta (*Pentachaeta bellidiflora*). None of these species are likely to be present at the project site due to a lack of suitable habitat.

Below, **Table 2** summarizes the potential for special-status wildlife and plants to occur on the proposed project site.

**Table 2. Summary of Special-status Species Constraints**

| **Species and Special-status Listing Status** | **Potential to Occur in Navigable Slough** | **Notes** |
|---|---|---|
| California Ridgeway's rail (FE/SE) | Not expected | May be present in other areas of the Colma Creek-San Bruno Creek complex where suitable cover in the form of cordgrass or other tall vegetation is present. |
| Salt marsh harvest mouse (FE/SE) | Moderate to High | No CNDDB records exist for salt marsh harvest mouse within 3 miles of Navigable Slough; however, due to the presence of suitable habitat, salt marsh harvest mouse should be presumed to occur here unless presence/absence surveys are conducted to confirm otherwise. |
| Salt marsh wandering shrew (SSC) | Moderate | No CNDDB records exist for salt marsh wandering shrew within 3 miles of Navigable Slough, however, this species is not well studied and the marshes present in Navigable Slough have suitable pickleweed habitat for this species at an elevation believed to be utilized by salt marsh wandering shrew. |
| Green sturgeon (FT/SSC); steelhead (FE); longfin smelt (FC/ ST/ SSC) | Not expected | Life histories of these species, combined with degradation of the available aquatic habitat in Navigable Slough makes their presence highly unlikely. Two culverts, beneath Highway 101 and South Airport Drive, may prevent fish from accessing upstream habitat in Navigable Slough at low tides. |
| San Francisco garter snake (FE/SE) | Low | Lack of freshwater habitat would probably preclude this species from Navigable Slough. |
| Alameda song sparrow (SSC); saltmarsh common yellowthroat (SSC) | Moderate (nesting and foraging) | Documented within 3 miles of the project area; some suitable nesting habitat (e.g., tall stands of sweet fennel) available in uplands. |
| American peregrine falcon (FP) | Not expected (nesting); Moderate (foraging) | No suitable nesting habitat in the vicinity of the Slough, but peregrine falcons are aerial hunters that could enter the airspace over the Slough to prey on ducks, shorebirds and rock pigeons, but would not otherwise forage in the project area. |

| Species and Special-status Listing Status | Potential to Occur in Navigable Slough | Notes |
|---|---|---|
| Mallard duck (MBTA); Canada goose (MBTA) | Moderate (nesting); High (foraging) | Observed using Navigable Slough during site visit. Limited upland habitat for nesting. |
| California seablight (FE/CRPR 1B.1) | Low | Historically, California seablight occurred in high tidal marsh in parts of San Francisco Bay, where it was extirpated due to habitat loss. The nearest of these, at Pier 98 in San Francisco, is over 6 miles from Navigable Slough, where it was reintroduced onto beach habitat. In the absence of beaches within the Navigable Slough study area, and without efforts to reintroduce it, the potential for this species to occur is very low. |
| Pacific manzanita (SE/CRPR 1B.1); San Bruno manzanita (SE/ CRPR 1B.1); beach layia (FE/SE/CRPR 1B.1); robust spineflower (FE/ CRPR 1B.1); two-fork clover (FE/ CRPR 1B.1); white-rayed pentachaeta (FE/ SE/ CRPR 1B.1) | Unlikely | Documented in the CNDDB within 3 miles of project area, but suitable habitat lacking. |

KEY:
Federal (U.S. Fish and Wildlife Service) Status:
FE = Listed as Endangered by the Federal Government
FT = Listed as Threatened by the Federal Government
FC = Federal Candidate for listing
State (California Department of Fish and Wildlife) Status:
SE = Listed as Endangered by the State of California
ST = Listed as Threatened by the State of California
FP = California Fully Protected species
SSC = California Species of Special Concern
Other Status:
MBTA = Protected by the Migratory Bird Treaty Act

California Rare Plant Ranks (CRPR):
List 1A = Plants presumed extant in California
List 1B = Plants rare, threatened, or endangered in California and elsewhere
List 2A = Plants presumed extirpated in California, but more common elsewhere
List 2B = Plants rare, threatened, or endangered in California, but more common elsewhere
An extension reflecting the level of threat to each species is appended to each rarity category as follows:
.1 – Seriously threatened in California
.2 – Fairly threatened in California
.3 – Not very threatened in California

### Environmental Constraints to Consider

Habitat changes, both temporary and permanent, and including any discharge of fill material into waters of the U.S. or of the State, or construction within San Francisco Bay Conservation and Development Commission (BCDC)'s 100-foot shoreline band jurisdiction, could trigger compensatory mitigation requirements from regulatory agencies. The proposed project will need to consider potential changes to tidal elevations and corresponding effects on existing tidal marsh habitat, aquatic species, and upland bird nesting habitat throughout Navigable Slough, and potentially downstream.

There may be an opportunity to enhance existing habitat within the Slough by planting native species and removing non-native, invasive species in the channel.

Because salt marsh wandering shrew and salt marsh harvest mouse habitat is present at Navigable Slough, presence of these species can be assumed or protocol-level surveys can be conducted to determine presence/absence. We recommend determining presence or absence of the species because this documentation may influence the project design and permitting/mitigation strategy. Additionally, a botanical survey following the CDFW *Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities* (CDFW, 2009) is recommended to determine presence of rare plants in the marshes within Navigable Slough, such as California seablight.

Due to the likelihood of in-water work and the potential for affecting waters of the U.S., a jurisdictional delineation of wetlands and waters is recommended early in the project development process. This effort would identify and quantify the extent of jurisdictional features at the project site.

## *Cultural Resources*

ESA reviewed existing background materials related to cultural resources in the vicinity of the Navigable Slough Area of Potential Effects (APE), including the Draft CEQA document for the Colma Creek Flood Control Maintenance Project and the supporting cultural resources study (Basin, 2015), and the CEQA document for the South San Francisco / San Bruno Water Quality Control Plant Capital Improvement Project and the supporting cultural resources study (Koenig, 2014). Based on this review, there are no previously recorded cultural resources (including architectural and archaeological resources) in the approximately 3,000-foot-long Navigable Slough APE, from the mouth at Colma Creek to the western upstream end of the slough.

In 2015, Basin Research Associates (Basin) completed background research and an assessment of cultural resources for the adjacent Colma Creek Flood Control Maintenance Project, which included the downstream 850 feet (260 meters) of Navigable Slough (Basin, 2015). Background research included a records search at the Northwest Information Center (NWIC) of the California Historical Resources Information System (File Nos. 14-0524 and 14-0813) and a review of reference material from the Bancroft Library, University of California at Berkeley and Basin Research Associates, San Leandro. Basin also contacted the Native American Heritage Commission and several Native American tribes/individuals with an interest in the project vicinity. The intent of the research was to identify historic properties (prehistoric and historic-era resources) that may be listed, determined, or potentially eligible for inclusion on the National Register of Historic Places (National Register) and the California Register of Historical Resources (California Register) and that could be affected by the Colma Creek Flood Control Maintenance Project. The background research included the Colma Creek Flood Control Maintenance Project area and a ¼-mile radius (which includes the Navigable Slough APE).

Based on the results of this research (as of January 2015) no cultural resources had been previously recorded in the Navigable Slough APE. The nearest recorded resource is CA-SMA-380 (P-41-002164). The site is "... an apparent prehistoric shell midden" mapped south of Littlefield Avenue between the railroad tracks and the north side of Colma Creek. Evidence of the site was noted in three of eleven 2-inch diameter GeoProbe samples at a depth of approximately 16.5 to 21 feet (5.2 to 8.9 m) below both historic and natural fill. The discontinuous cultural layers included species characteristic of different habitats (rocky tidal zones, tidal and subtidal zones, and muddy or sandy beaches and flats) - Bay Mussel (*Mytilus trossulus*), California Oyster (*Ostrea lurida*), Macoma clam (*Macoma nasuta* and/or *M. secta*), boring clams, and a piece of Gaper clam (*Tresus nuttali*). Several "tiny" fish bones (some burnt), crab claws, and two "tiny" obsidian flakes, a possible chert flake, fire-cracked rock, and gravels were noted (Clark, 2006 with Clark 2006/form). The site is approximately 1,000 feet (320 meters) from the Navigable Slough APE.

For the Colma Creek Flood Control Maintenance Project, Basin concluded that:

> …the archival and literature record and focused subsurface archaeological testing within and adjacent to the [Colma] creek alignment suggests a moderate to high potential for exposing significant subsurface archaeological resources with integrity adjacent to the stream channel at depths greater than 1.5 to 5.0 meters below the present grade. This observation is based on data from two buried prehistoric sites in [Colma Creek] Reaches 1 and 3 discovered during subsurface coring.[1] It is probable that these former surface resources were buried by overbank flooding prior to the channelization of the creek for flood control. No surface indications of archaeological resources have been noted over the past 25 years during numerous construction projects [Basin, 2016:19].

Basin did not recommend any additional subsurface testing or the development of a formal *Post-Review Discovery Plan* due to the low potential for exposing significant archaeological materials. This conclusion was based in part on the proposed minimal ground disturbing maintenance activities for the Colma Creek Flood Control Maintenance Project. Maintenance activities included sediment removal; repair of blocked culverts; bank repair; debris and trash removal; vegetation management; and maintenance of trash capture devices; all activities with a low potential to excavate into native soils beneath artificial fill.

On December 13, 2017 an ESA archaeologist conducted an archaeological pedestrian survey of areas along the banks of Navigable Slough in South San Francisco. Ground visibility was limited to approximately 10% due to dense vegetation along the slough banks. Certain sections of bank were inaccessible due to heavy vegetation. The ground in the accessible areas appeared very disturbed by modern activity, and a great deal of modern trash was present throughout. Soil was a compact light brown sandy silt (modern fill) and medium compact dark brown silt (marsh deposits). No historical or prehistoric materials or sites were encountered during the survey.

### Environmental Constraints to Consider

Based on the results of this research (as of January 2015) no cultural resources had been previously recorded in the Navigable Slough APE. However, any ground disturbing activities proposed on the channel banks would impact archaeological resources should they exist.

[1] Site CA-SMA-355 is a prehistoric site identified on the bank of Colma Creek buried under 1.5 to 7.3 meters of natural and artificial overburden. The site is approximately 1.5 miles northwest of the Navigable Slough APE.

Several Native American tribes have an interest in the general project vicinity and would need to be consulted (per the requirements of Public Resources Code Section 21080.3.1 and Section 106 of the National Historic Preservation Act).

To further ascertain the potential for a future project on Navigable Slough to impact buried archaeological resources, ESA has completed an updated records search at the NWIC and a surface survey of the Navigable Slough APE. There are no changes to the baseline conditions concluded by Basin in 2015 (i.e. no known cultural resources are in the Navigable Slough APE). Given the moderate to high archaeological sensitivity of the Navigable Slough APE, ESA recommends conducting an additional assessment that considers the depth of ground disturbing activities associated with the proposed project. If feasible, geotechnical borings within the Navigable Slough APE would further determine whether subsurface buried archaeological resources exist in the APE that would be potentially impacted by the project. ESA would also update and revise the Native American consultation for the project (per the requirements of Public Resources Code Section 21080.3.1 and Section 106 of the National Historic Preservation Act).

## References

*Note: Numbers in parenthesis correspond to list of existing flood studies reviewed in the first section of this memo.*

Baye, Peter R., 2006. *California Seablite* (Suaeda californica) *Reintroduction Plan, San Francisco Bay, California*. Prepared for U.S. Fish and Wildlife Service, August 2006.

California Department of Fish and Wildlife (CDFW), 2009. *Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities*, State of California, California Natural Resources Agency, November 24, 2009.

CDFW, California Natural Diversity Database RareFind 5 data download within 3 miles of Navigable Slough. Accessed November 2017.

Collins, P.W., 1998. *Salt marsh wandering shrew*, (Sorex vagrans halicoetes), in *Terrestrial Mammal Species of Special Concern in California (Draft)*, Bolster, B.C., ed., California Department of Fish and Wildlife. available online at: file:///C:/Users/elw/Downloads/MSSC_05%20(1).pdf

(1) Federal Emergency Management Agency (FEMA). 2017. San Mateo County Flood Insurance Study. FIS Number 06081CV001C.

Goals Project, 2000. *Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish and wildlife*. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. P.R. Olofson, editor. San Francisco Bay Regional Water Quality Control Board, Oakland, Calif.

Leidy, R.A., G.S. Becker, B.N. Harvey, 2005. Historical distribution and current status of steelhead/rainbow trout (*Oncorhynchus mykiss*) in streams of the San Francisco Estuary, California. Center for Ecosystem Management and Restoration, Oakland, CA.

(4) Michael Baker International. 2016. South San Francisco Storm Drain Master Plan. Prepared for City of South San Francisco.

(2) Moffatt & Nichol and AGS. 2015. San Bruno Creek / Colma Creek Resiliency Study. Prepared for San Francisco International Airport and the California Coastal Conservancy.

(5) Moffat & Nichol. 2016. San Bruno Tidegates Certification Feasibility. Prepared for County of San Mateo, Department of Public Works.

Moyle, P.B., 2002. Inland Fishes of California. University of California Press, Berkeley, California.

National Research Council. 2012. Sea Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.

Olofson Environmental, Inc., 2012. California Ridgway's Rail Surveys for the San Francisco Estuary Invasive *Spartina* Project 2012. Prepared for the State Coastal Conservancy, November 2016.

Olofson Environmental, Inc., 2014. California Ridgway's Rail Surveys for the San Francisco Estuary Invasive *Spartina* Project 2014. Prepared for the State Coastal Conservancy, October 2014.

Olofson Environmental, Inc., 2015a California Ridgway's Rail Surveys for the San Francisco Estuary Invasive *Spartina* Project 2015. Prepared for the State Coastal Conservancy, September 2015.

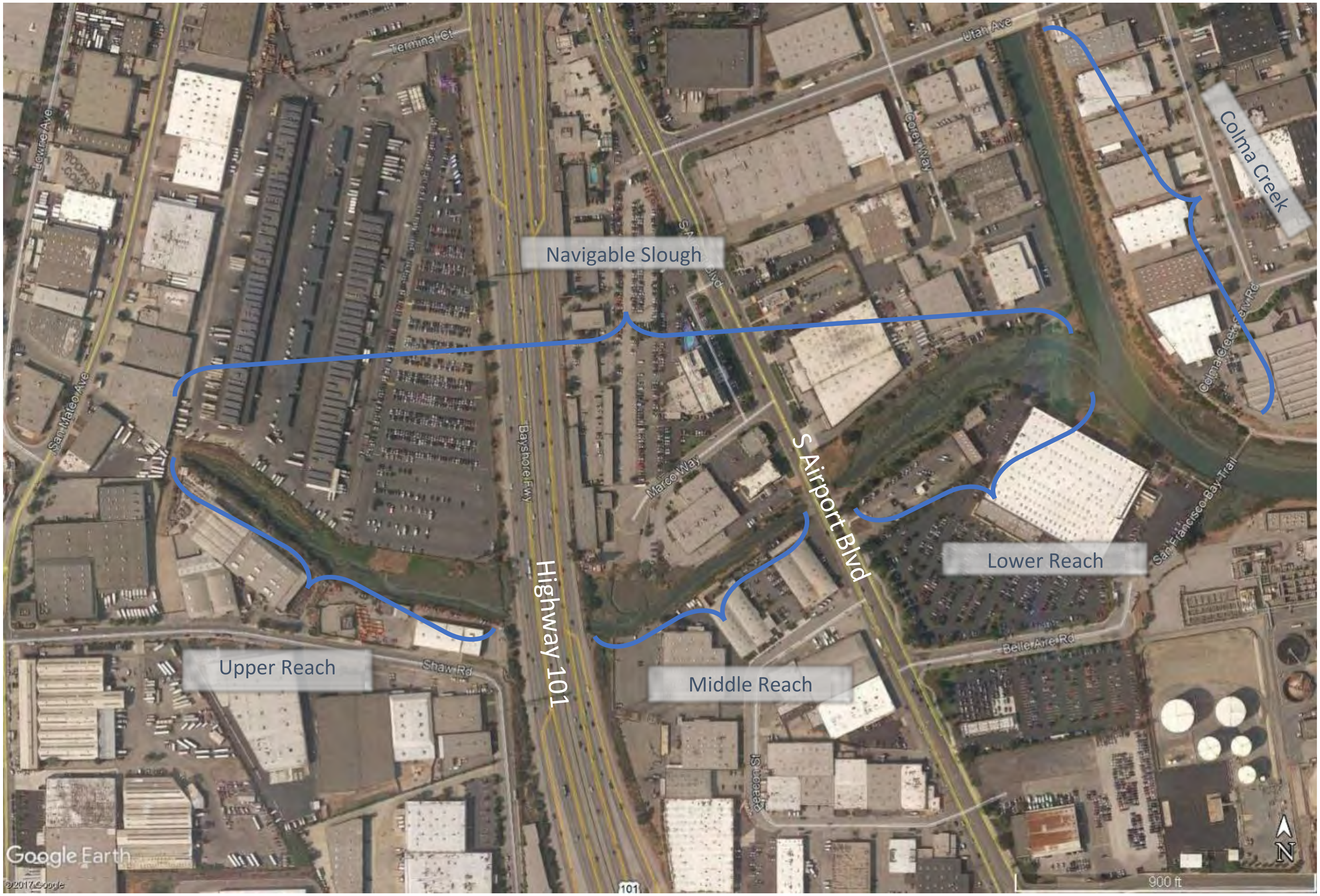
Olofson Environmental, Inc., 2015b. San Francisco Estuary Invasive *Spartina* Project: 2014 ISP Monitoring and Treatment Period, Prepared for the State Coastal Conservancy, August 2015.

Olofson Environmental, Inc., 2016. California Ridgway's Rail Surveys for the San Francisco Estuary Invasive *Spartina* Project 2016. Prepared for the State Coastal Conservancy, November 2016.

U. S. Coast Survey. 1867. Map Showing the Approaches to San Francisco California. T-Sheet 1067.

U.S. Fish and Wildlife Service., 2013. Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California. Sacramento, California. xviii+ 605 pp. August 2013. Available at: http://www.fws.gov/sacramento/es/Recovery-Planning/Tidal- Marsh/Documents/TMRP_Volume1_RP.pdf

(3) WRECO. 2017. Colma Creek Flood Control Channel Improvement Project – Utah Avenue to Navigable Slough. Prepared for the County of San Mateo. Draft, July 2017.



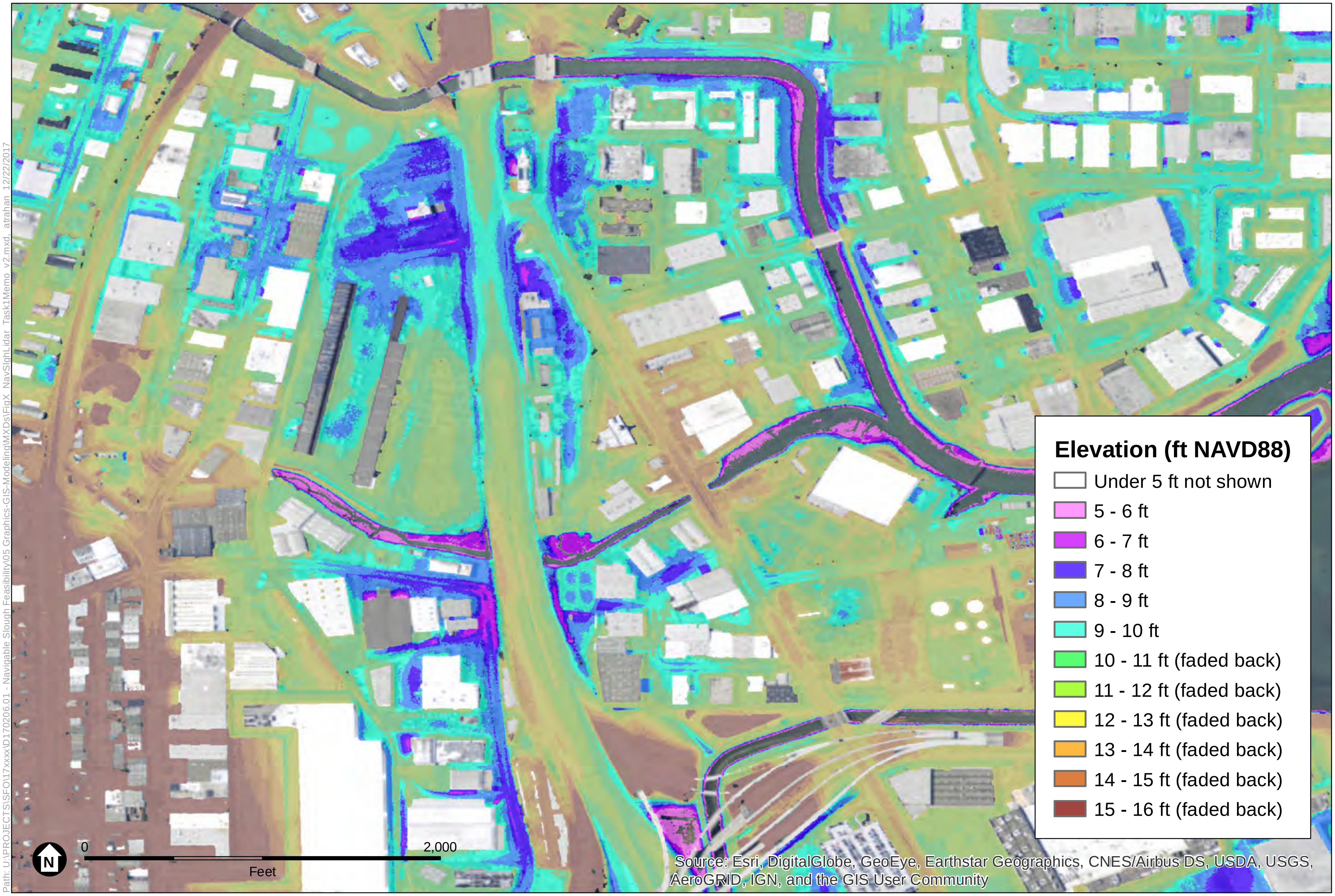

SOURCE: Basemap, ESRI 2017

Navigable Slough Feasibility Study

**Figure 1**

Navigable Slough Reaches

Path: U:\PROJECTS\SFO\17xxxx\D170206.01 - Navigable Slough Feasibility\05 Graphics-GIS-Modeling\MXDs\FigX_NavSlghLidar_Task1Memo_v2.mxd, atrahan 12/22/2017



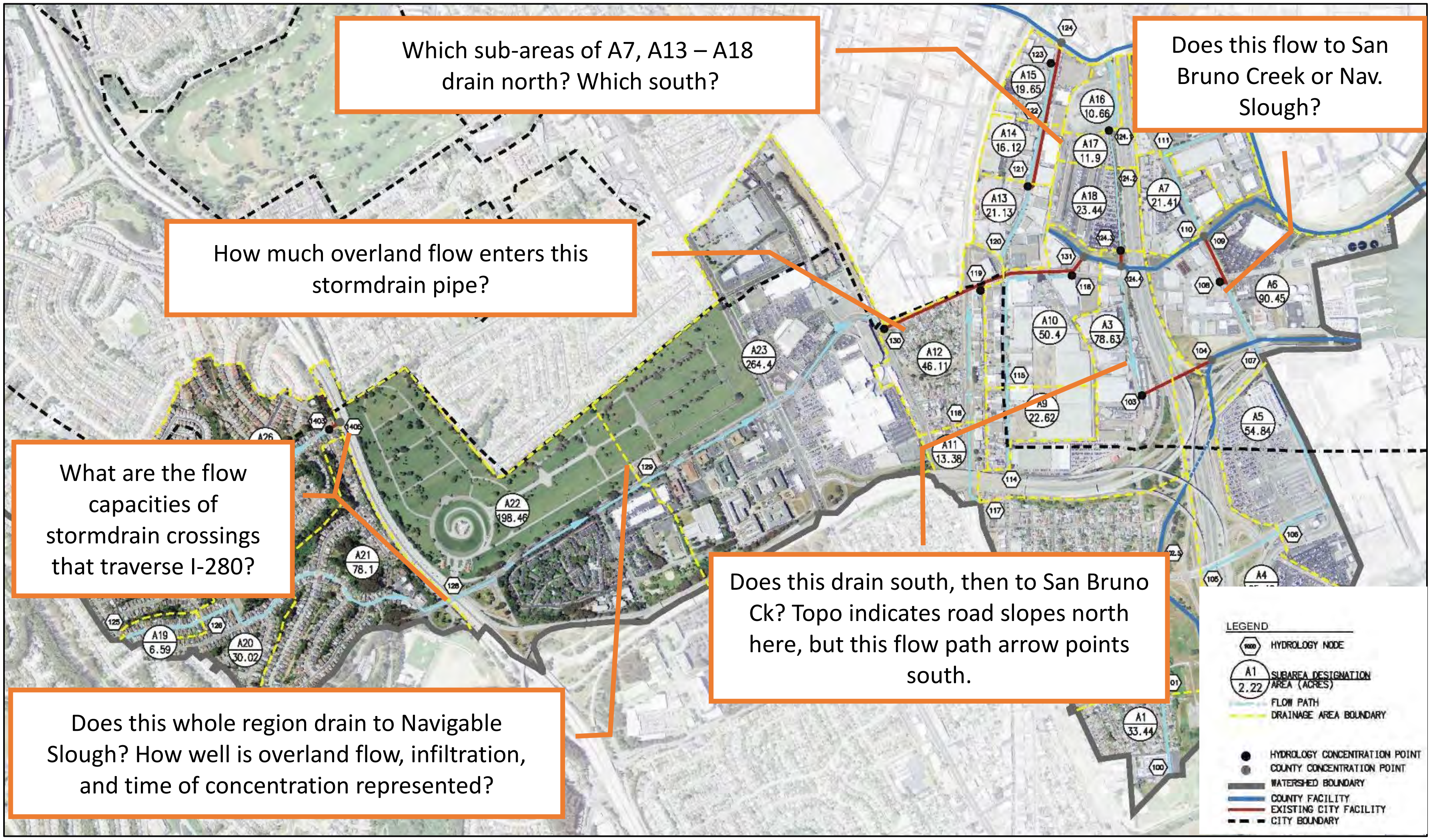

SOURCE: Basemap, ESRI 2017; LiDAR, USGS 2011

Navigable Slough Feasibility Study

**Figure 2**

Topography near Navigable Slough

ESA



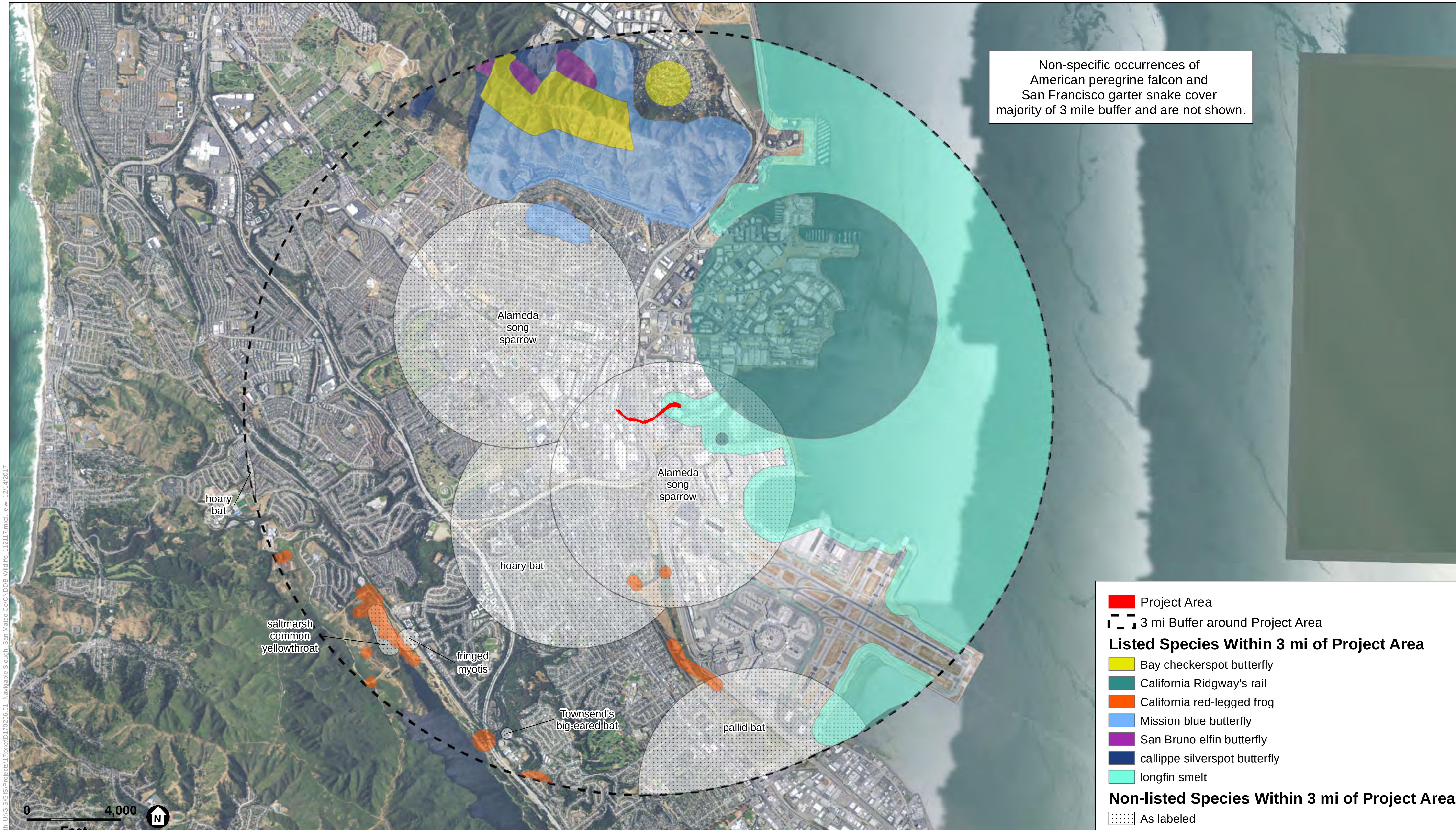

SOURCE: Michael Baker International 2016

Navigable Slough Feasibility Study

**Figure 3**

Stormdrain System Questions

Annotations on SSF SDMP “Subwatershed A Hydrology Map”



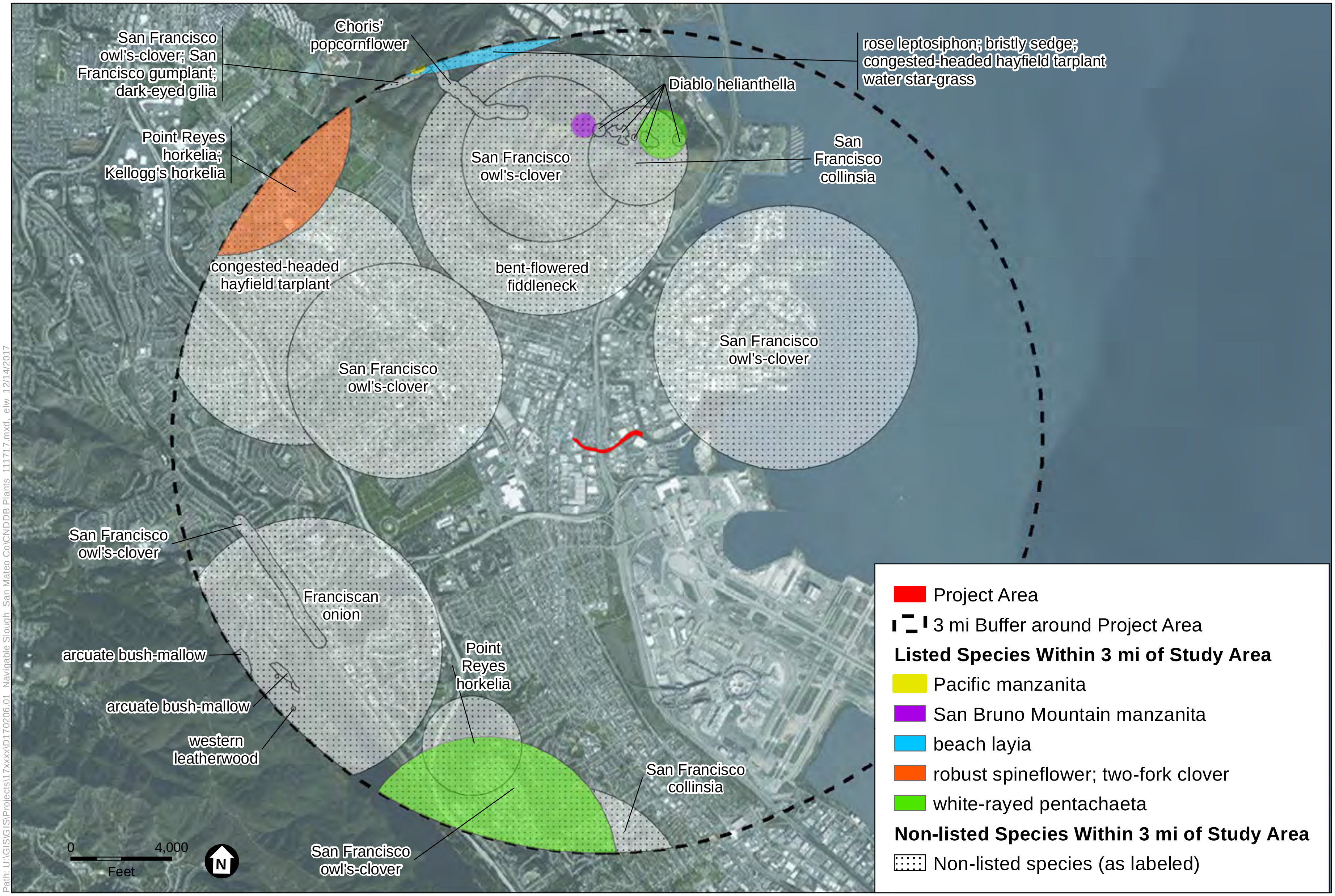

SOURCE: ESRI, 2017; ESA, 2017; CDFW, 2017

ESA

Navigable Slough Feasibility Study

**Figure 4**

Special-status Wildlife Within 3 Miles of Project Area




SOURCE: ESRI, 2017; ESA, 2017; CDFW, 2017; CNPS, 2017

Navigable Slough Feasibility Study

**Figure 5**

Special-status Plants Within 3 Miles of Project Area

ESA

# Navigable Slough Evaluation for Salt Marsh Harvest Mouse Habitat

Performed by: Joseph DiDonato, Wildlife Biologist
Wildlife Consulting & Photography
2624 Eagle Avenue
Alameda, CA 94501

Date of Survey: July 2, 2018

## Site description:

Navigable Slough is a tidally-influenced channel flowing into Colma Creek in San Mateo County, CA, north of the San Francisco International Airport. The general vicinity is highly developed and very industrialized. The slough runs east-west and crosses under Highway 101 and South Airport Boulevard through culverted structures. The slough is bordered by varied earthen habitat on its northern and southern banks and includes vegetated areas of pickleweed (*Salicornia virginica*) and marsh gumplant (*Grindelia stricta* var. *angustifolia*) as well as several other non-wetland plant species. These include various non-native annual grasses, coyote brush (*Baccharis pilularis*), fennel (*Foeniculum vulgare),* and a host of planted or ruderal non-native plant species. Scattered throughout the site are small patches of Atriplex spp., alkali heath (*Frankenia salina*), marsh jaumea (*Jaumea carnosa*), marsh rosemary (*Limonium californicum*) and Algerian sealavender (*Limonium ramosissimum*). The areas that constitute the habitat above the mean high water level are densely vegetated (overgrown) and often contain extensive amounts of litter and garbage. Several areas of the slough contain debris including shopping carts, broken cement and other man-made waste. Areas of hardscape along the slough include cement and asphalt borders, industrial lots with cement walls and fences, and at least three transmission line structures.

Several areas along the slough have expansive marsh plains covered in dense pickleweed and range in size from approximately 0.1 to 0.65 acres. At least three areas include larger (0.44 – 0.65 acre) sections covered in pickleweed. These include the mouth of Navigable Slough at Colma Creek and the marsh plain immediately east and west of Highway 101. The habitat at these locations consists of dense pickleweed, ranging in height from 30 to 48 cm.

## Potential Salt Marsh Harvest Mouse Habitat:

The salt marsh harvest mouse (SMHM; *Reithrodontomys raviventris*) is protected as a federal and state endangered species and is also a state “Fully Protected” species. The latter designation offers no legal avenue to allow for the take of the species except for research and recovery purposes. SMHM occur only within the San Francisco and San Pablo Bays within tidal and non-tidal wetland habitat along the Bay’s edge. The vegetated habitat within which SMHM are most closely associated and that serves as their primary core habitat is pickleweed marsh. The height and density of pickleweed which SMHM occupies varies by site. For example, pickleweed height at Montezuma Wetlands in Solano County averages 35-40 cm and SMHM have been successfully trapped at that site for greater than 10 years (DiDonato, 2017). SMHM seek both refuge within this habitat and feed on the seeds of this and other marsh plants. SMHM have adapted to daily tidal inundation and during periods of extreme high tides will utilize upland habitat as refuge from flooding.

The California Natural Diversity Database (CNDDB), a state maintained database of listed species, does not show any records of SMHM in Navigable Slough. This is likely because no trapping has been conducted at the site and no reports have been submitted to the state. No other records of SMHM at this site have been discovered.

I visited the project area of the Navigable Slough on July 2, 2018, accompanied by ESA Wildlife Biologist, Erika Walther, to evaluate the habitat for the potential to support SMHM. During the course of the evaluation, I collected photographs and notes at the site which included a description of the habitat, a list of existing dominant plants, and the existing conditions at the site. I walked the entirety of the slough from Colma Creek on its eastern terminus to the western end where the "natural" slough becomes culverted just before San Mateo Avenue. At that point the slough is no longer daylighted.

## Conclusion:

At least three areas along Navigable Slough have relatively large marsh plains covered in dense pickleweed ranging in height from 30-48 cm. These include the mouth of Navigable Slough at Colma Creek (Figure 1, plates 1and 2), the area immediately east of Highway 101 (Figure 2, plates 1and 2) and the area immediately west of Highway 101 (Figure 3, plates 1 and 2). These three areas have the potential to support SMHM strictly based on the vegetative makeup, their location within the tidal elevation, and their continued existence as a natural marsh plain within the San Francisco Bay. These areas are connected by fringe marsh habitat along both sides of the channel.

Due to the species' status as a state Fully Protected species, the California Department of Fish and Wildlife does not allow for a presence/absence survey to determine whether or not the site is unoccupied; and the U.S. Fish and Wildlife Service (USFWS) is supporting this approach. For purposes of formal agency consultation, the USFWS is expected to assume the presence of SMHM at Navigable Slough based on the presence of suitable habitat and site location within the mouse's historic range on the San Francisco Peninsula.

## References:

DiDonato, J.E. 2017. *Montezuma Wetlands Project, Phases II, III, and IV, Salt Marsh Harvest Mouse Trapping, 2017.* MWLLC.


Note: extensive areas of pickleweed on marsh plain, bordered by upland habitat (red arrow)

**Figure 1**
Navigable Slough at Colma Creek


**Plate 1:** Marsh Plain at Colma Creek (looking north)


**Plate 2:** Marsh plain at Colma Creek (looking northeast)


Note: extensive areas of pickleweed on marsh plain, bordered by upland habitat (red arrow)

**Figure 2**
Navigable Slough at Highway 101 (East side of 101)


**Plate 1:** Marsh plain east of Highway 101 (looking west)


**Plate 2:** Marsh plain east of Highway 101 (looking northeast)


Note: extensive areas of pickleweed on marsh plain, bordered by upland habitat (red arrows)

**Figure 3**
Navigable Slough at Highway 101 (West side of 101)


**Plate 1:** Marsh plain west of Highway 101 (looking east)


**Plate 2:** Marsh plain west of Highway 101 (looking west)

# Appendix D
## Cost Estimates

**Measure 1 - Storm Drain Flap Gates**

**Construction Costs**

| Line # | Item | Quantity | Unit | Unit Cost | Cost |
|---|---|---|---|---|---|
| 1 | Undergroun pipeline inspection | 1 | LS | $5,000 | $5,000 |
| 2 | Retrofit storm drain | 3 | EA | $6,000 | $18,000 |
| Contingency | | | | 30% | $5,400 |
| **Subtotal: Construction** | | | | | $28,400 |

**Other Costs**

| | | |
|---|---|---|
| Design | 20% | $5,680 |
| Environmental Compliance & Permitting | 20% | $5,680 |
| Project Management | 2% | $568 |
| Construction Admin/Inspection | 2% | $568 |
| Project Contingency | 10% | $2,840 |

| | |
|---|---|
| **Total cost** | **$45,000** |

* In 2018 dollars, for planning purposes only. Estimates include contingency, design, and environmental compliance, but do not include environmental mitigation or right-of-way costs. The estimates' anticipated accuracy range is +50%/-30%.

**Measure 2: Floodwall Barriers**

Option A

**Construction Costs**

| Line # | Quantity | Length (FT) | Unit | Unit Cost | Cost |
|---|---|---|---|---|---|
| 1 | Steel sheet pile floodwall | 400 | LF | $2,000 | $800,000 |
| Contingency | | | | 30% | $240,000 |
| **Subtotal: Construction** | | | | | $1,040,000 |

**Other Costs**

| | | | |
|---|---|---|---|
| Design | | 20% | $208,000 |
| Environmental Compliance & Permitting | | 20% | $208,000 |
| Project Management | | 2% | $20,800 |
| Construction Admin/Inspection | | 2% | $20,800 |
| Project Contingency | | 10% | $104,000 |

| | |
|---|---|
| **Total cost** | **$1,600,000** |

Option B

**Construction Costs**

| Line # | Quantity | Length (FT) | Unit | Unit Cost | Cost |
|---|---|---|---|---|---|
| 1 | Steel sheet pile floodwall | 1000 | LF | $2,000 | $2,000,000 |
| Contingency | | | | 30% | $600,000 |
| **Subtotal: Construction** | | | | | $2,600,000 |

**Other Costs**

| | | | |
|---|---|---|---|
| Design | | 20% | $520,000 |
| Environmental Compliance & Permitting | | 20% | $520,000 |
| Project Management | | 2% | $52,000 |
| Construction Admin/Inspection | | 2% | $52,000 |
| Project Contingency | | 10% | $260,000 |

| | |
|---|---|
| **Total cost** | **$4,000,000** |

Option C

**Construction Costs**

| Line # | Quantity | Length (FT) | Unit | Unit Cost | Cost |
|---|---|---|---|---|---|
| 1 | Steel sheet pile floodwall | 4000 | LF | $2,000 | $8,000,000 |
| Contingency | | | | 30% | $2,400,000 |
| **Subtotal: Construction** | | | | | $10,400,000 |

**Other Costs**

| | | | |
|---|---|---|---|
| Design | | 20% | $2,080,000 |
| Environmental Compliance & Permitting | | 20% | $2,080,000 |
| Project Management | | 2% | $208,000 |
| Construction Admin/Inspection | | 2% | $208,000 |
| Project Contingency | | 10% | $1,040,000 |

| | |
|---|---|
| **Total cost** | **$16,000,000** |

* In 2018 dollars, for planning purposes only. Estimates include contingency, design, and environmental compliance, but do not include environmental mitigation or right-of-way costs. The estimates' anticipated accuracy range is +50%/-30%.

**Measure 3: Self-Regulating Tide Gate & Pump Station**

**Construction Costs**

| Line # | Item | Quantity | Unit | Unit Cost | Cost |
|---|---|---|---|---|---|
| 1 | Supply SRT | 1 | LS | $150,000 | $150,000 |
| 2 | Installl SRT | 1 | LS | $30,000 | $30,000 |
| 3 | Pump station - 200 cfs / 180k gpm | 1 | LS | $9,415,000 | $9,415,000 |
| Contingency | | | | 30% | $2,878,500 |
| **Subtotal: Construction** | | | | | $12,473,500 |

**Other Costs**

| | | |
|---|---|---|
| Design | 20% | $2,494,700 |
| Environmental Compliance & Permitting | 20% | $2,494,700 |
| Project Management | 2% | $249,470 |
| Construction Admin/Inspection | 2% | $249,470 |
| Project Contingency | 10% | $1,247,350 |

| | |
|---|---|
| **Total cost** | **$19,200,000** |

* In 2018 dollars, for planning purposes only. Estimates include contingency, design, and environmental compliance, but do not include environmental mitigation or right-of-way costs. The estimates' anticipated accuracy range is +50%/-30%.

## Measure 4: Habitat and Recreation Shoreline Enhancements

**Construction Costs**

| Line # | Item | Length (FT) | Width (FT) | Depth (FT) | Quantity | Unit | Unit Cost | Cost |
|---|---|---|---|---|---|---|---|---|
| 1 | Mob/de-mob | | | | 1 | LS | $10,000 | $10,000 |
| 2 | Water management | | | | 1 | LS | $15,000 | $15,000 |
| 3 | Clearing & grubbing | | | | 1.27 | AC | $10,000 | $12,700 |
| 4 | Earthwork & grading | | | | 3,000 | CY | $25 | $75,000 |
| 5 | Re-vegetation | | | | 1.27 | AC | $25,000 | $31,750 |
| 6 | Fill to raise trail | 1000 | 15 | 4 | 2,200 | CY | $50 | $110,000 |
| 7 | Re-pave trail | 1000 | 10 | | 10,000 | SF | $2 | $20,000 |
| 8 | Re-plant next to trail | 1000 | 5 | | 0.11 | AC | $25,000 | $2,870 |
| 9 | Drainage, signage, etc. | | | | | | 10% | $27,731.96 |
| Contingency | | | | | | | 30% | $83,195.88 |
| **Subtotal: Construction** | | | | | | | | $388,247 |

**Other Costs**

| | | |
|---|---|---|
| Design | 20% | $77,649 |
| Environmental Compliance & Permitting | 20% | $77,649 |
| Project Management | 2% | $7,765 |
| Construction Admin/Inspection | 2% | $7,765 |
| Project Contingency | 10% | $38,825 |

| | |
|---|---|
| **Total cost** | **$600,000** |

* In 2018 dollars, for planning purposes only. Estimates include contingency, design, and environmental compliance, but do not include environmental mitigation or right-of-way costs. The estimates' anticipated accuracy range is +50%/-30%.