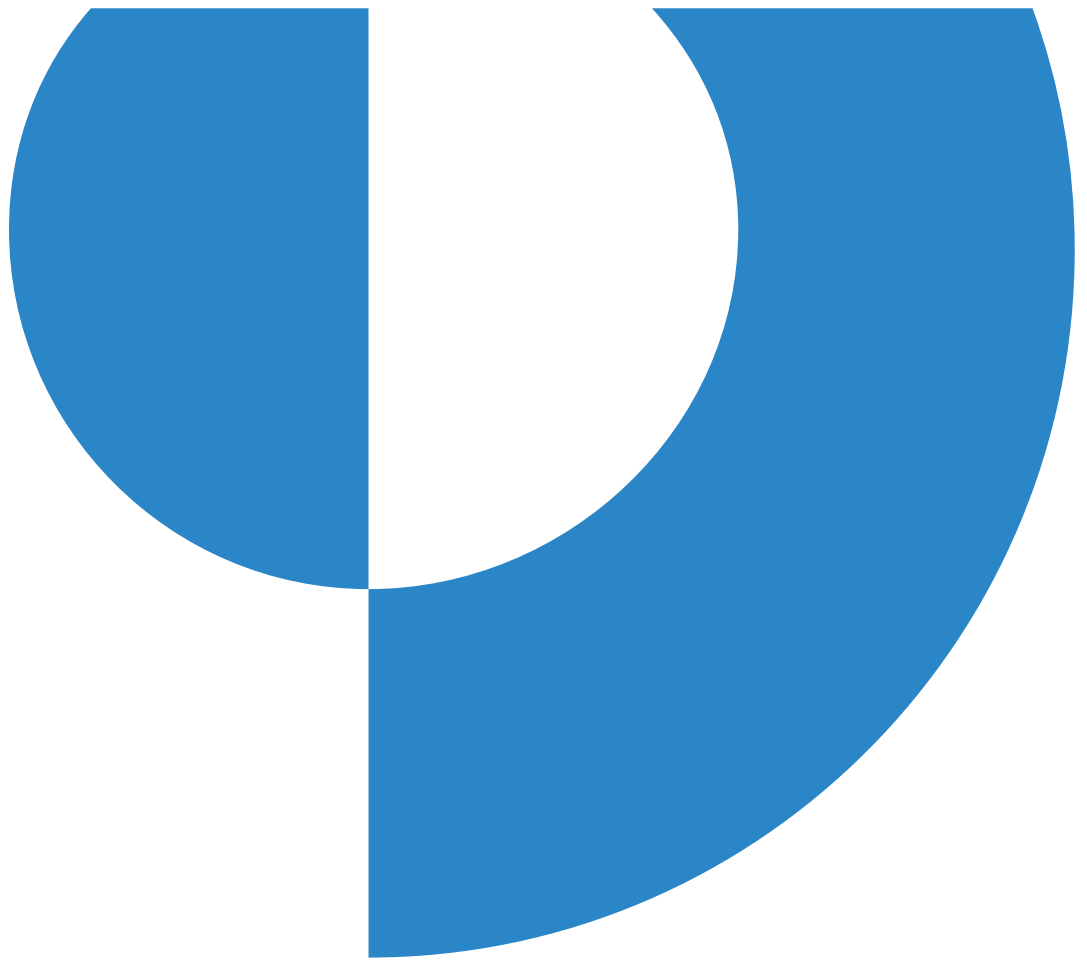


APPENDIX E HYDRODYNAMIC ANALYSIS



Oakland Harbor Turning Basins Widening Project

Hydrodynamic Impact Analysis

June 7, 2023

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Mott MacDonald
155 Montgomery Street
Suite 1400
San Francisco
CA 94104
United States of America

T +1 (415) 968 3495
mottmac.com

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Executive Summary

Mott MacDonald evaluated the potential changes in local water movements (hydrodynamics) from the proposed widening of the Inner Harbor Turning Basin (IHTB) and Outer Harbor Turning Basin (OHTB) at the Oakland Seaport (Seaport) to accommodate efficient movement of larger container vessels. This analysis was performed to support the Port of Oakland during the California Environmental Quality Act (CEQA) compliance process. The analysis focused on changes in hydrodynamics and flushing of adjacent areas caused by the widened turning basin dimensions and did not include assessment of construction-phase impacts.

A San Francisco Bay-wide hydrodynamic model was developed and validated using currents and water levels measured in the Seaport area. An Existing Conditions numerical model was developed using recent hydrographic survey data, and a Proposed Project model was developed based on Proposed Project design details provided by the US Army Corps of Engineers, San Francisco District.

Bay-wide hydrodynamics were simulated for a 4-month period for both Existing Conditions and the Proposed Project. Spatial patterns of velocity differences caused by the Proposed Project were evaluated during peak ebb (outflowing tide) and peak flood (inflowing tide) currents, and statistical differences were evaluated over the full simulation periods at select locations near the turning basins. In addition, a flushing (water exchange and circulation) assessment was performed by inserting a conservative tracer (dye which does not decay over time) into backwater areas of the Inner Harbor and Outer Harbor, in both the Existing Conditions and Proposed Project models, to evaluate whether the turning basin expansions could affect the rate of flushing (water exchange) in adjacent areas.

Modeling results show that widening of the turning basins causes minor changes in current speeds (mix of increases and decreases) in the immediate vicinity of the turning basins with negligible differences at distances greater than one turning basin diameter away (1,800 to 2,000 feet). Flushing analysis results indicate negligible change in flushing times within backwater areas of the Inner Harbor (east of the IHTB), and a slight reduction in flushing time in the northeast corner of the Outer Harbor.

In one sensitivity test, turning basin widening impacts were also evaluated in a simulation period with higher Delta outflows to the Bay (different than the base simulation period), and results were found to be consistent with results from the base period simulation. In another sensitivity test, potential turning basin widening hydrodynamic impacts were evaluated with an assumed sea level rise of 7.5 feet incorporated into the base period simulation. Results indicate that potential hydrodynamic and flushing impacts from turning basin widening during future conditions with 7.5 feet of sea level rise are consistent with those for present-day sea level conditions.

1 Introduction

1.1 Background

Mott MacDonald evaluated potential hydrodynamic impacts of the proposed widening of the turning basins at the Seaport to accommodate efficient movement of larger container vessels. Analysis was performed as a subconsultant to AECOM for the Port of Oakland in support of the CEQA compliance process. Figure 1 shows the Seaport's existing configuration, including turning basins and navigable waterways which are presently maintained to a depth of 50 feet (mean lower low water [MLLW]).

1.2 Proposed Project

Figure 2 shows the Proposed Project design. The Proposed Project would increase the width of the OHTB from 1,650 to 1,965 feet at its present depth of 50 feet (MLLW), dredged with 3H:1V (three horizontal to one vertical) side slopes. The Proposed Project would increase the width of the IHTB from 1,500 to 1,834 feet at its present depth of 50 feet (MLLW). In the northeast and southeast areas of the IHTB (Howard Terminal and the Alameda shoreline, respectively), the dredged side slope of 1.5H:1V terminates at a sheetpile wall in 22 feet (MLLW) of water depth. In the northwest area of the widened IHTB (near Schnitzer) the IHTB terminates at a submerged sheetpile wall (structure top at the mudline) to be installed at an existing seabed elevation of approximately -10 feet (MLLW). Existing and Proposed Project turning basin elevation models (water depths) are shown in Figure 3.

1.3 Methodology

Potential changes in hydrodynamics caused by the Proposed Project were evaluated using numerical modeling. The Mike21 FM model (DHI 2023) was utilized in two-dimensional mode to simulate hydrodynamics within San Francisco Bay and at the Proposed Project site. Mike21 FM was chosen due to its capability to simulate flows accurately in San Francisco Bay. The model was implemented using an unstructured mesh (grid with variable triangle sizes upon which calculations are made) which allows for efficient and accurate shoreline delineation as well as localized increases in resolution in important areas. Impacts potentially caused by the Proposed Project were evaluated in terms of changes in peak ebb and flood current velocities¹, changes in long-term hydrodynamics at locations adjacent to the basins, changes in discharge through each waterway, and changes in flushing time in areas behind the turning basins. Results are presented in the form of maps, time histories, and statistics.

2 Numerical Modeling

2.1 Model Setup

The hydrodynamic modeling domain included the entire San Francisco Bay from approximately 40 miles offshore in the Pacific Ocean, upstream to the Sacramento and San Joaquin Rivers. Figure 4 shows a close-up of the modeling grid at the Proposed Project site. The modeling grid

¹ All references to current speeds or velocities in this report refer to *depth-averaged* current speeds or velocities.

element (calculation point) sizes range from approximately 3 miles at the open ocean boundary to approximately 20 feet in the turning basins.

Three different elevation models were constructed: 2012 Conditions (Validation Period), Existing Conditions, and Proposed Project (today's bathymetry, but with widened turning basins). Table 1 lists the local elevation data sources used to construct each elevation model. All three elevation models were implemented on the same modeling grid to facilitate an accurate comparison between Existing Conditions and Proposed Project hydrodynamics.

Table 1. Elevation Model Local Data Sources

Elevation Model	Local Data Sources ¹
2012 Conditions (Validation Period)	1. USACE August 13th, 2012, Outer Harbor Survey 2. USACE July 25th - August 13th, 2012, Inner Harbor Survey
Existing Conditions	1. USACE January 27th, 2023, Inner Harbor Condition Survey 2. USACE January 27th - February 8th, 2023, Outer Harbor Condition Survey 3. Port of Oakland January 3rd – 17th, 2023, Berth Surveys
Proposed Project	1. Proposed Project Design 2. USACE January 27th, 2023, Inner Harbor Condition Survey 3. USACE January 27th - February 8th, 2023, Outer Harbor Condition Survey 4. Port of Oakland January 3rd – 17th, 2023 Berth Surveys

Notes:

1. All elevation models utilized NOAA 1/9th Arc Second San Francisco Bay Delta Continuously Updated Digital Elevation Model (CIRES 2014) for areas outside the project area.

Boundary conditions included Pacific Ocean water levels (tides) from the Global Ocean Tide Model DTU10 (Cheng et al 2010), and Delta outflows from the DAYFLOW model (CDWR 2023). The Global Ocean Tide Model DTU10 was selected because it has proven to provide accurate tides in the Pacific Ocean offshore of San Francisco Bay. The DAYFLOW model was chosen for prescribing Delta outflow data because it provides the best estimate of total flows coming from the Delta. A spatially uniform manning's roughness (standard input parameter for describing bottom friction in hydraulic models) value of 0.02 was used in all simulations; this value has been shown in numerous previous models to accurately calibrate the Mike21 model with current velocities in San Francisco Bay given appropriate resolution, elevation data and boundary conditions.

2.2 Simulations

Simulations were conducted for three different time periods. The model was first validated for a June 2012 period during which NOAA collected acoustic Doppler current profiler (ADCP) data in multiple locations outside and within the Seaport. Hydrodynamic impacts of the Proposed Project were then evaluated using a 4-month base case simulation (primary simulation from which conclusions are drawn) for a summer-fall period in 2014. The 2014 base case simulation period was selected due to its low Delta outflows. Although Delta outflow does not significantly influence hydrodynamics at the Seaport, a sensitivity test simulation (test to confirm that variations in assumptions or selected model inputs do not affect the study conclusions) was conducted using a winter period with higher Delta outflows, to evaluate sensitivity of any impacts of the Proposed Project to varying hydrologic conditions. Last, an additional sensitivity test was performed to evaluate hydrodynamic impacts of the Proposed Project with 7.5 feet of sea level rise. This sea level rise sensitivity test simulation was performed using the base case simulation period, but with offshore water level boundary conditions raised 7.5 feet for both Existing Conditions and Proposed Project scenarios. The simulation time frames are summarized in Table 2 below with DAYFLOW model Delta outflows used for Base Case and High-Flow periods shown in Figure 5.

Table 2. Simulation Overview

Simulation	Time Period	Approximate Duration
Validation	June 2 to 14, 2012	2 weeks ¹
Base Case	June 15 to October 15, 2014	4 months
Higher-flow period (Sensitivity)	January 1 to March 31, 2017	3 months ²
Base Case with 7.5ft sea level rise (Sensitivity)	June 15 to October 15, 2014	4 months

Notes:

1. Validation period covers the time period during which field data were available.
2. Higher-flow period (Sensitivity) was selected based on the duration of notable flows coming from the Delta.

2.3 Validation

Figure 6 shows a comparison of measured and predicted currents at three locations (SFB-07, SFB-13, and SFB-14; NOAA 2012) near the Proposed Project. The high coefficients of determination (r^2 , or general measure of similarity between two datasets) indicate that the model accurately reproduces measured current velocities, especially in areas where the measurements are not influenced by eddying (circular water currents) from the shoreline. Differences in measured and predicted velocities are mostly attributable to variability in the field data and eddies shedding off the shoreline during tidal swings. In addition, Figure 6 shows a comparison of measured and predicted water levels at Alameda (NOAA Station AAMC1-9414750; NOAA 2023), and a resulting coefficient of determination (r^2) that indicates excellent model performance.

3 Results

3.1 Existing Conditions Hydrodynamics

Hydrodynamics within southern central San Francisco Bay are dominated by tidal currents. Figure 7 shows an example snapshot of typical peak ebb and flood currents at the Proposed Project site under Existing Conditions. Currents in the western half of the Outer Harbor are organized during ebb/flood conditions and can exceed a velocity of 1 foot per second, while currents within the interior of the Outer Harbor, including the OHTB, are dominated by weak, disorganized eddies with velocities generally below 0.2 feet per second. Flow within the Inner Harbor is typically aligned with the navigation channel and has typical peak ebb and flood currents ranging from 0.5 to 1.0 feet per second. In the IHTB, localized movements of eddies regularly occurs during transitions between ebb and flood tide.

3.2 Proposed Project Impacts on Hydrodynamics

Model results indicate that changes to hydrodynamics caused by the Proposed Project are likely to be minor and localized. Figure 8 shows maps of instantaneous velocity change caused by the Proposed Project relative to Existing Conditions, during typical peak ebb and flood conditions. At the Outer Harbor, the Proposed Project causes maximum instantaneous depth-averaged velocity changes of approximately +/- 0.3 feet per second. These changes are minor (small portion of typical Bay currents) and occur in areas of deepening from the Proposed Project at the north side of the OHTB which are relatively small. In areas farther than a turning basin diameter away, changes are negligible. In the Inner Harbor, the Proposed Project causes maximum

instantaneous depth-averaged velocity changes of approximately +/- 0.2 feet per second, which are limited to the immediate vicinity of the IHTB (within approximately 500 feet).

Potential changes in hydrodynamics were also characterized using longer-term time histories of velocities at locations adjacent to the turning basins. Figure 9 shows a comparison of current velocities for Existing Conditions and Proposed Project at locations adjacent to the turning basins including visual comparisons of velocity time histories (left column), velocity cumulative frequency distributions (center column), and velocity regressions with coefficients of determination (r^2 , right column).

The left column of Figure 9 provides a visual comparison of current velocity time histories for Existing Conditions and the Proposed Project, which indicates that changes adjacent to the turning basins are likely to be negligible. The center column of Figure 9 demonstrates that the velocity cumulative frequency distributions for Existing Conditions and the Proposed Project are essentially the same, which also indicates that changes adjacent to the turning basins are likely to be negligible. The right column of Figure 9 shows high coefficients of determination between Existing Conditions and the Proposed Project (very close to 1.0), indicating extremely high similarity in currents before and after Proposed Project construction. This also indicates that velocity changes adjacent to the turning basins are likely to be negligible.

3.3 Proposed Project Impacts on Flushing

Potential impacts to water quality and flushing (water exchange and circulation) caused by the Proposed Project were evaluated in two separate ways. First, the total water volume moving through the Inner and Outer Harbor waterways during the simulation periods was calculated at the two cross-sections shown in Figure 10. Calculations at these flux planes showed a negligible difference in total water exchange between Existing Conditions and the Proposed Project over the 4-month simulation.

Second, flushing time was evaluated in local nearby embayments (small coves) by inserting a conservative, passive tracer into confined areas in the hydrodynamic model. Figure 10 shows the initial tracer distribution (at 100 percent concentration) in embayments of the Inner and Outer Harbor, as well as time histories of tracer concentrations at the far interior points in those embayments, for both Existing Conditions and the Proposed Project, where 0 percent concentration indicates complete flushing has been achieved. Results indicate that the Proposed Project is likely to cause slightly more exchange in the shoreline area near Berth 10 in the Outer Harbor, likely due to changes in local eddying and a larger water volume present in the Outer Harbor after turning basin expansion. Overall, the Proposed Project is likely to have a negligible impact on flushing times within local embayments in both the Outer Harbor and Inner Harbor.

3.4 Sensitivity Testing

Additional sensitivity testing simulations described in Section 2.2 were performed to evaluate the sensitivity of Proposed Project impacts to increased Delta outflow, and to a future sea level rise of 7.5 feet. Figure 11 characterizes the changes in current velocities due to the Proposed Project, in the same format as Figure 9, for the higher-flow period. Figure 12 characterizes the changes in current velocities due to the Proposed Project, in the same format as Figure 9, for the future sea level rise simulations. The comparisons include visual comparisons of velocity time histories (left column), velocity cumulative frequency distributions (center column), and velocity regressions with coefficients of determination (r^2 , right column).

The time histories of current velocity for Existing Conditions and the Proposed Project visually indicate that changes are likely to be negligible, as in the base case simulation. The cumulative

statistical distributions of velocities for Existing Conditions and the Proposed Project are essentially identical, and the high coefficients of determination indicate that hydrodynamic changes at these locations adjacent to the turning basins are likely to be negligible.

The sensitivity test simulation results show that regardless of Delta outflow or future sea level rise anticipated in the future, the potential hydrodynamic impacts of the Proposed Project are likely to be negligible outside the immediate vicinity of each turning basin and changes in current velocities would remain minor in the immediate vicinity of each turning basin.

4 Conclusions

Numerical modeling was performed to evaluate potential changes in hydrodynamics resulting from widening of the Seaport's IHTB and OHTB. Analysis of numerical modeling results indicates the following:

- Changes in current velocities caused by the Proposed Project are likely to be minor in the immediate vicinity of each turning basin and negligible outside the immediate vicinity of each turning basin.
- Changes in water exchange through each harbor are likely to be negligible, resulting in negligible local changes in water quality.
- Changes in water exchange (flushing) in nearby embayments are likely to be negligible, resulting in negligible changes in water quality.
- Conclusions made here using results of the present-day (no sea level rise) base case simulations are valid for future conditions with 7.5 feet of sea level rise, and for periods with higher Delta outflow.

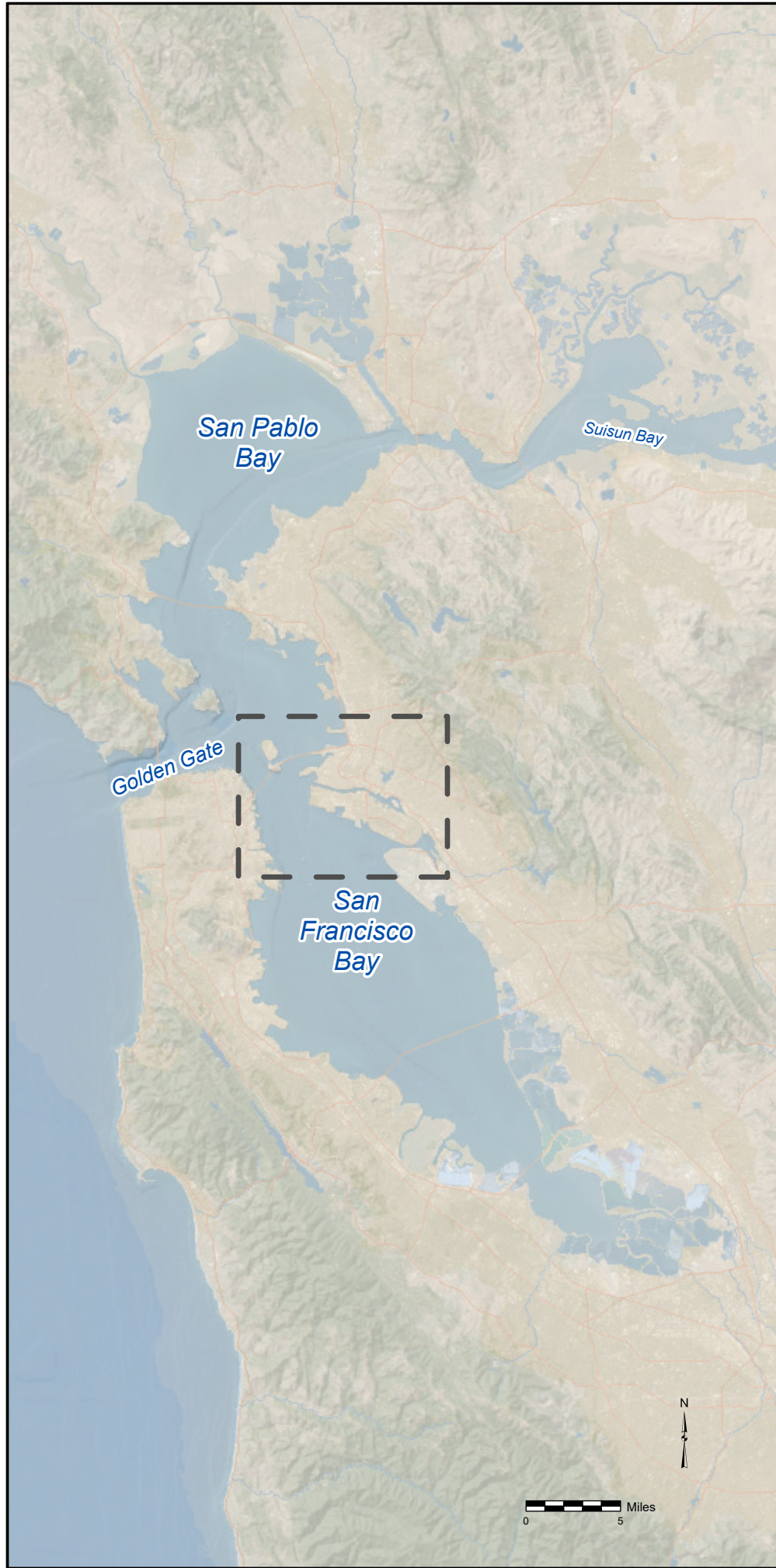
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- Existing Turning Basins
- ▬ Navigation Channel

Figure 1
Project Site Location

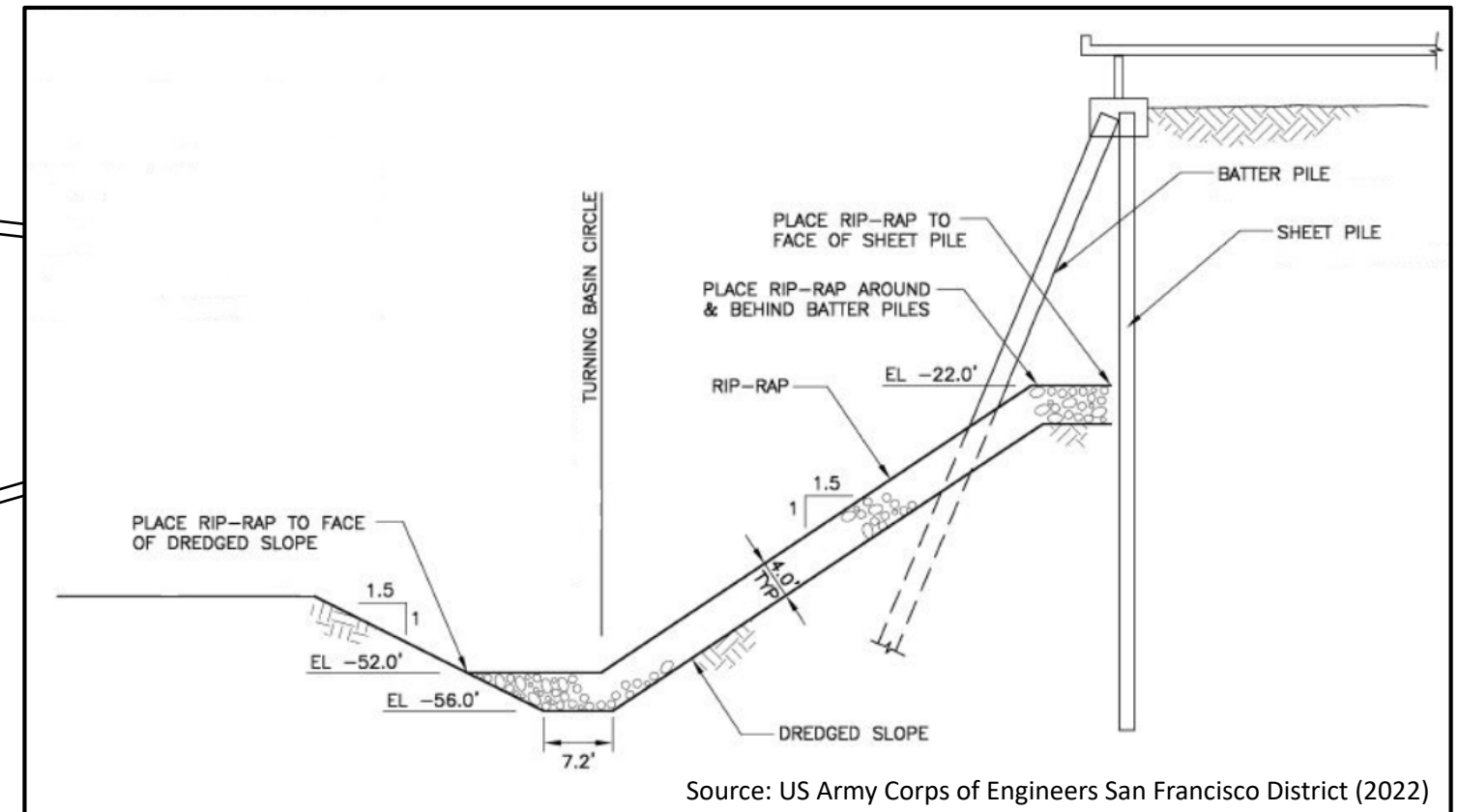
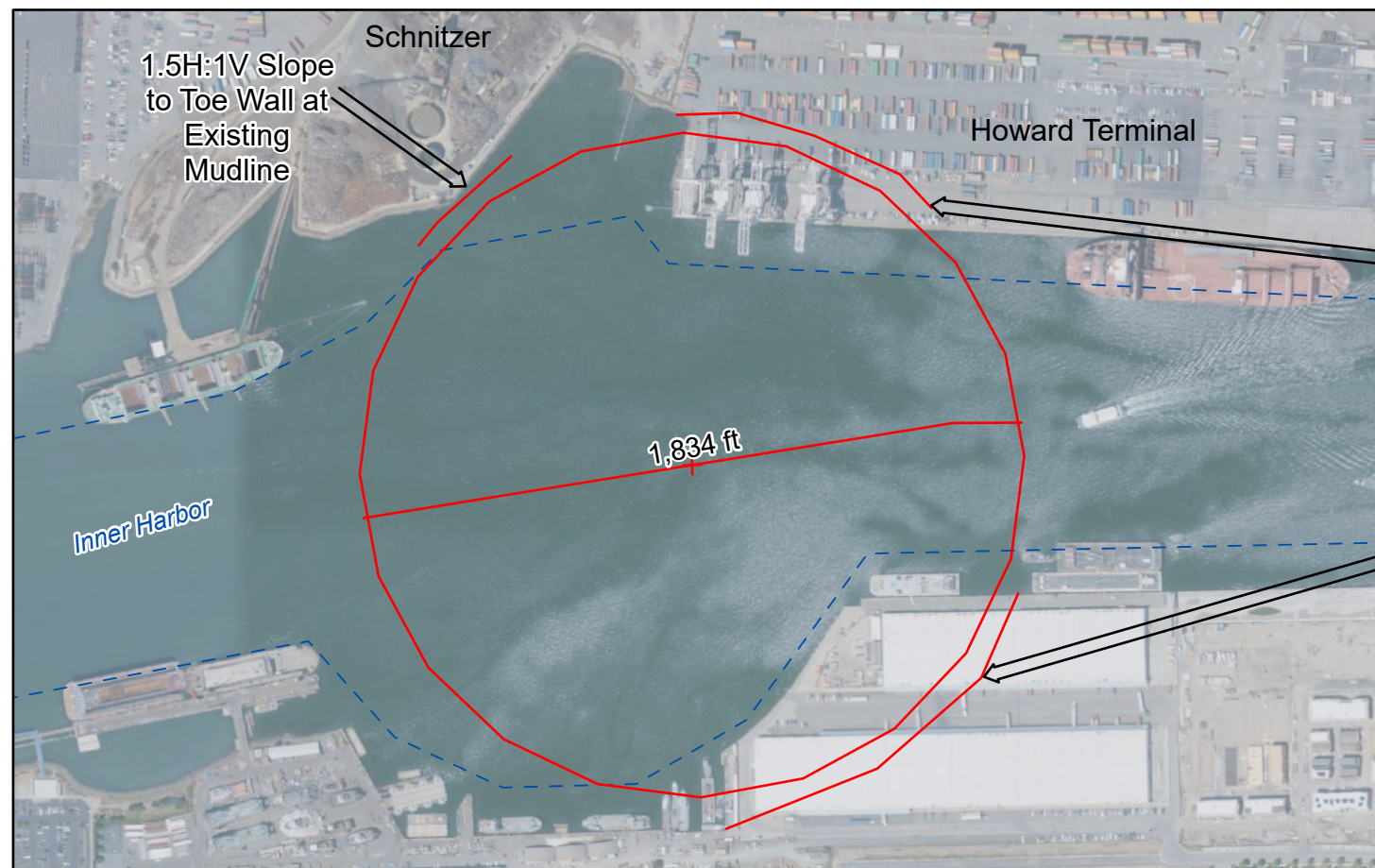


Figure 2

Proposed Project Design

1:5,929
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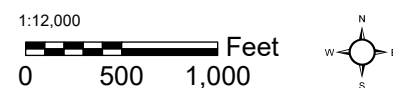
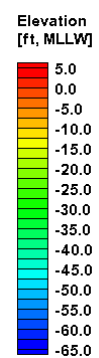
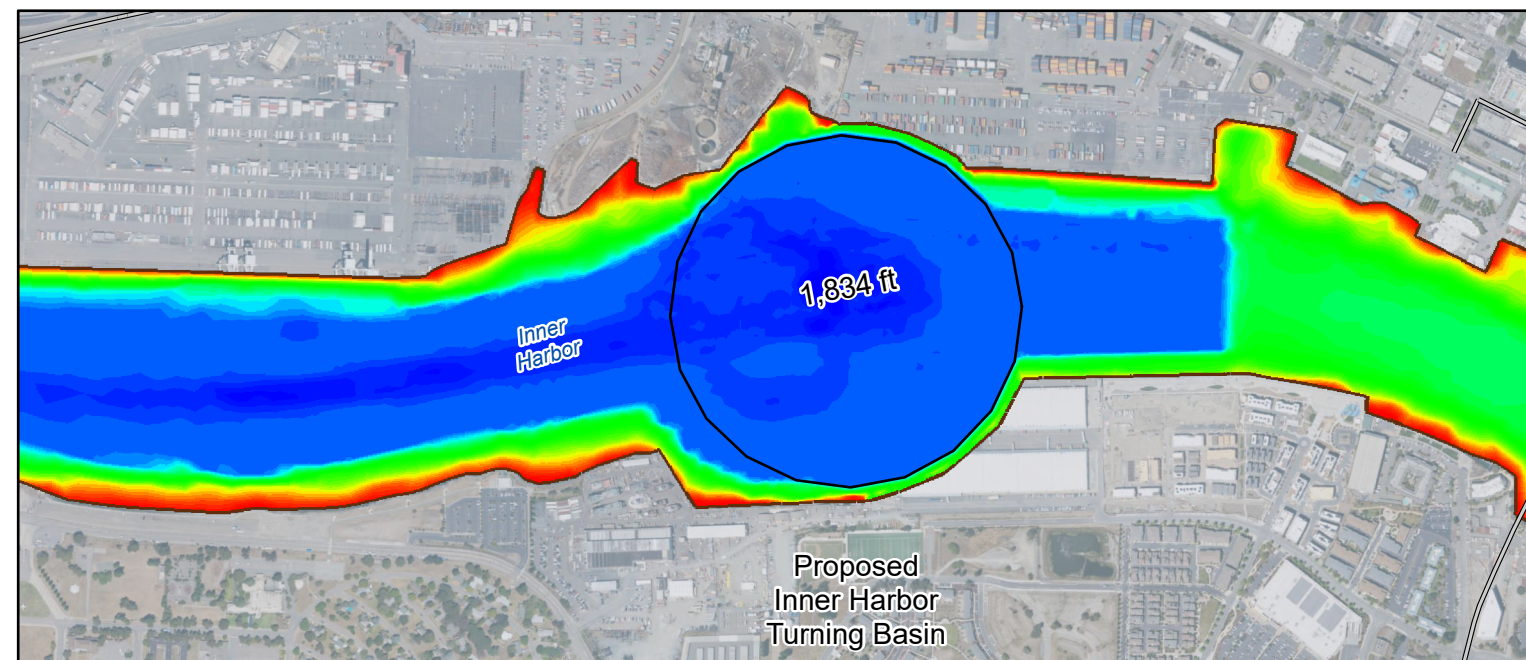
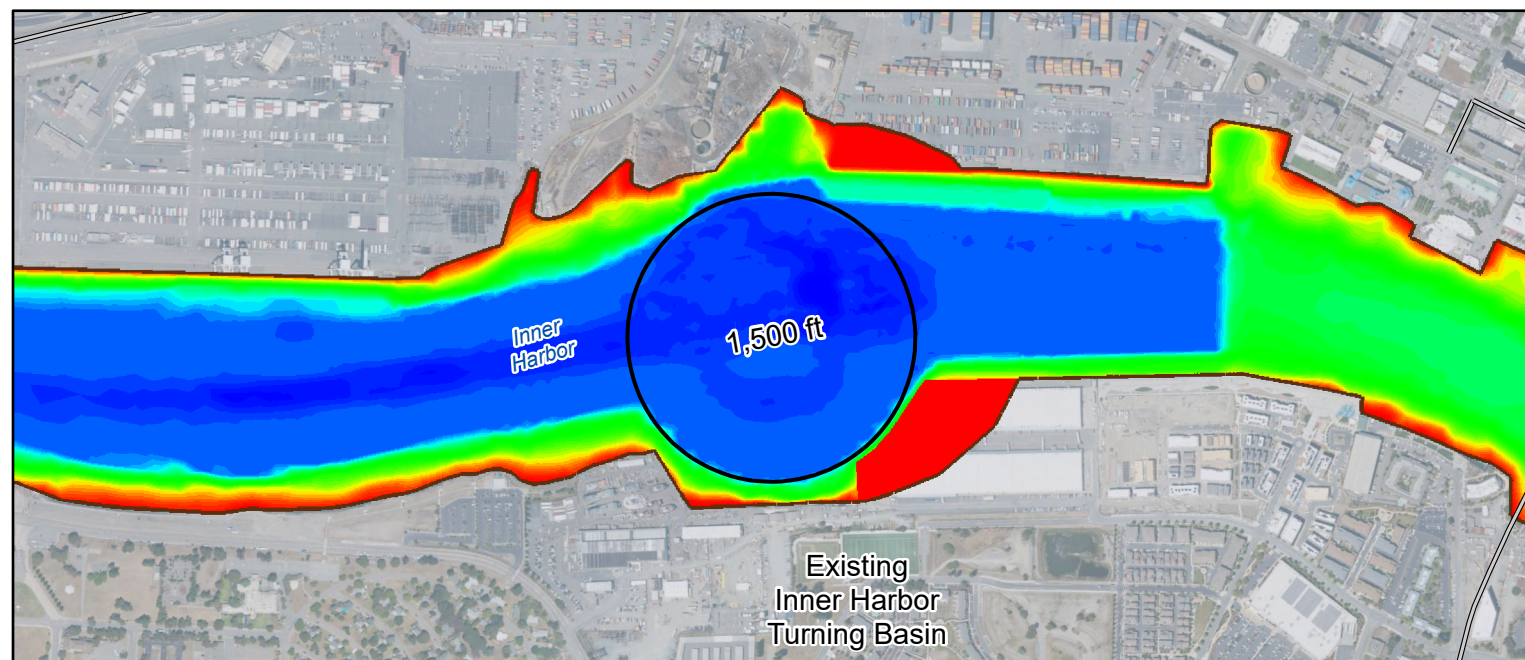
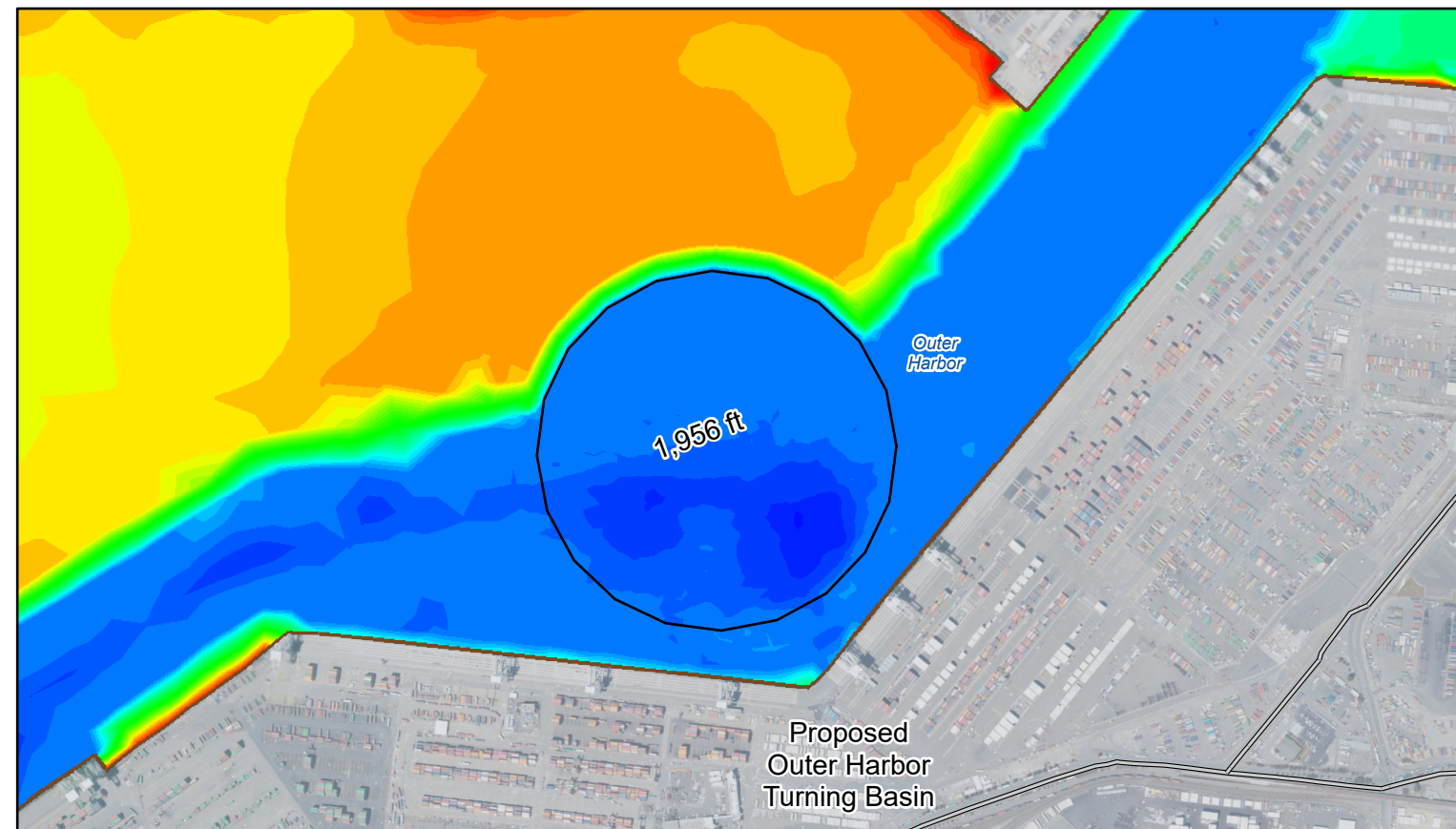
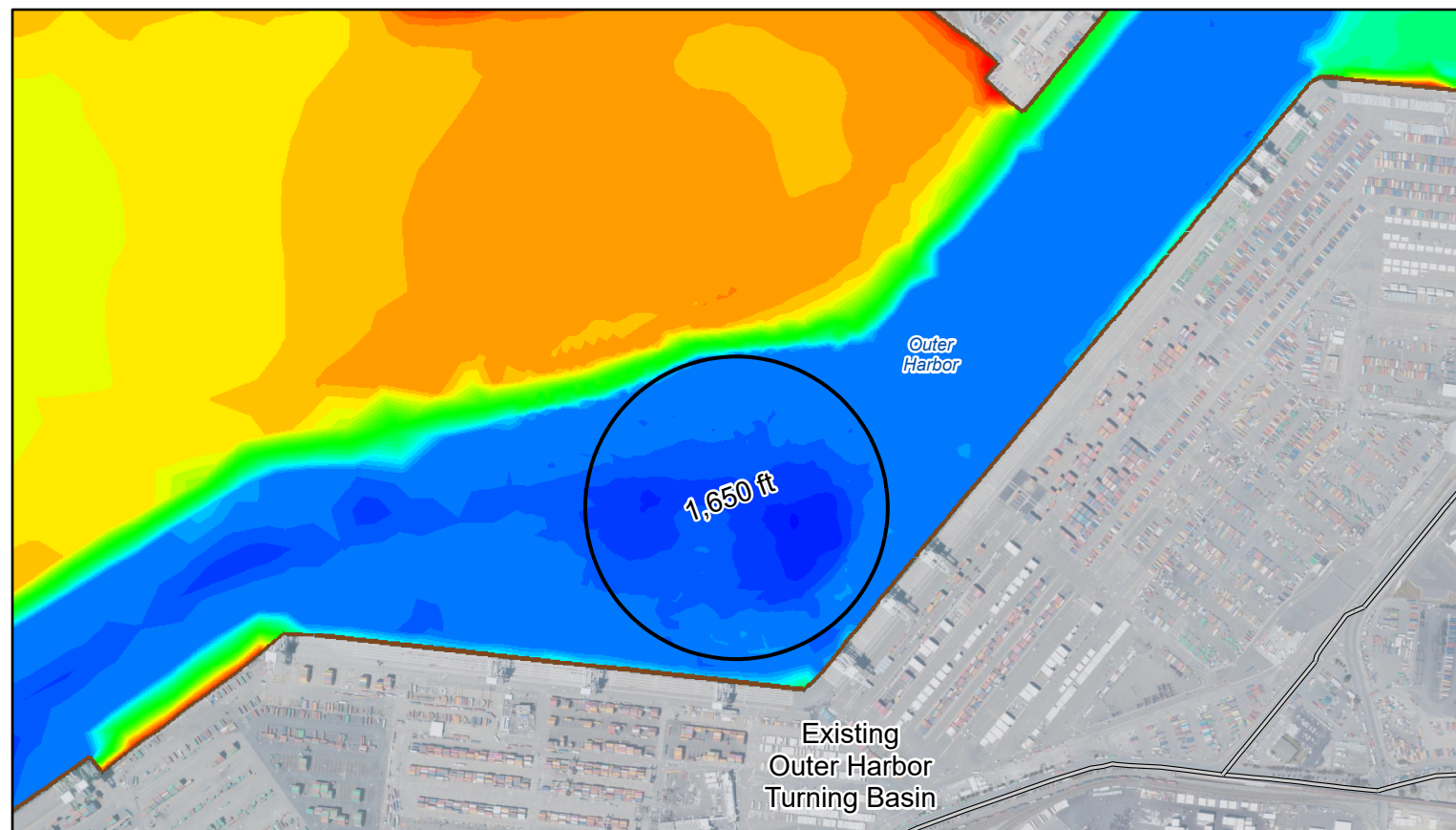


Figure 3
 Existing Conditions and Proposed Project Elevation Models

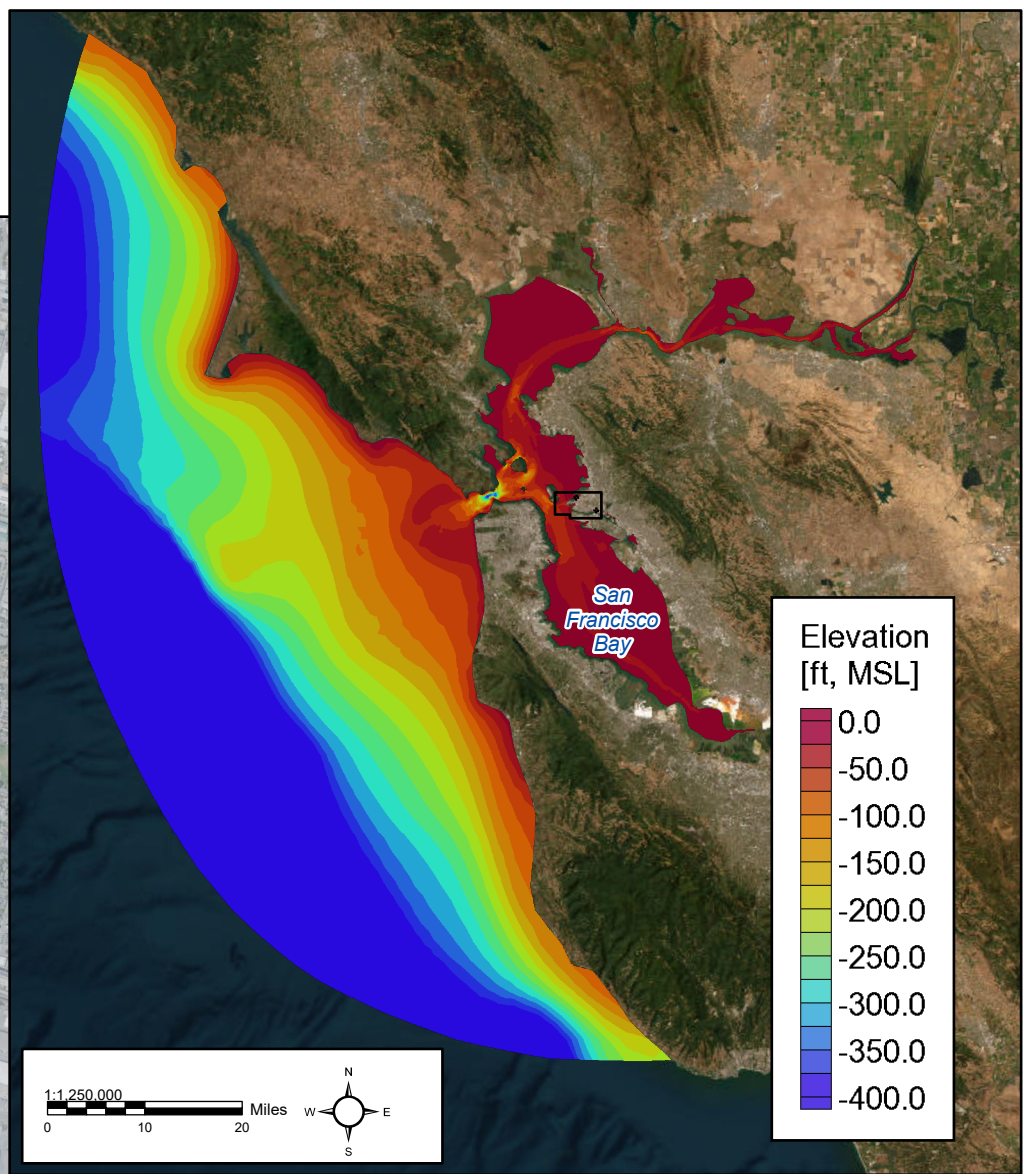
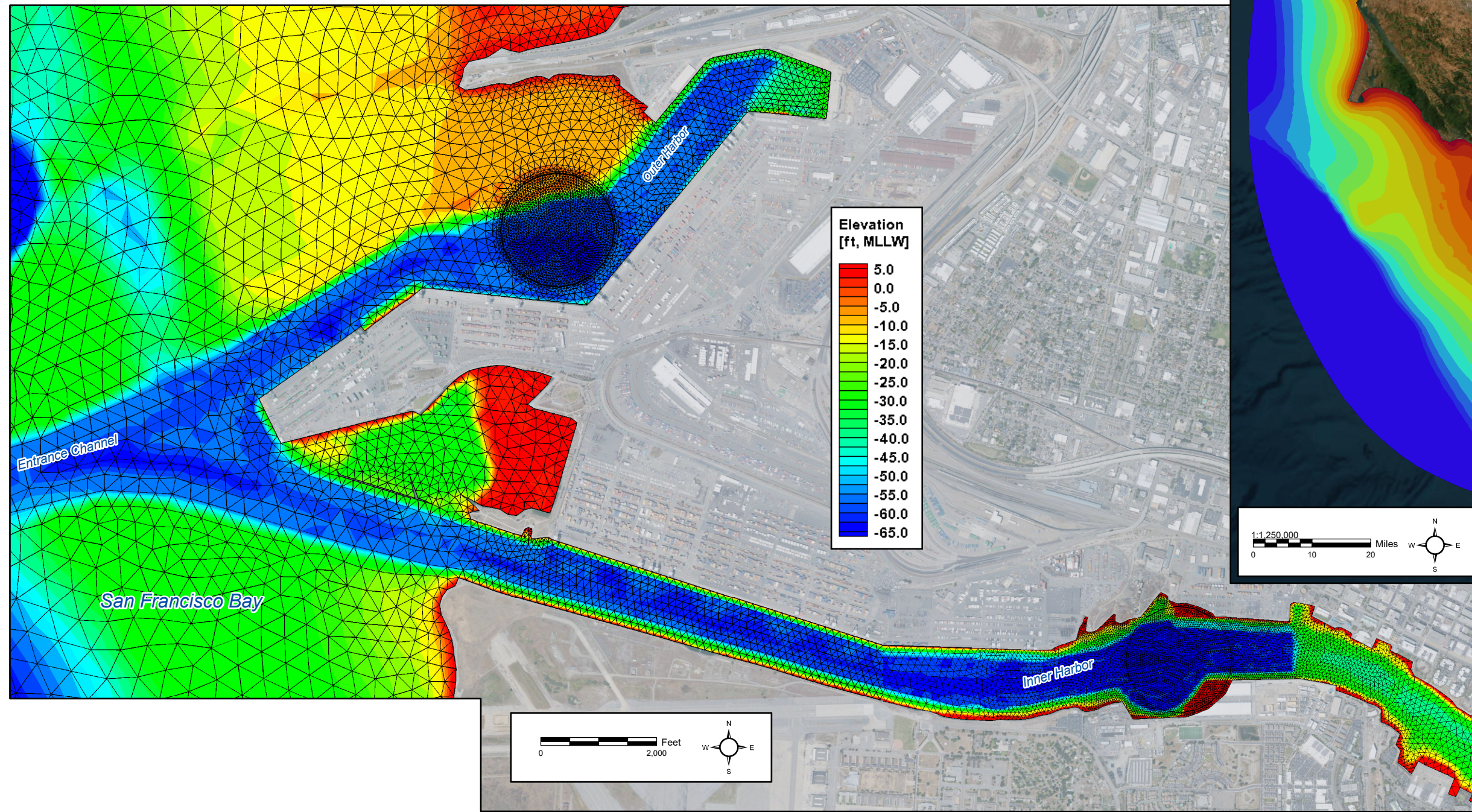


Figure 4
Model Domain Extents and Grid Close-up at Project Site

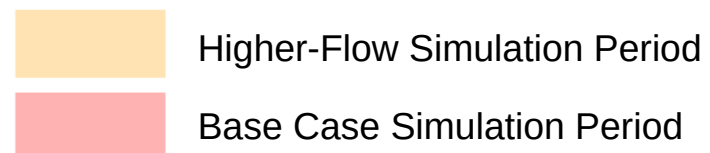
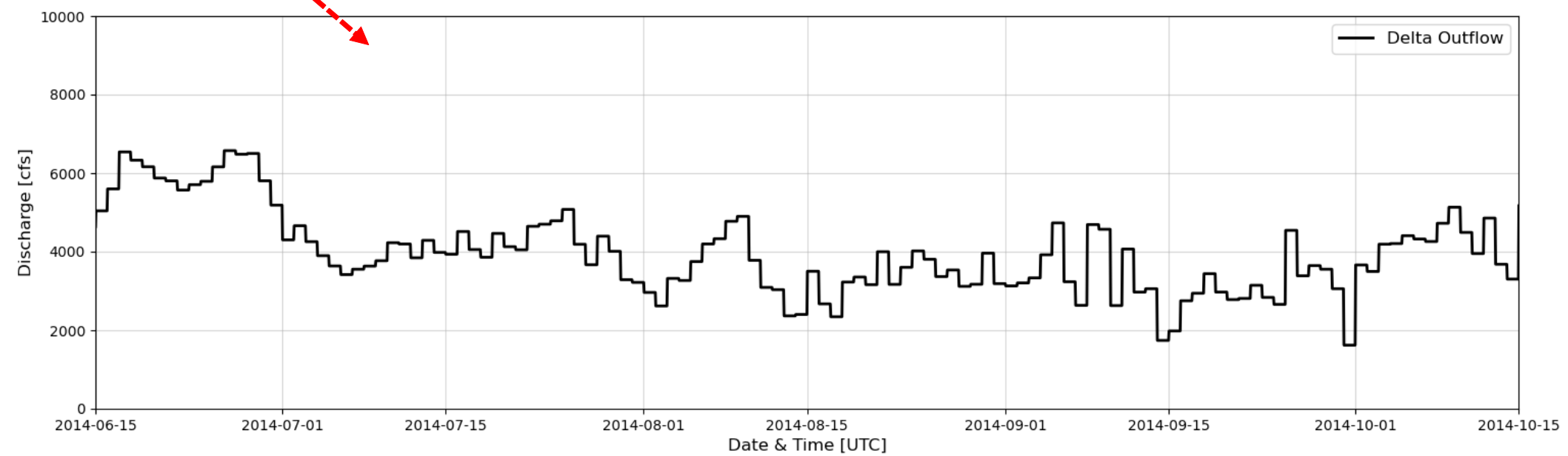
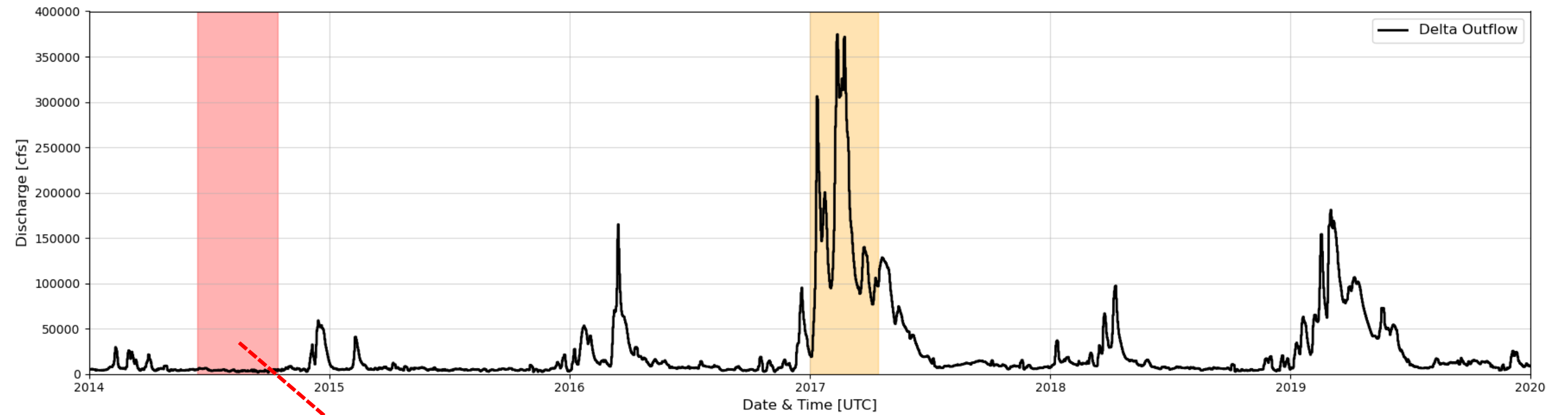


Figure 5

Delta Outflow During Base Case and Higher-Flow Sensitivity Test Simulations

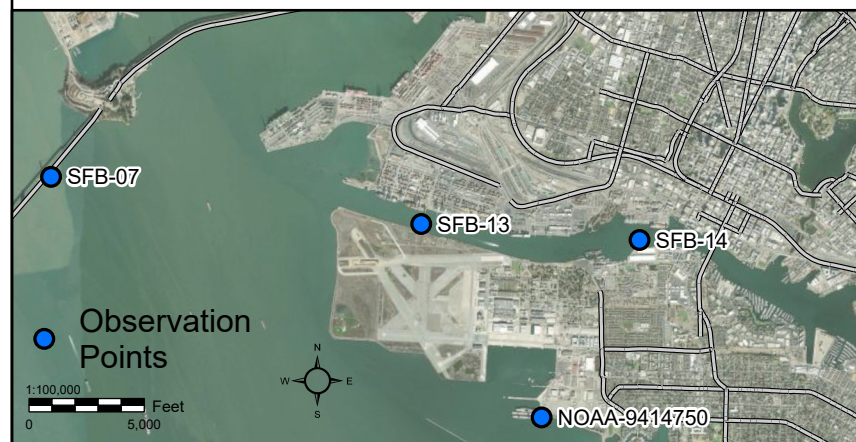
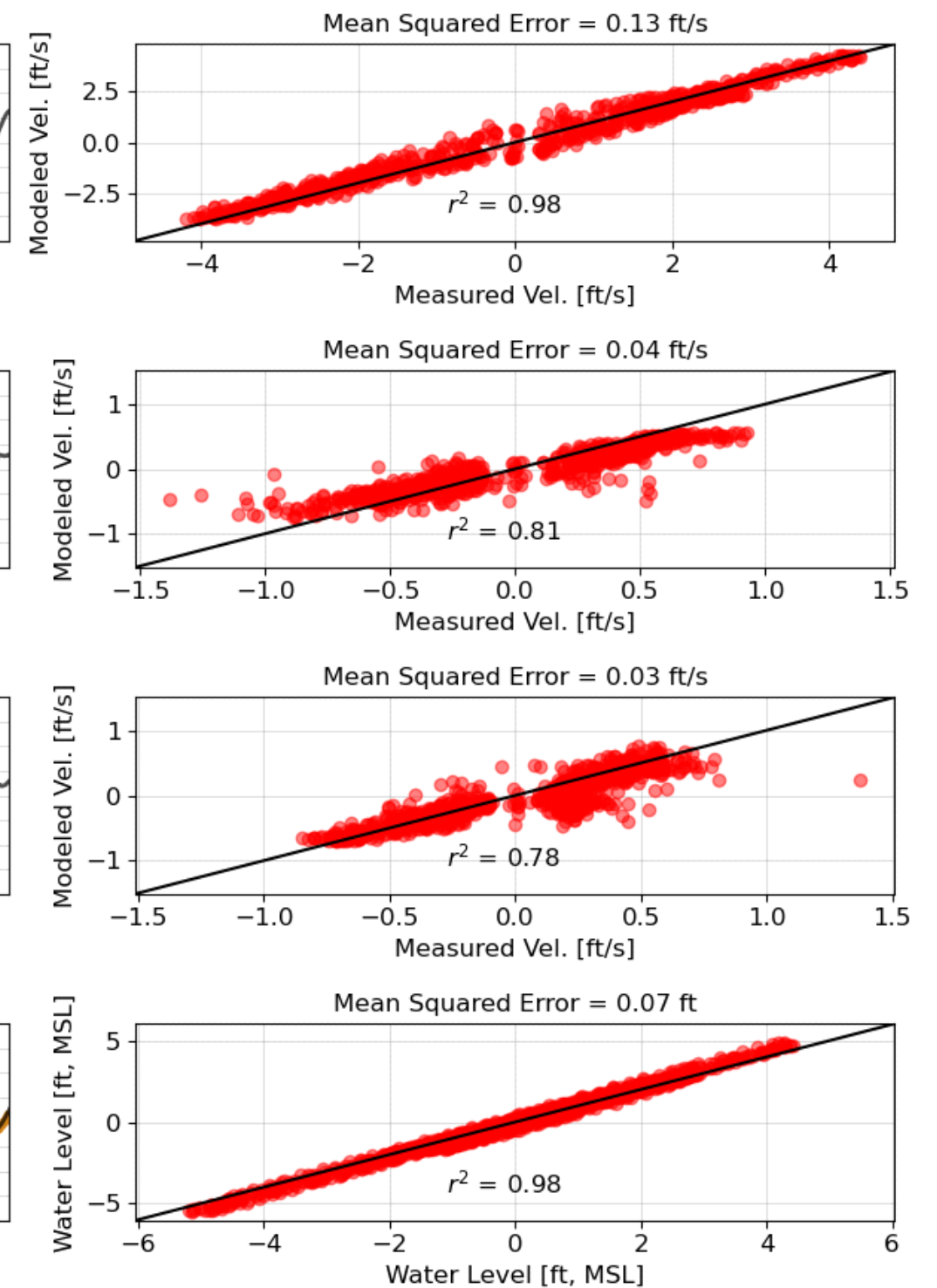
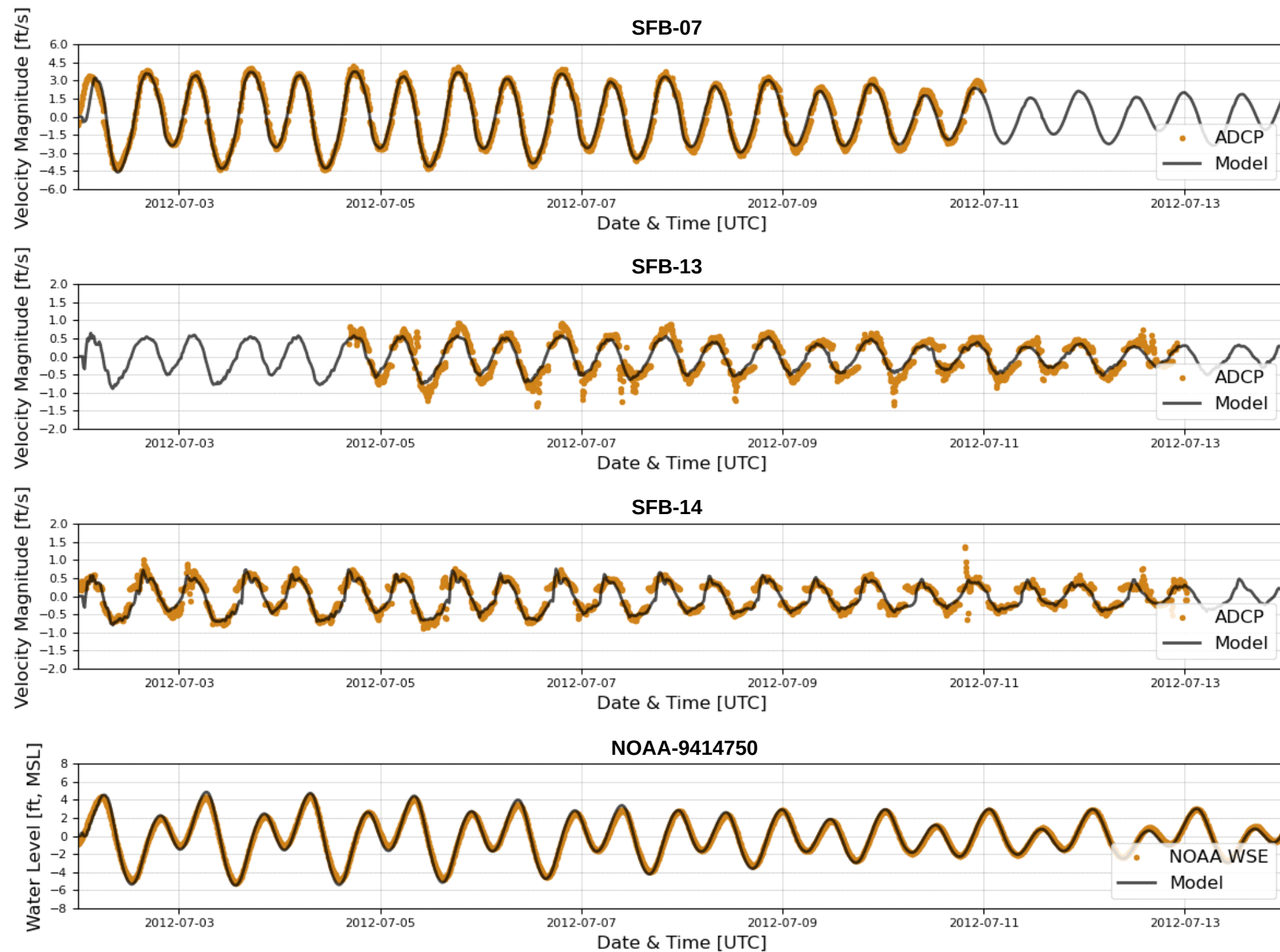
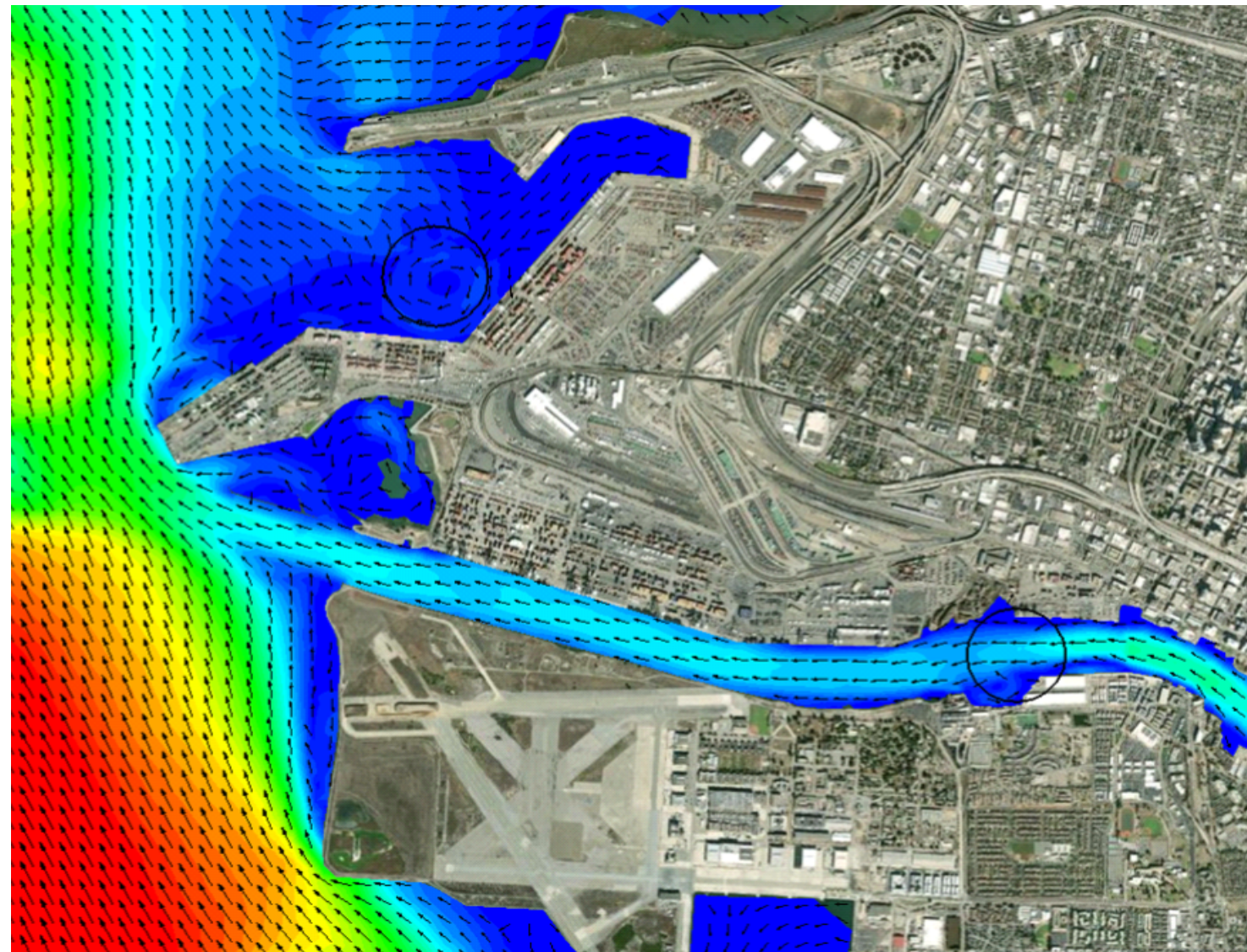


Figure 6

Model Validation with Measured Current Velocities and Water Levels

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Peak Ebb Currents



Peak Flood Currents

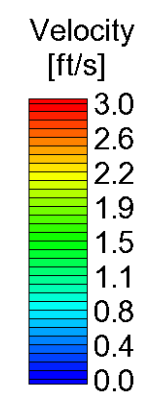
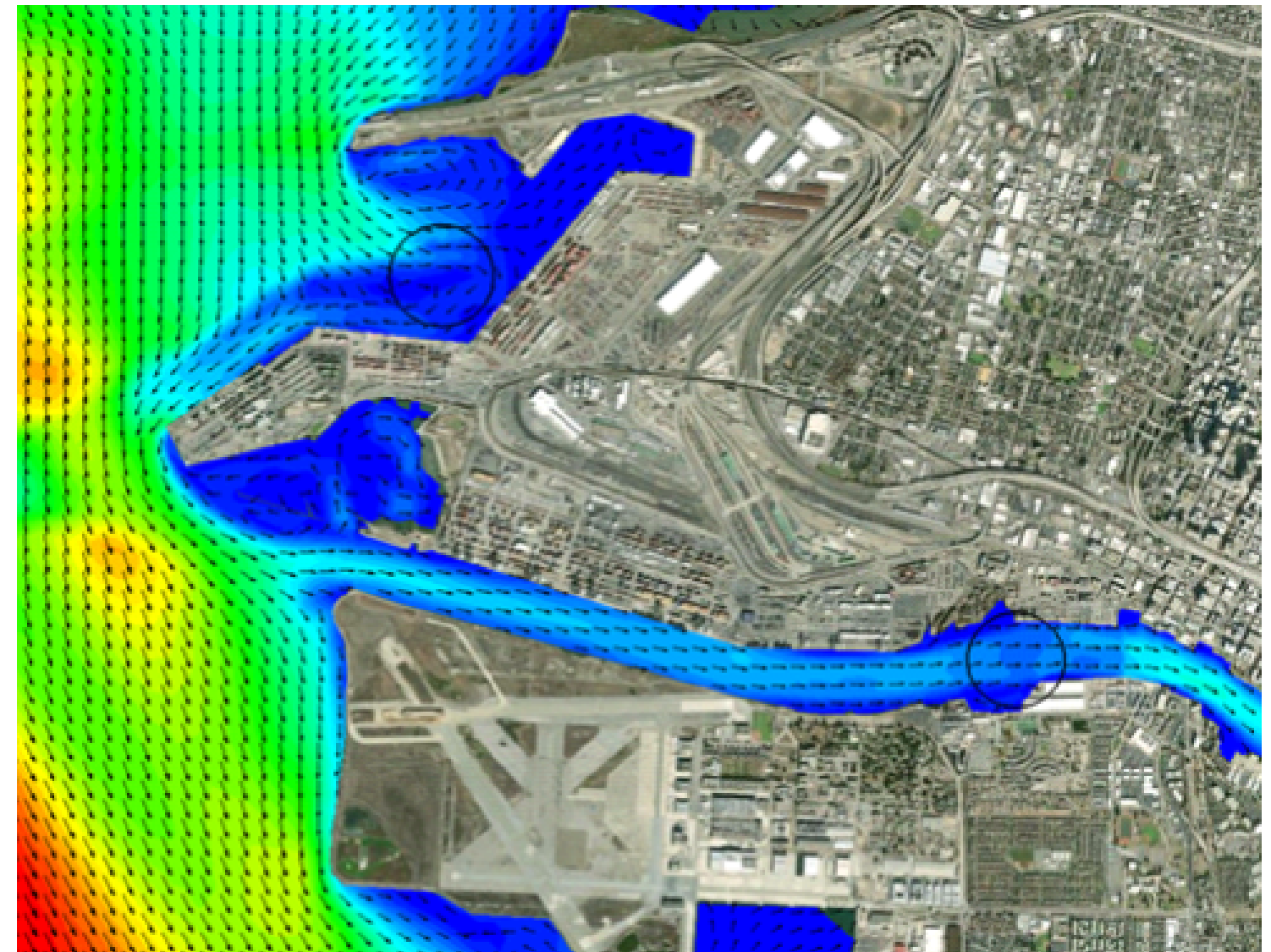
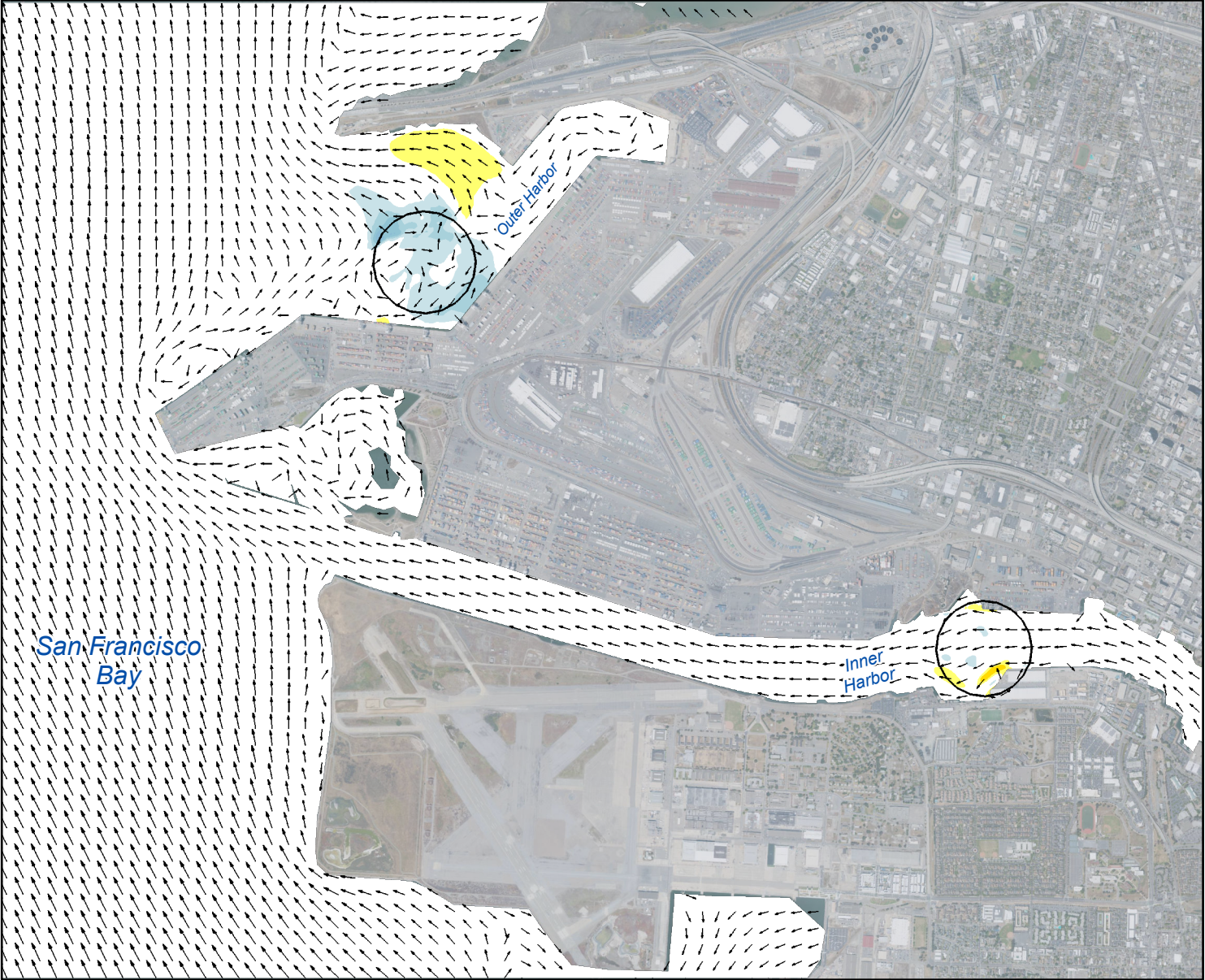


Figure 7

Existing Conditions Current Velocities at
Typical Peak Ebb and Flood

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Current Speed Change
During Peak Ebb Currents



Current Speed Change
During Peak Flood Currents

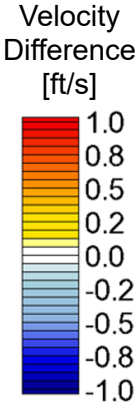
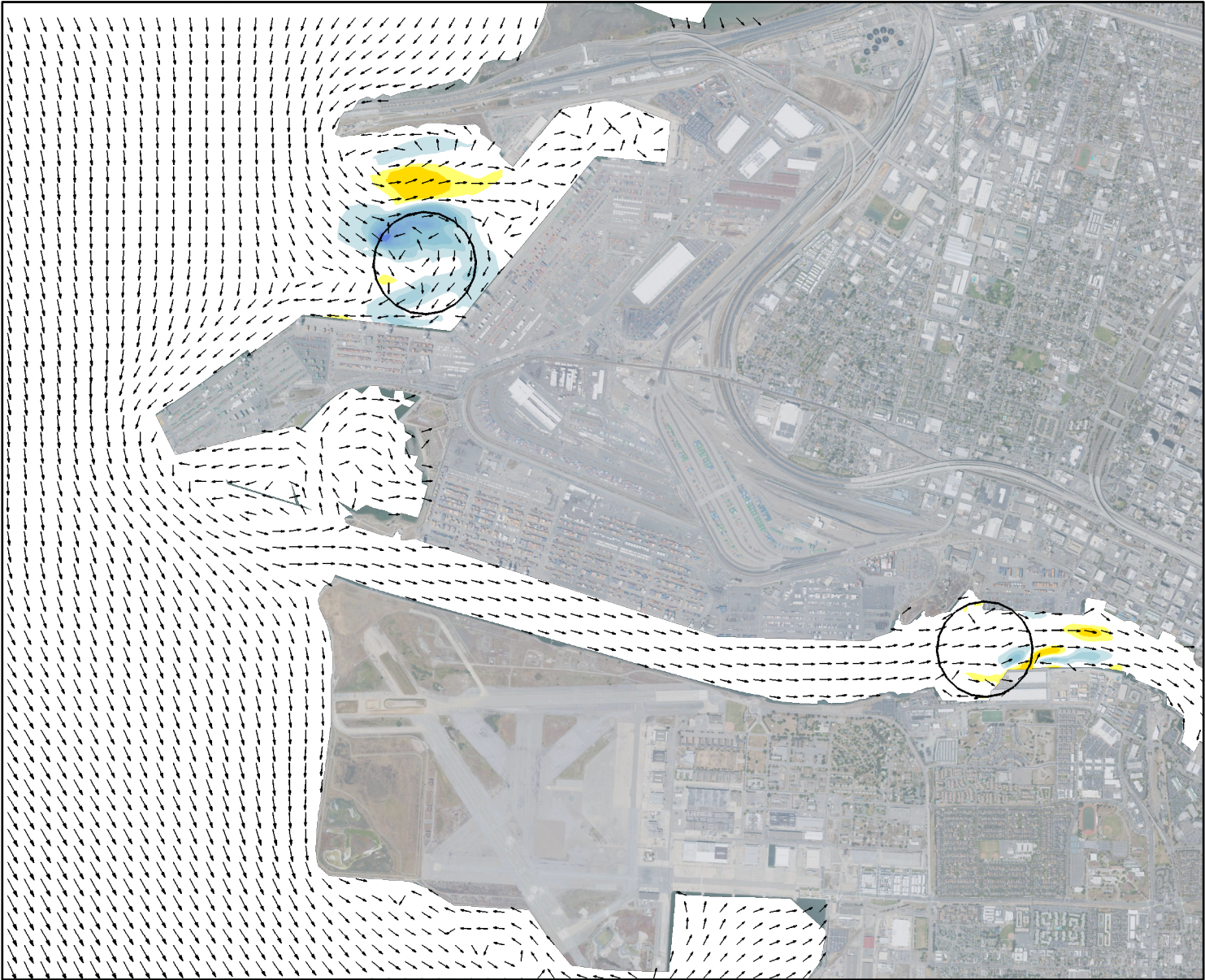


Figure 8
Current Velocity Changes Due to Proposed Project at
Typical Peak Ebb and Flood

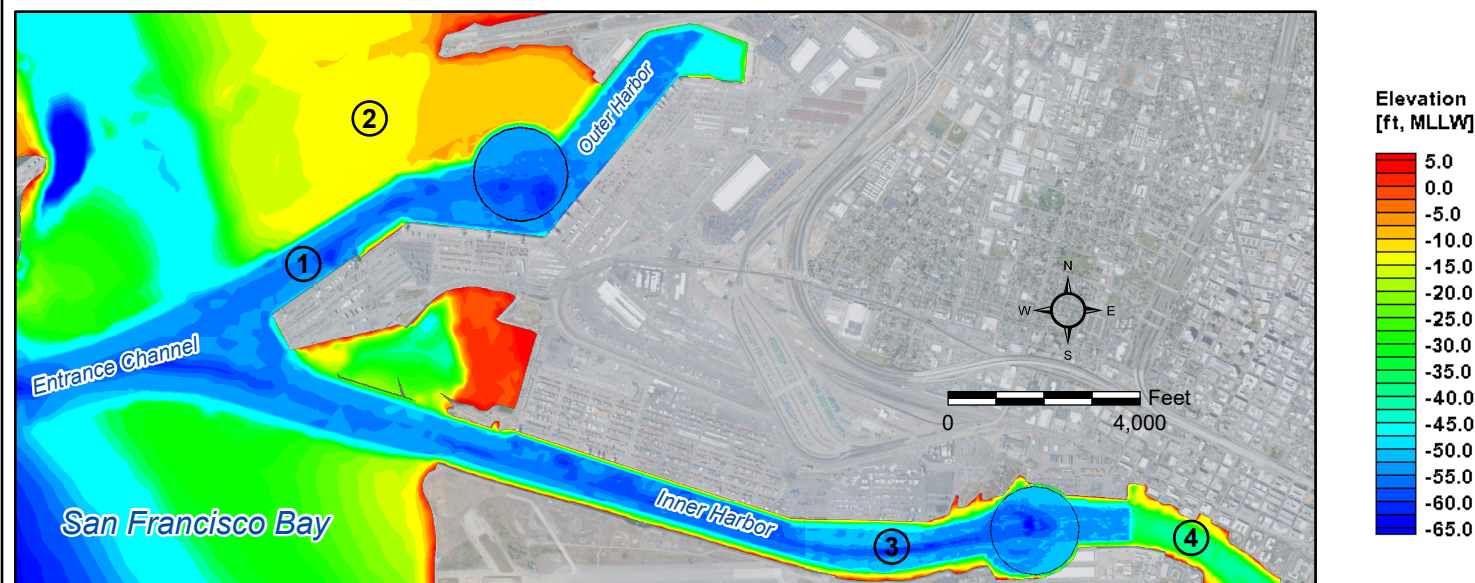
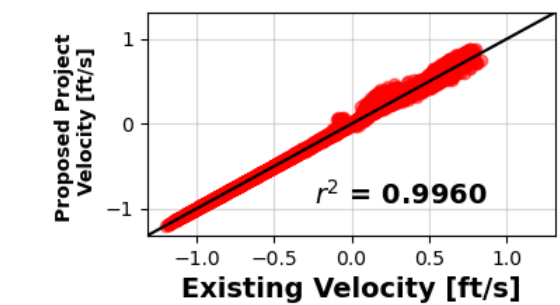
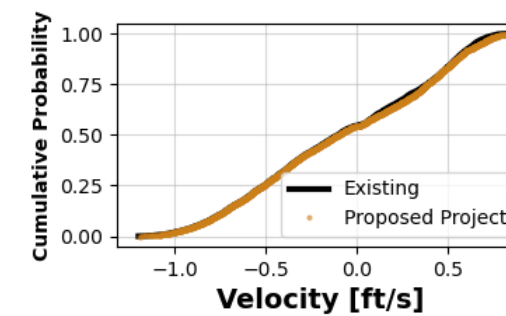
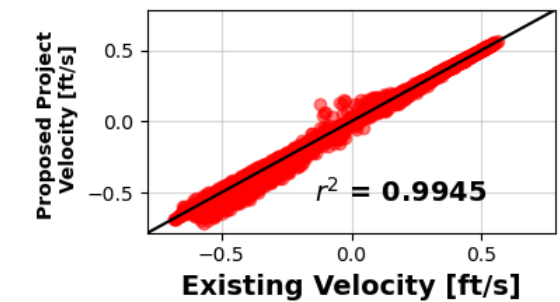
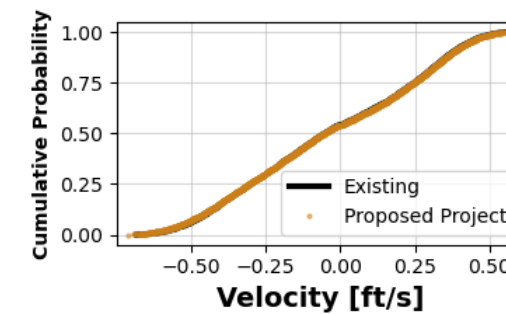
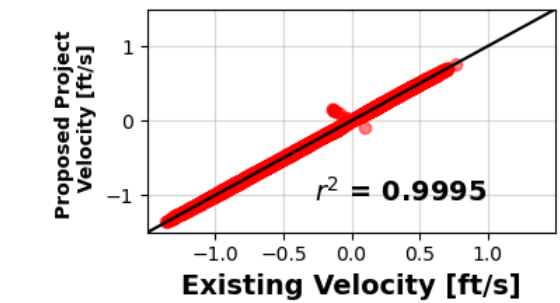
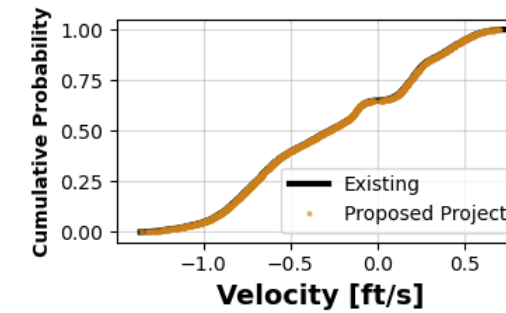
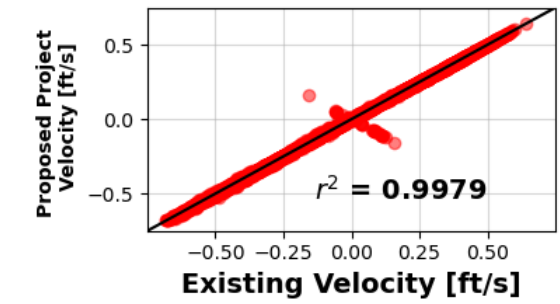
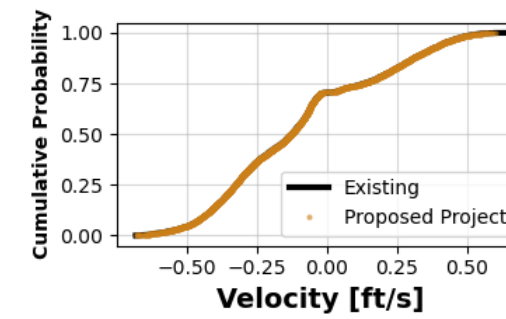
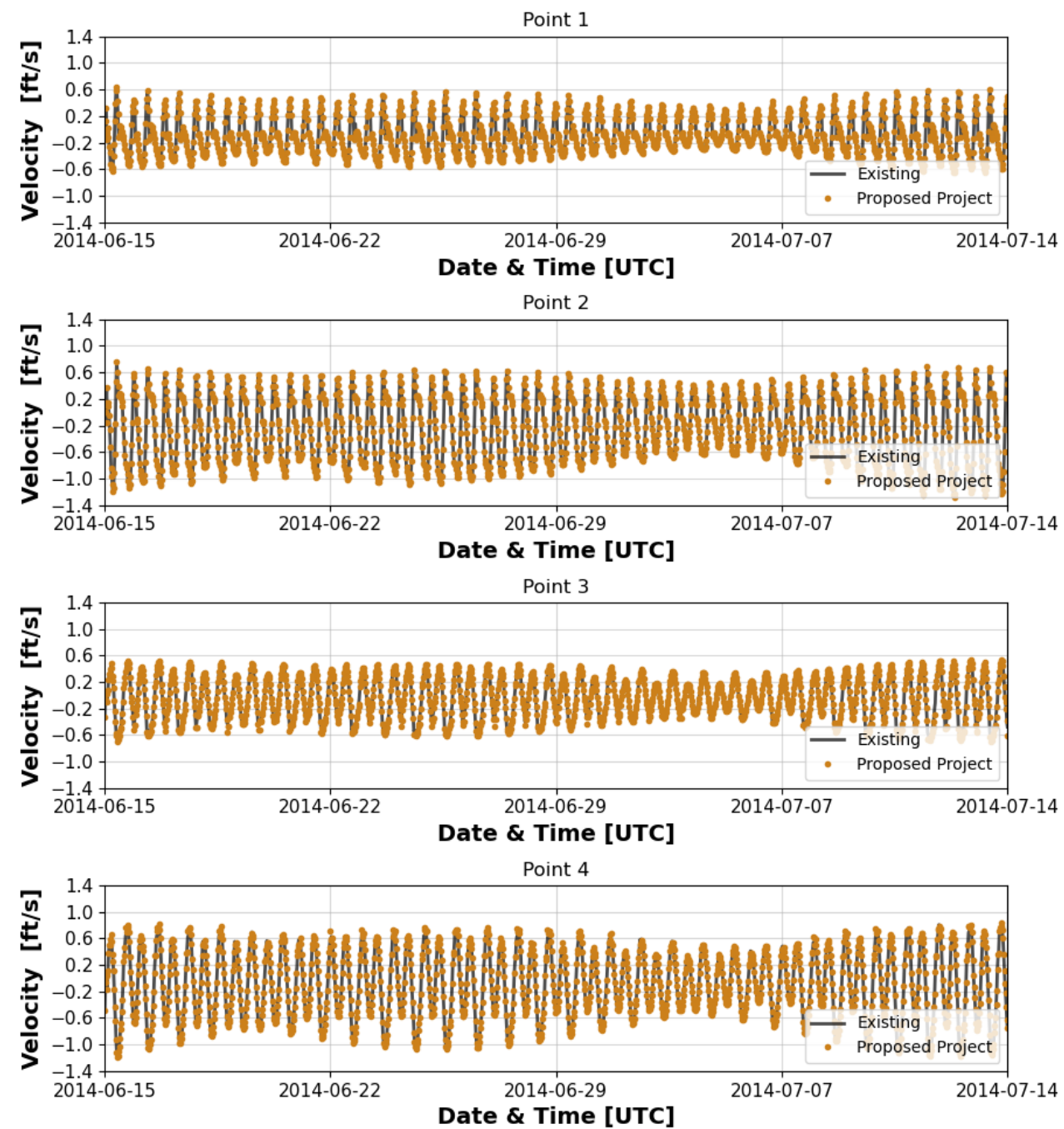


Figure 9

Comparison Between Current Velocities for Existing Conditions and Proposed Project Conditions, at Locations Adjacent to the Turning Basins (Base Case Simulation)

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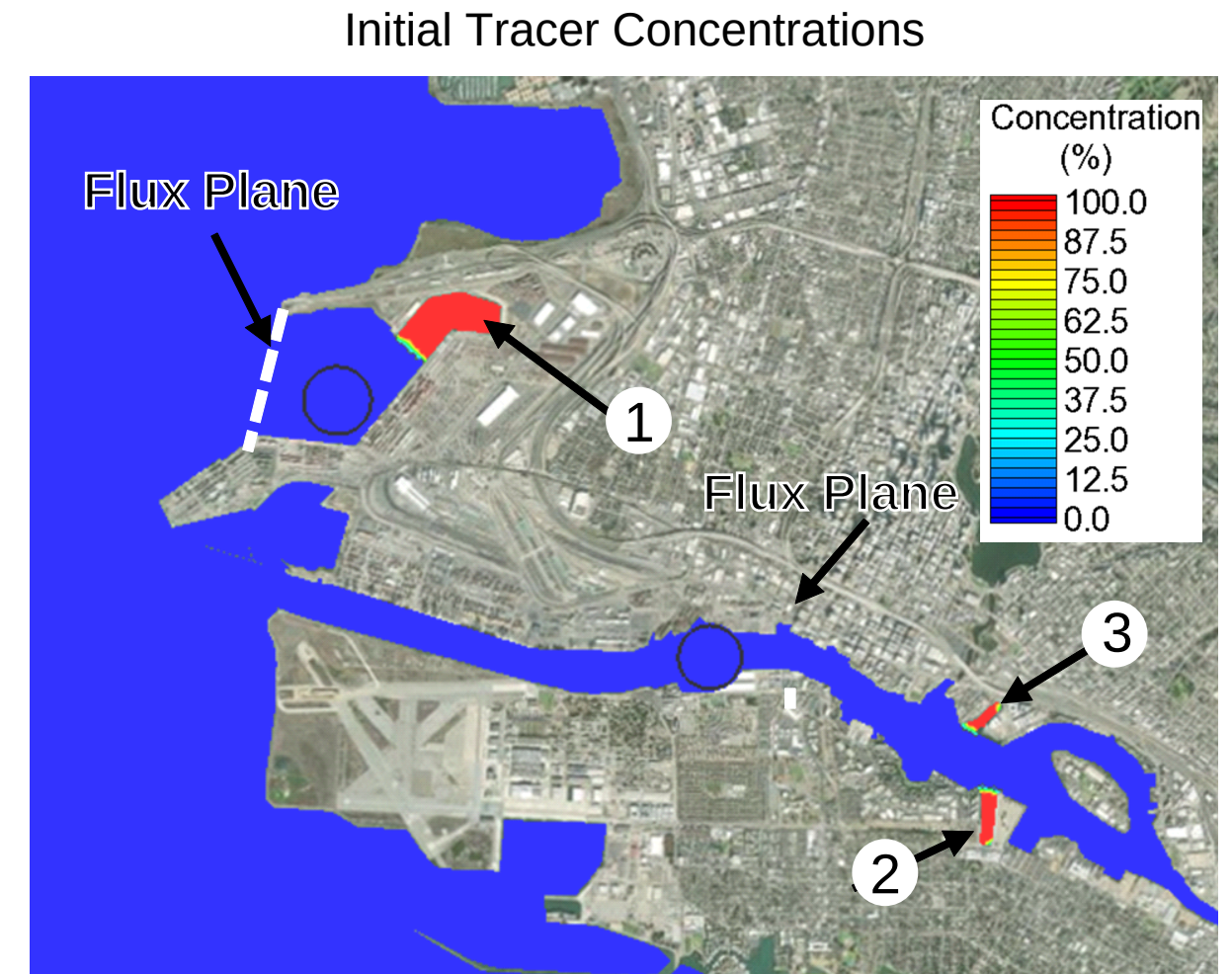
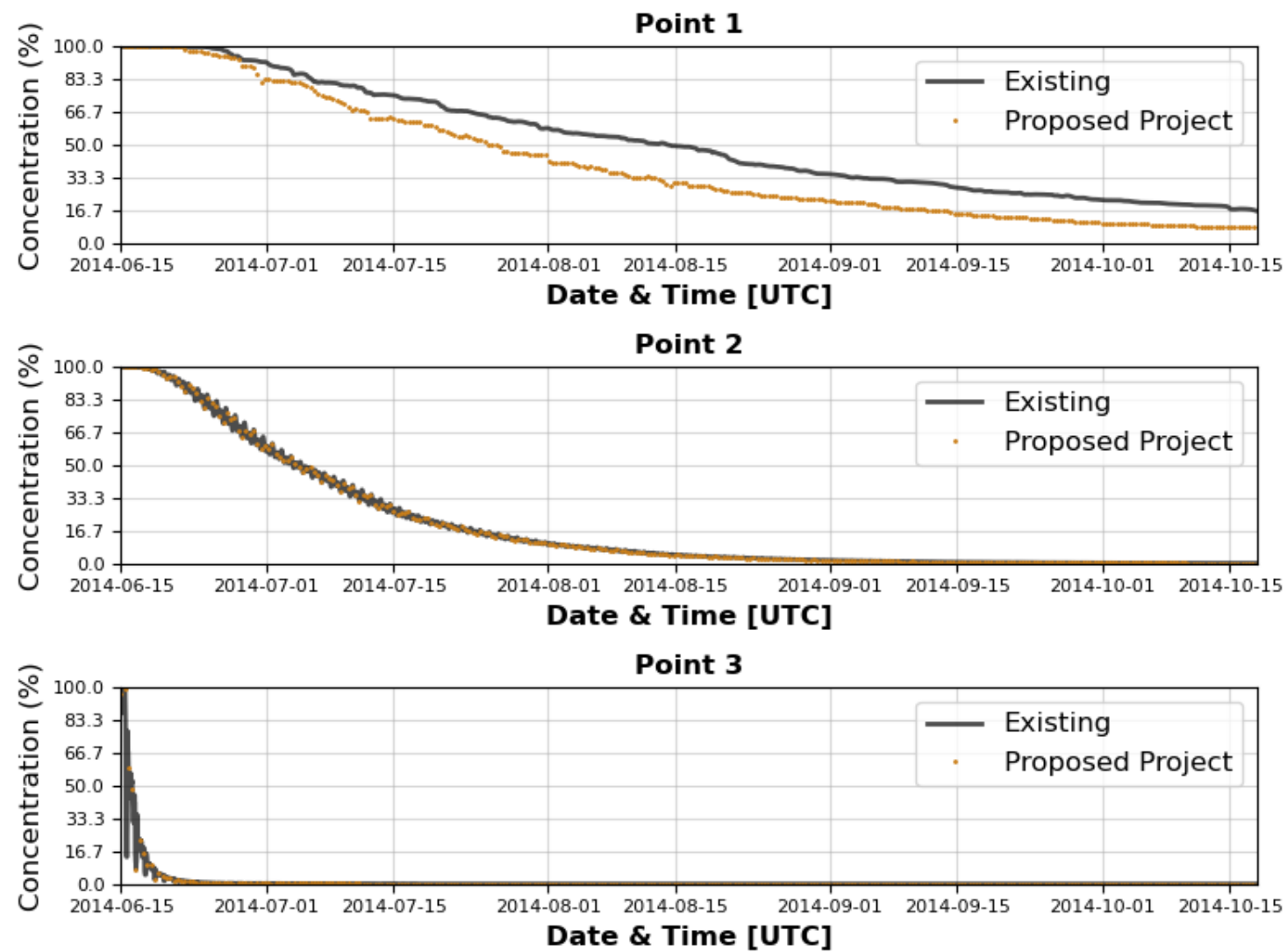


Figure 10
Flushing of Conservative Tracer at Locations Potentially Affected by the Proposed Project

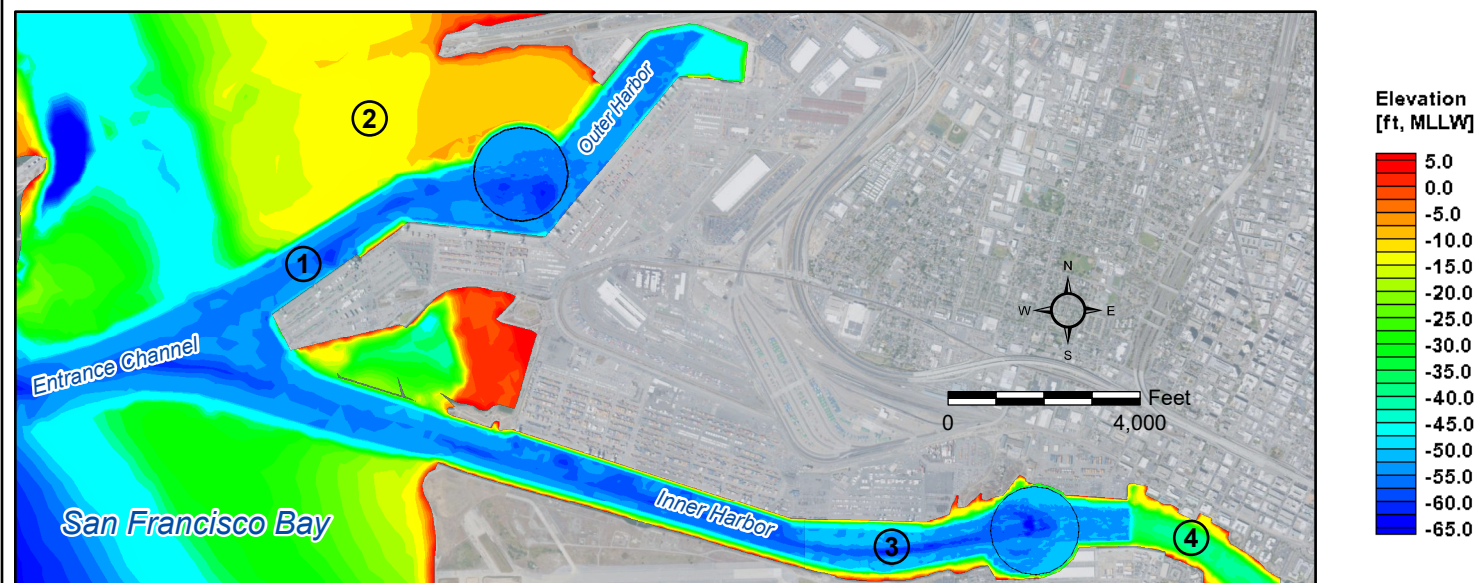
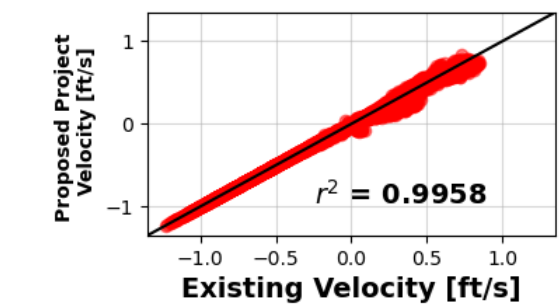
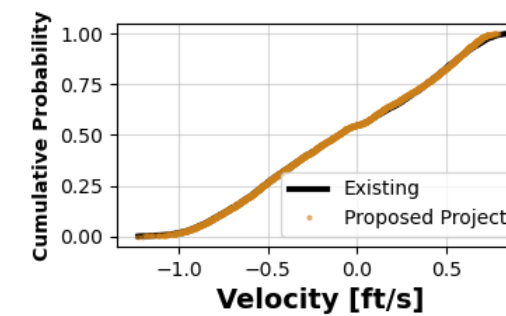
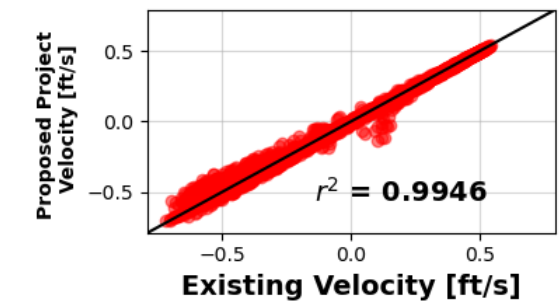
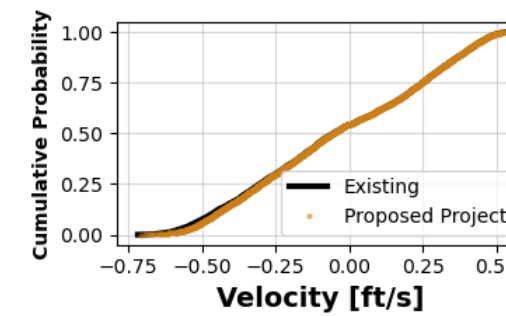
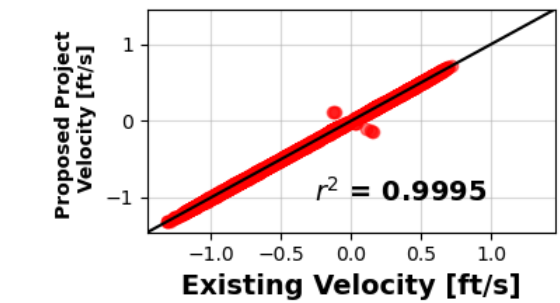
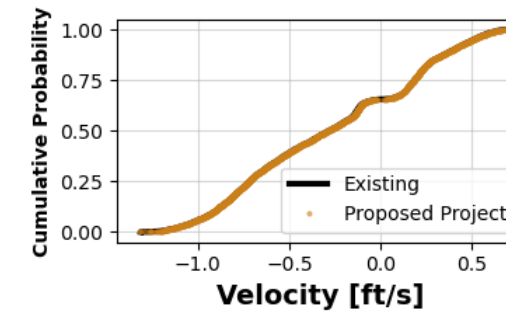
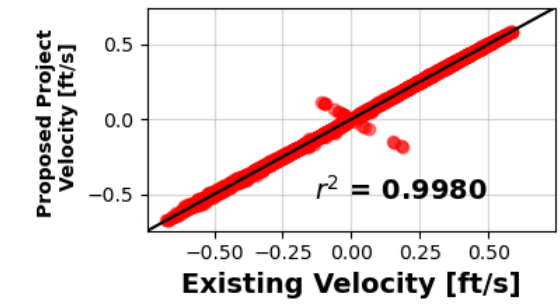
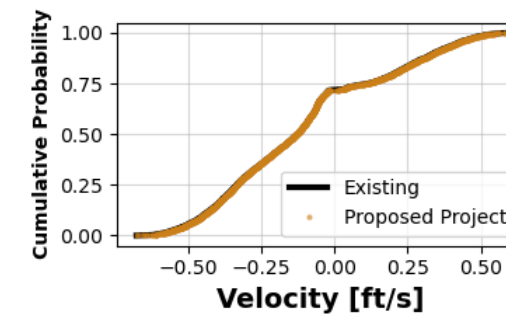
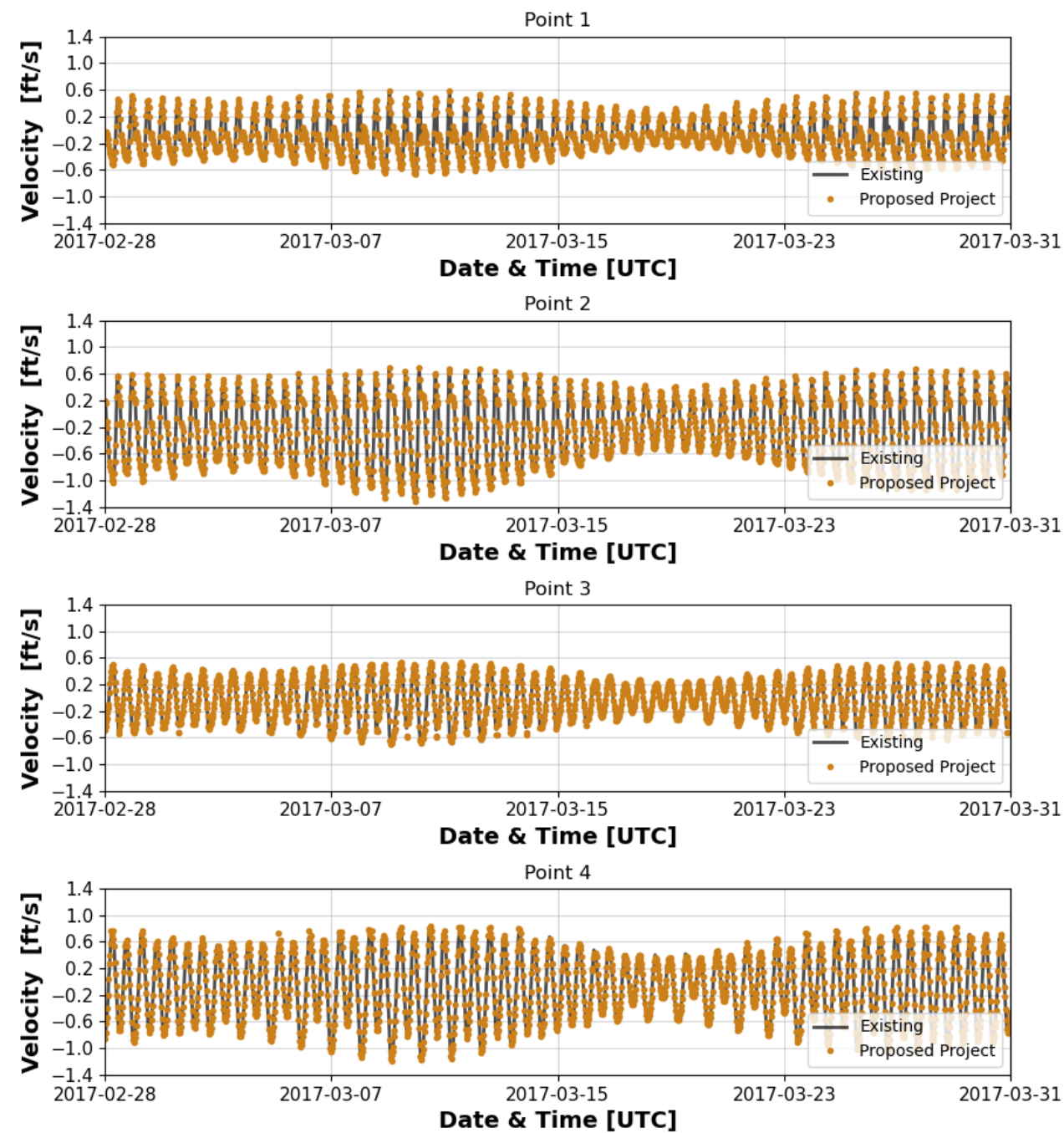


Figure 11

Comparison Between Current Velocities for Existing Conditions and Proposed Project Conditions, at Locations Adjacent to the Turning Basins (Higher-Flow Sensitivity Test Simulation)

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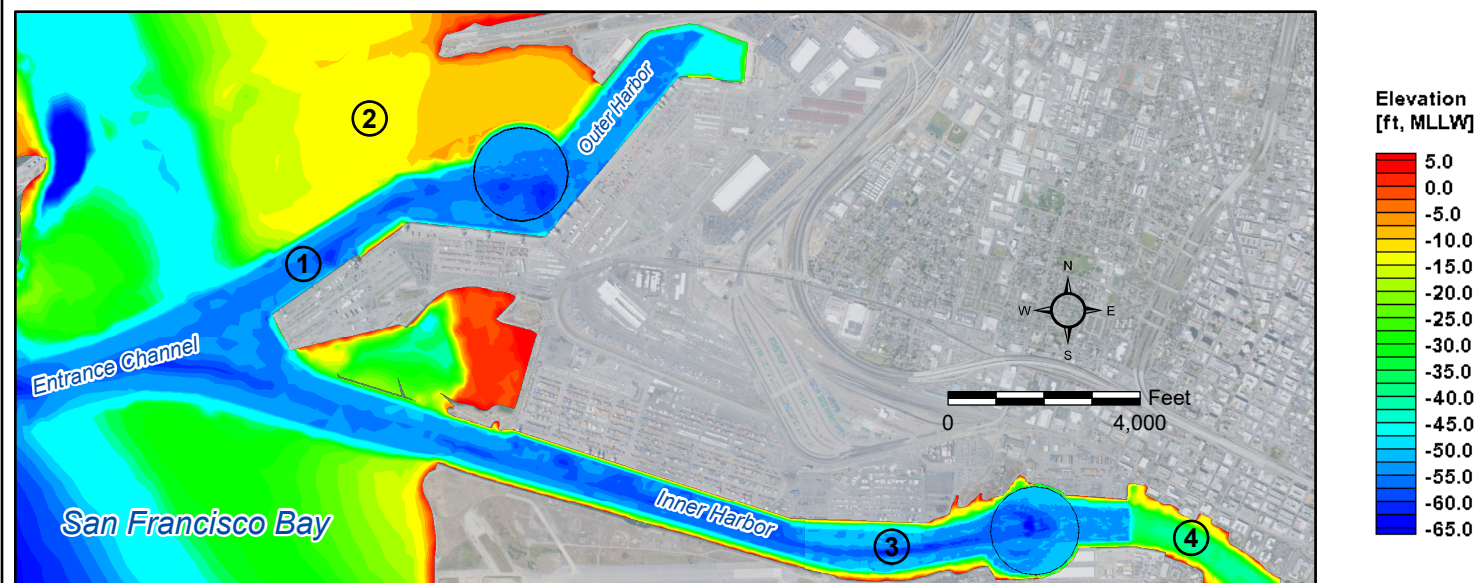
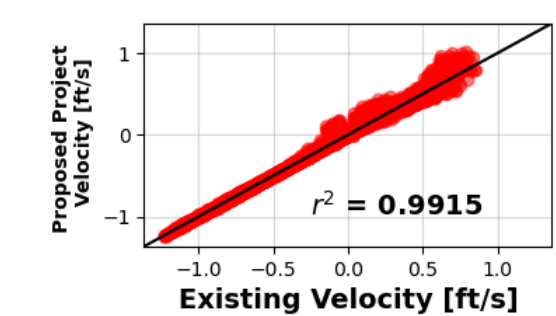
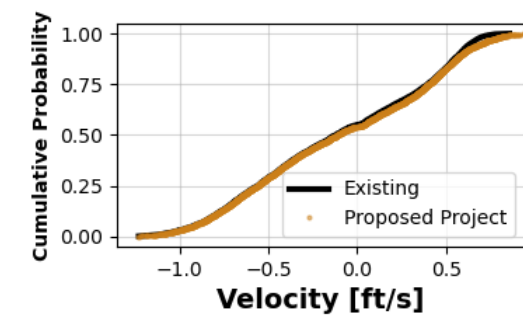
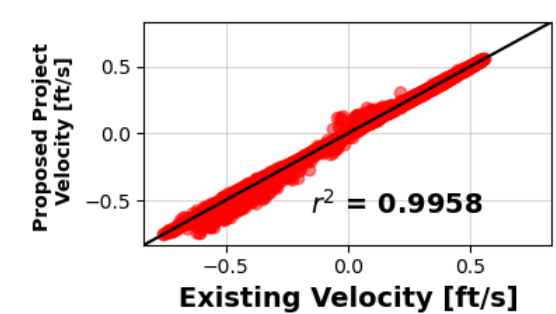
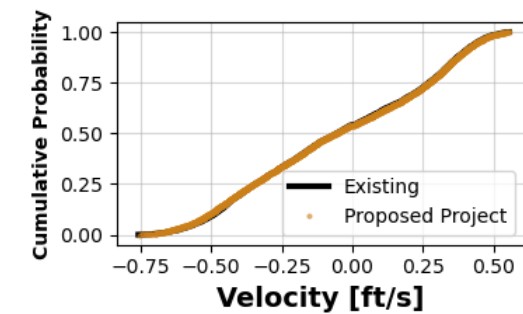
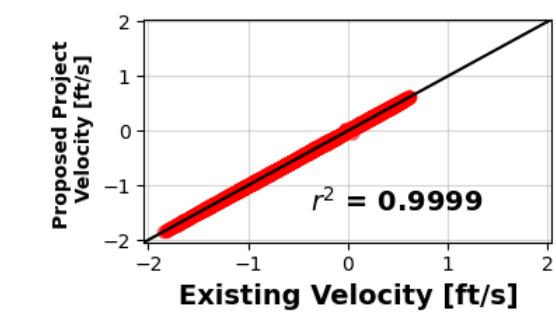
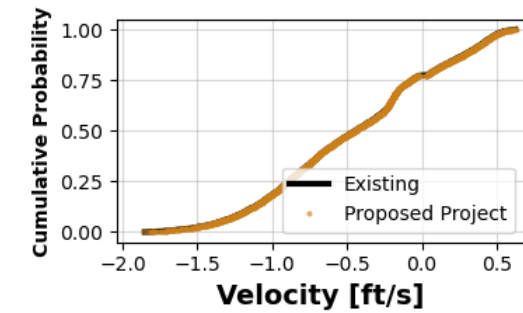
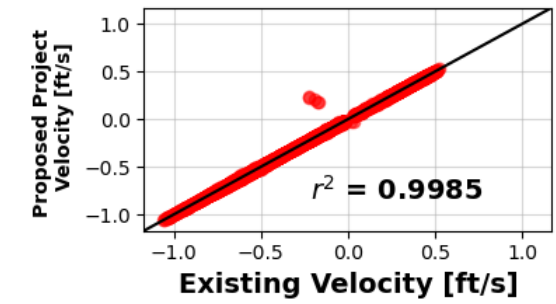
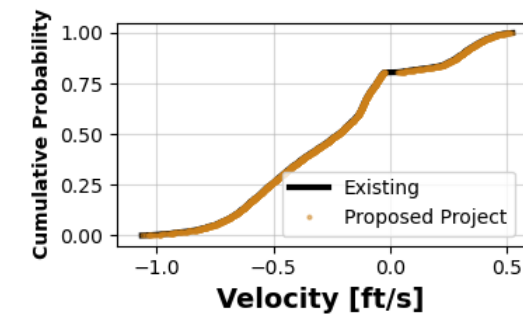
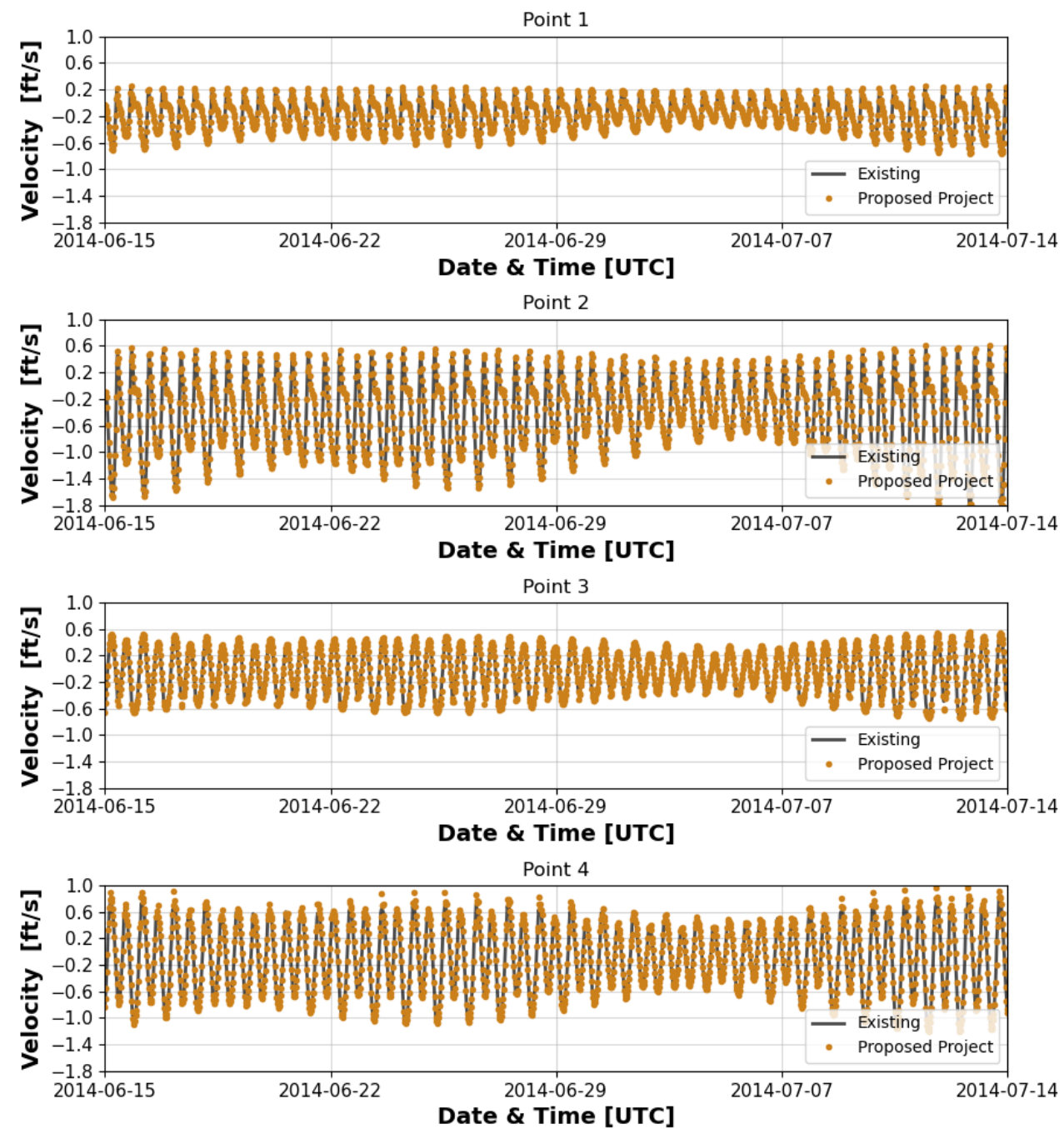


Figure 12

Comparison Between Current Velocities for Existing Conditions and Proposed Project Conditions, at Locations Adjacent to the Turning Basins (7.5 ft Sea Level Rise Sensitivity Test Simulation)

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