APPENDIX B
Sea Level Rise Analysis

moffatt & nichol

3780 Kilroy Airport Way, Suite 600
Long Beach, CA 90806

(562) 426-9551 ❖ Fax: (562) 424-7489
www.moffattnichol.com

Memorandum

To: Angela Reynolds, City of Long Beach

From: Chris Webb and Weixia Jin

Date: July 2, 2015

Subject: Sea Level Rise Modeling for SEADIP Area

Project: City SEADIP Project

1.0 INTRODUCTION

The City of Long Beach (the City) is updating their Local Coastal Program to address the Southeast Area Development Improvement Plan (SEADIP). As part of that work, the City needs to address sea level rise scenarios. The California Coastal Commission (CCC) provided guidance to the public for assessing sea level rise in planning (CCC, 2015). The City has retained Moffatt & Nichol (M&N) to apply this guidance to the SEADIP; specifically M&N was tasked to model the SEADIP Planning Area to predict areas that may be inundated by seawater under certain conditions. This document is a technical reference memorandum for use by the SEADIP planning team to consider in formulation of development actions into the future.

The CCC suggests that planning consider a range of sea level rise (SLR) scenarios. The City's planning document will address development actions out to year 2060. Therefore, sea level rise scenarios anticipated to potentially occur at that time horizon are considered in this SEADIP planning technical memo.

The SEADIP planning area is shown in Figure 1-1 on the following page. The area includes water bodies within all of Alamitos Bay and Marine Stadium, as well as portions of the Los Cerritos Channel and the San Gabriel River. Land areas border the water areas and include the Los Cerritos Wetlands, business areas along Pacific Coast Highway (PCH), residential areas north of Los Cerritos Channel both east and west of PCH, and the industrial areas straddling the San Gabriel River that include the AES and Haynes Power Plants.

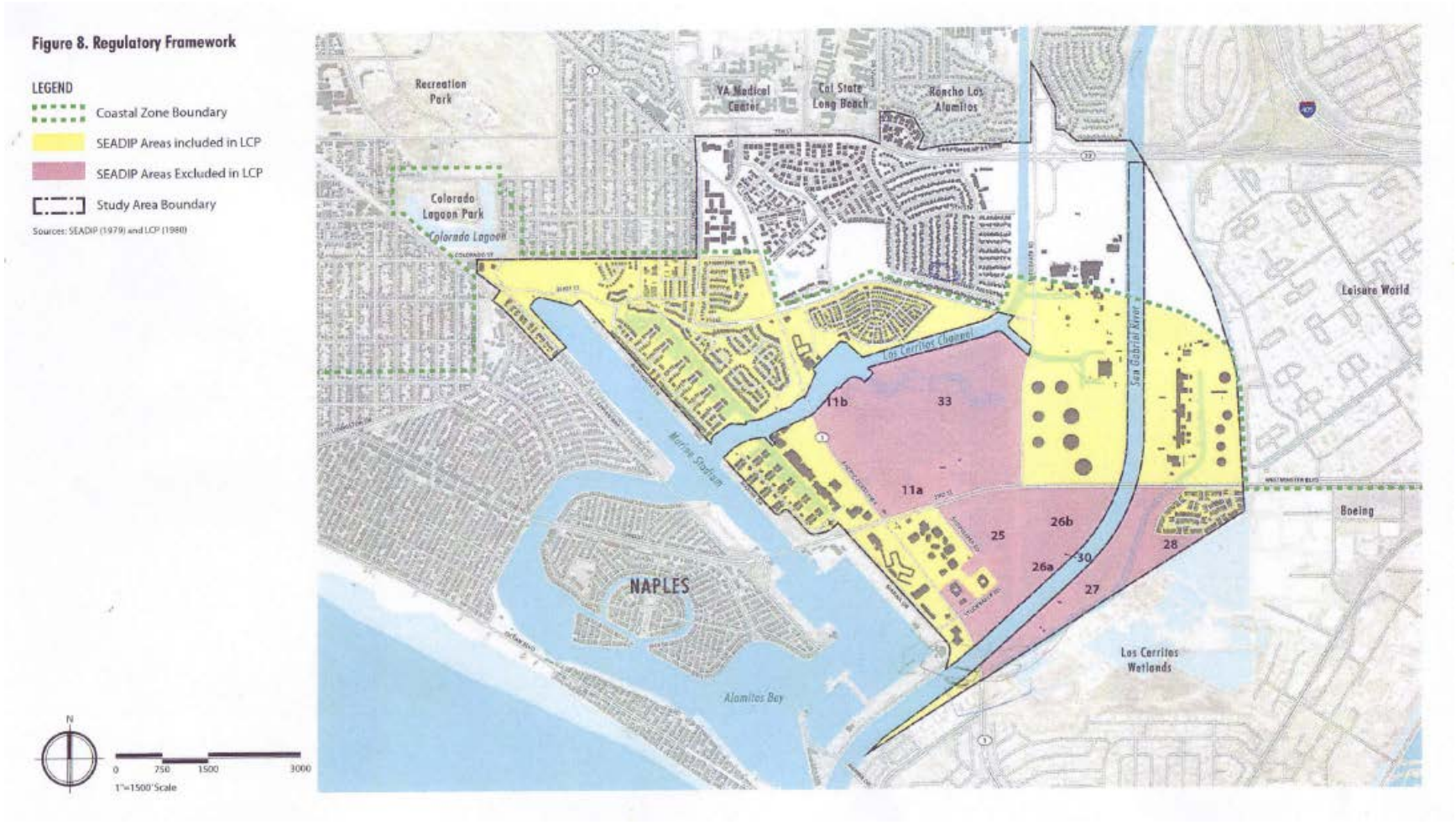

Figure 1-1: SEADIP Planning Area

2.0 STUDY OVERVIEW

This study follows the scope of work agreed upon between the City and M&N on February 3, 2015. Specific tasks include:

1. **Expand the Existing Hydrodynamic Model Area to Cover All Potential Risk Areas:** In 2011, M&N developed a numerical model to simulate the waterways in this area as part of the Los Cerritos Wetlands Conceptual Restoration Plan (CRP) (Moffatt & Nichol, 2011). This task entails adding areas within the SEADIP Planning Area that may be vulnerable to future inundation and that were not included in the model for Los Cerritos Wetlands.
2. **Model Existing Conditions and Two Sea Level Rise Scenarios, One With and Without Stormflow:** Model existing conditions, two SLR scenarios for the dry season and one SLR scenario for the wet season to identify potential areas of inundation. The two SLR scenarios were identified based on the range of projected SLR for the year 2060; the two SLR values modeled are 1.5 feet (ft), a median projection, and 2.6 ft, a high projection. Both of these conditions shall be modeled for the dry season, while the high SLR projection of 2.6 ft shall also be modeled for the wet season. The wet season simulation will model the 50-year stormflow from the Colorado Lagoon, the Los Cerritos Channel and the San Gabriel River, occurring coincident with a future high tide.
3. **Prepare Maps of Inundation Areas:** Results of the study will be presented as digital maps of areas to possibly be inundated by the scenarios modeled using the ArcView Geographic Information System (GIS). The City can use these maps as an overlay file in the SEADIP Planning Project.

3.0 METHODS

The model developed for this study is a two-dimensional depth averaged finite element hydrodynamic numerical model referred to as RMA-2, a federally-developed and approved model for tidal and storm flows. The model provides data of water levels and water flow velocities over time and space, and can be efficiently applied to this planning task with high accuracy. A description of this model, as well as a rationale for its selection for this application, can be found in Moffatt & Nichol, 2011.

3.1 MODEL DOMAIN

The RMA2 model requires the hydraulic system to be represented by a network of nodal points defined by coordinates in the horizontal plane and by water depths; elements are

created by connecting these adjacent points to form areas. Nodes can be connected to form 1- and 2-dimensional elements, having two to four nodes. The resulting nodal/element network is commonly called a finite element mesh and provides a computerized representation of the basin geometry and bathymetry.

As stated in Section 2.0, the RMA2 model for this study was based on a similar model for the Los Cerritos Wetlands (Moffatt & Nichol, 2011). The domain of this model included the entire Alamitos Bay, Marine Stadium, Colorado Lagoon, several miles along the San Gabriel River and Los Cerritos Channel, and the nearshore ocean. The ocean boundary is approximately two miles from the shoreline; this distance was deemed to be sufficient to minimize boundary effects within the area of interest. The domain for this model can be seen in Figure 3-1; Moffatt & Nichol, 2011 contains a complete description of the model.

Figure 3-1. Finite Element Model for the Los Cerritos Wetlands Model (aerial image courtesy of Google Earth)

The Los Cerritos Wetlands model was expanded for this study to include land areas within the SEADIP that may be vulnerable to inundation. This process involved adding additional nodes, defined by their geospatial location and elevation. Elevation data were based on topographic data provided by the City (City of Long Beach, 2015). In addition, bathymetry in the San Gabriel River was updated based on as-built plans provided by U.S. Army Corps of Engineers (USACE, 1960).

The model domain and finite element mesh used for the SEADIP Planning Area SLR study can be seen in Figure 3-2; Figure 3-3 shows the same mesh in the vicinity of the SEADIP Planning Area.

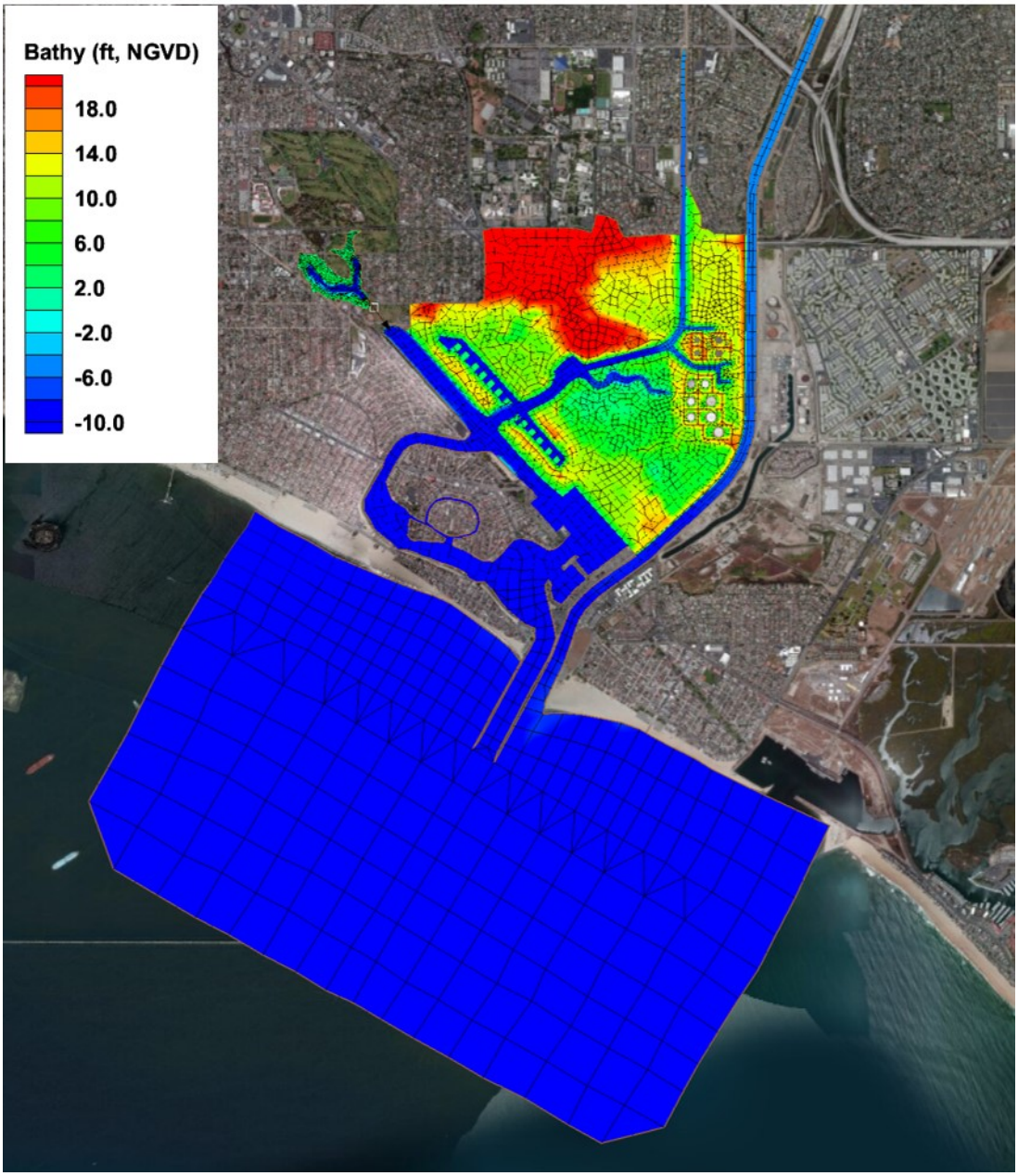

Figure 3-2. SEADIP SLR Study Model Domain and Finite Element Mesh

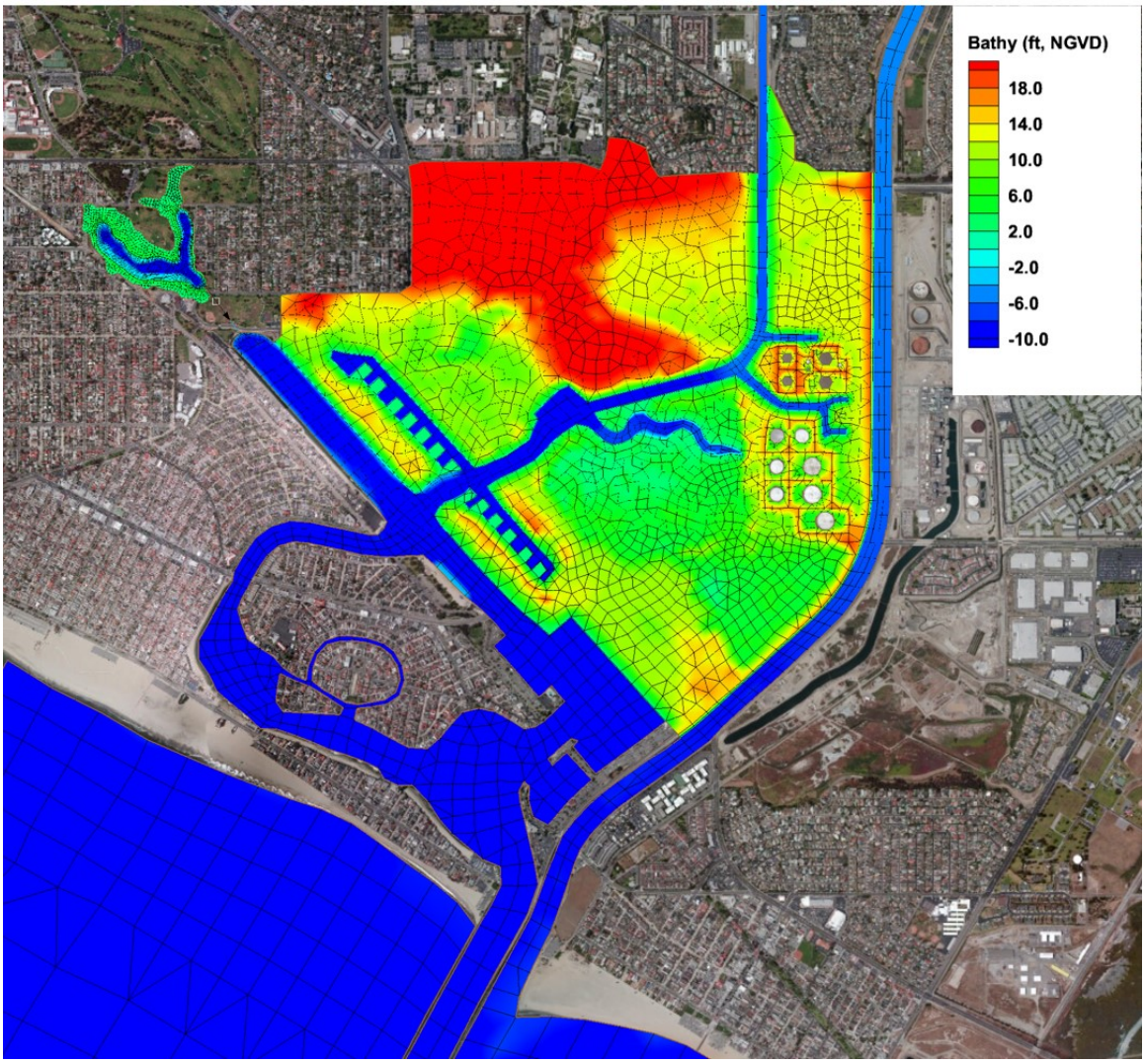

Figure 3-3. RMA2 Finite Element Mesh for the SEADIP Planning Area

3.2 BOUNDARY CONDITIONS

Boundary conditions are the inputs to the model. These include the tides, sea level rise, and storm event runoff. Dry season runoff is negligible in comparison to tidal and storm inputs to the wetlands and is not included in the two dry season simulations. Groundwater within the study area has a relatively high elevation, has been found to be saline and is strongly influenced by tidal movement (AECOM, 2011), however is not a relevant factor for hydraulic modeling of SLR impacts.

3.2.1 Tides

There are no official tide stations within Alamitos Bay; the nearest tide station administered by National Oceanic and Atmospheric Administration (NOAA) at Los

Angeles Outer Harbor (NOAA, 2004) was assumed to represent the ocean boundary tidal conditions. The diurnal tide range is approximately 5.49 ft from Mean Lower Low Water to Mean Higher High Water. Tidal data were analyzed to extract a two week period selected to represent typical spring tide conditions; this two week tidal record can be seen in Figure 3-4.

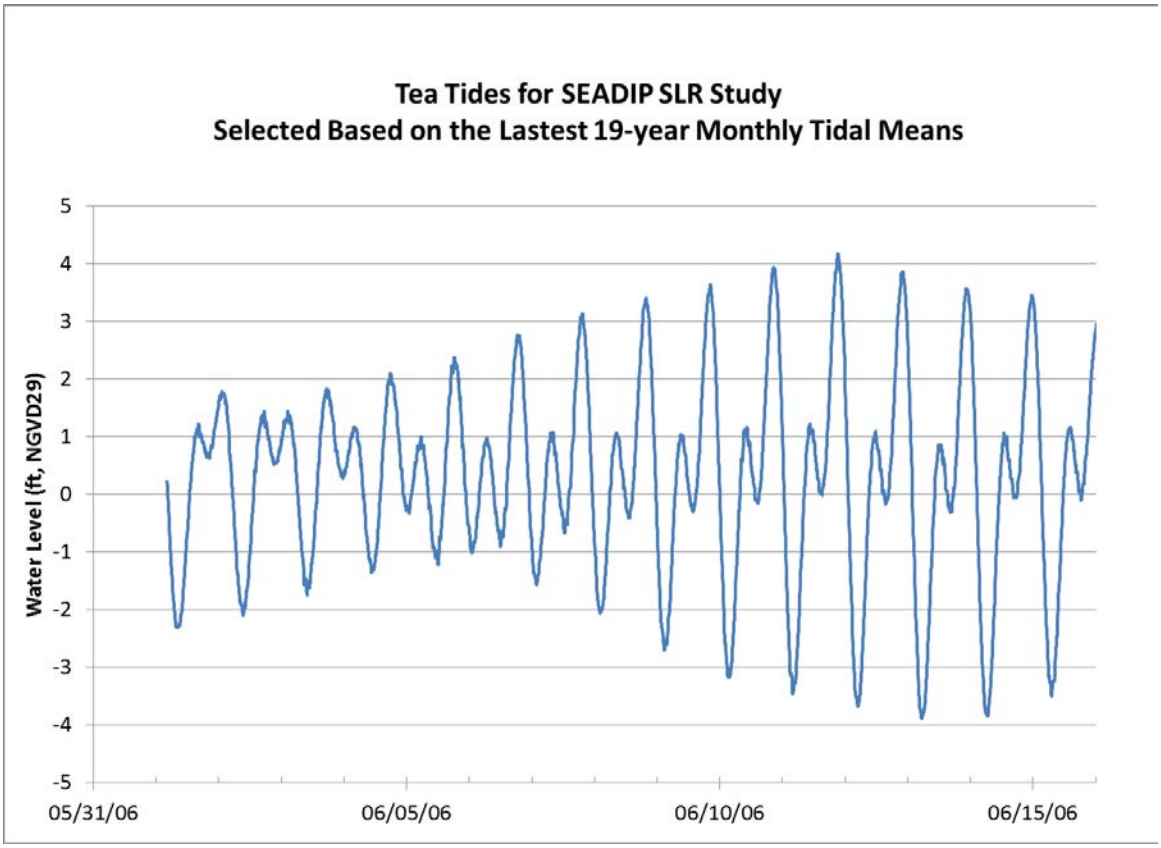

Figure 3-4. Typical Spring Tides

3.2.2 Sea Level Rise

As mentioned in Section 2.0, SLR values of 1.5 ft and 2.6 ft were simulated for this study. These values are based upon projections for 2060 contained in NRC, 2012 – generally considered the best available science for the region at the time of this memorandum. Data derived from the NRC report were used to project the range of potential SLR values at year 2060 to be 0.5 ft to 2.6 ft; thus, 1.5 ft represents a median SLR value and 2.6 ft represents an upper-end SLR scenario. Sea level rise was simulated by adding 1.5 ft and 2.6 ft to the ocean water levels used for modeling.

3.2.3 Storm Events

The wet season simulation considered simultaneously occurring 50-year stormflow in the San Gabriel River, the Los Cerritos Channel, and the Colorado Lagoon. The hydrograph for the San Gabriel River was derived from USACE, 1991; the hydrograph for the Los

Cerritos Channel was provided in Imaa, 2015, and the hydrograph of outflow from the Colorado Lagoon was provided in Everest International Consultants, Inc., 2007. The 50-year hydrographs for all of these sources can been seen in Figure 3-5.

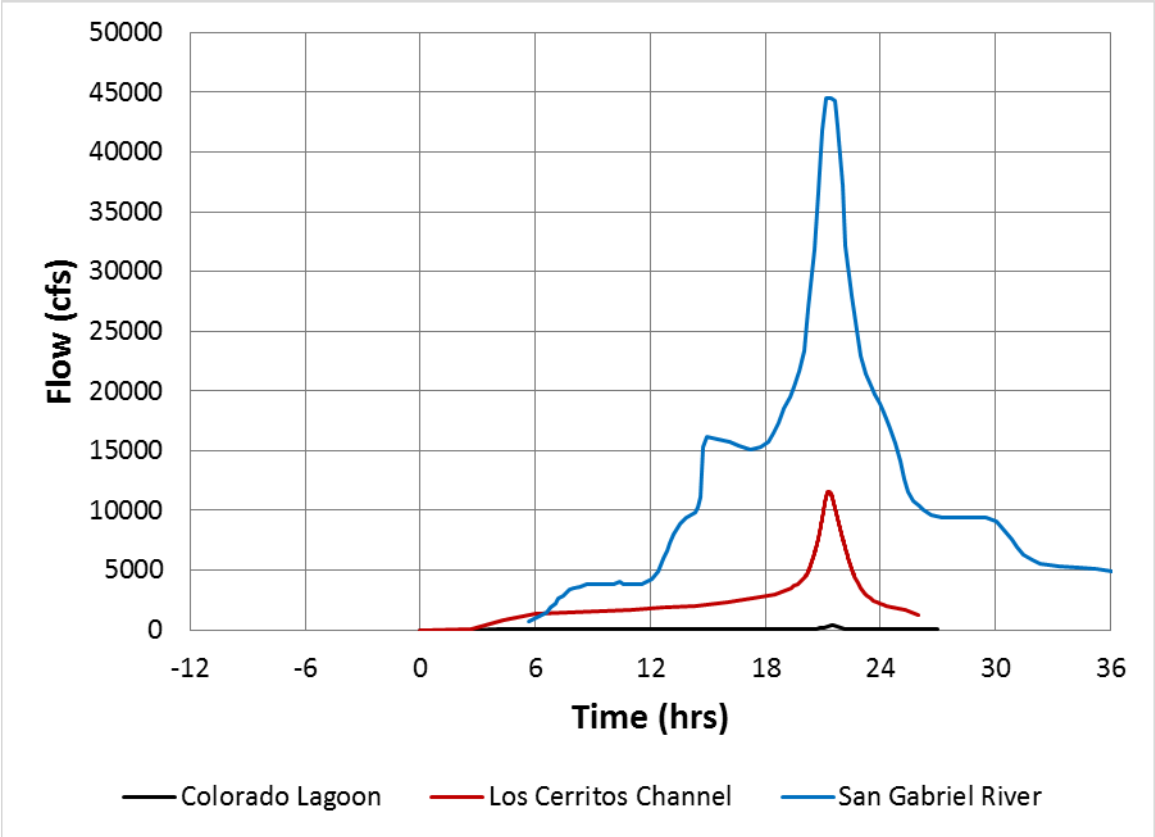

Figure 3-5. 50-year Hydrograph for the Colorado Lagoon, the Los Cerritos Channel, and the San Gabriel River

3.3 SIMULATIONS

Four simulations were performed for this study:

1. Simulation 1 represented existing tides without SLR during dry conditions;
2. Simulation 2 included 1.5 ft of SLR during dry conditions;
3. Simulation 3 included 2.5 ft of SLR during dry conditions, and
4. Simulation 4 included 2.5 ft of SLR and 50-year stormflow whose peak coincided with high tide.

Each simulation lasted approximately 48 hours. The first 12 hours served as a warm-up period and contained one high tide. The following 36 hours simulated 1.5 tidal cycles,

including the highest high tide shown in Figure 3-4. All simulations were performed using the NGVD29 vertical datum.

Figure 3-6 through Figure 3-9 show how a combination of the boundary conditions were applied to each simulation.

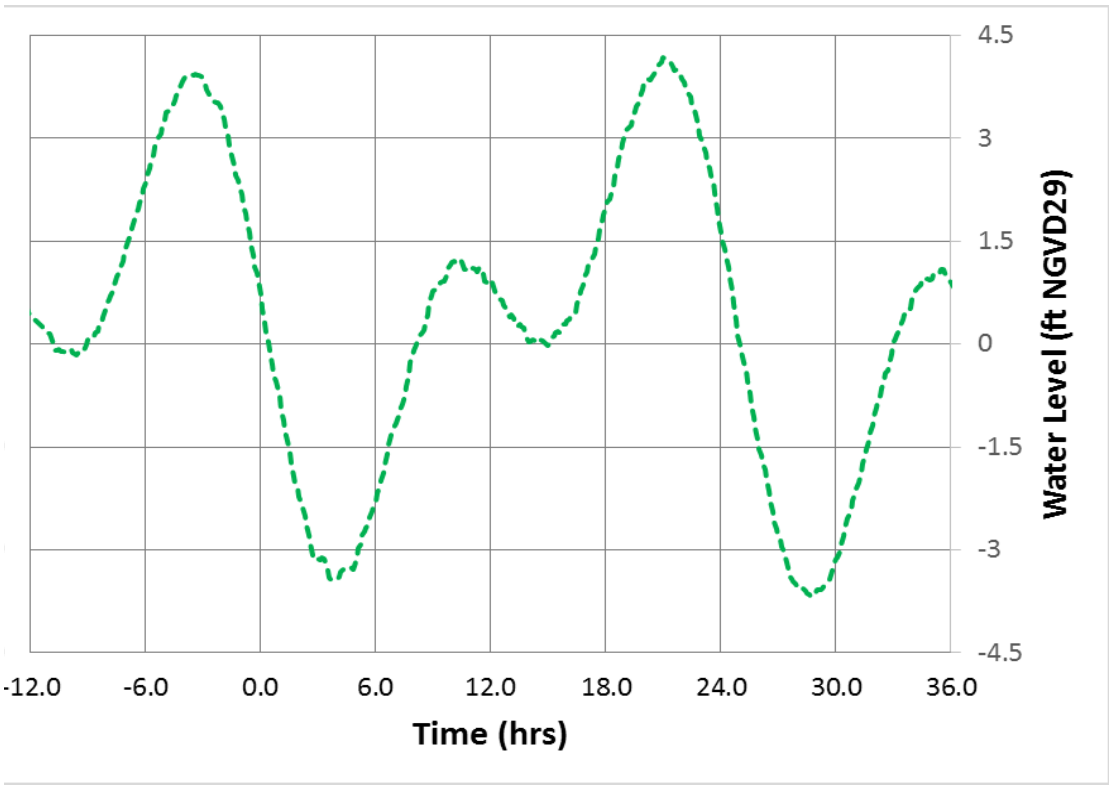

Figure 3-6. Simulation 1 Boundary Conditions

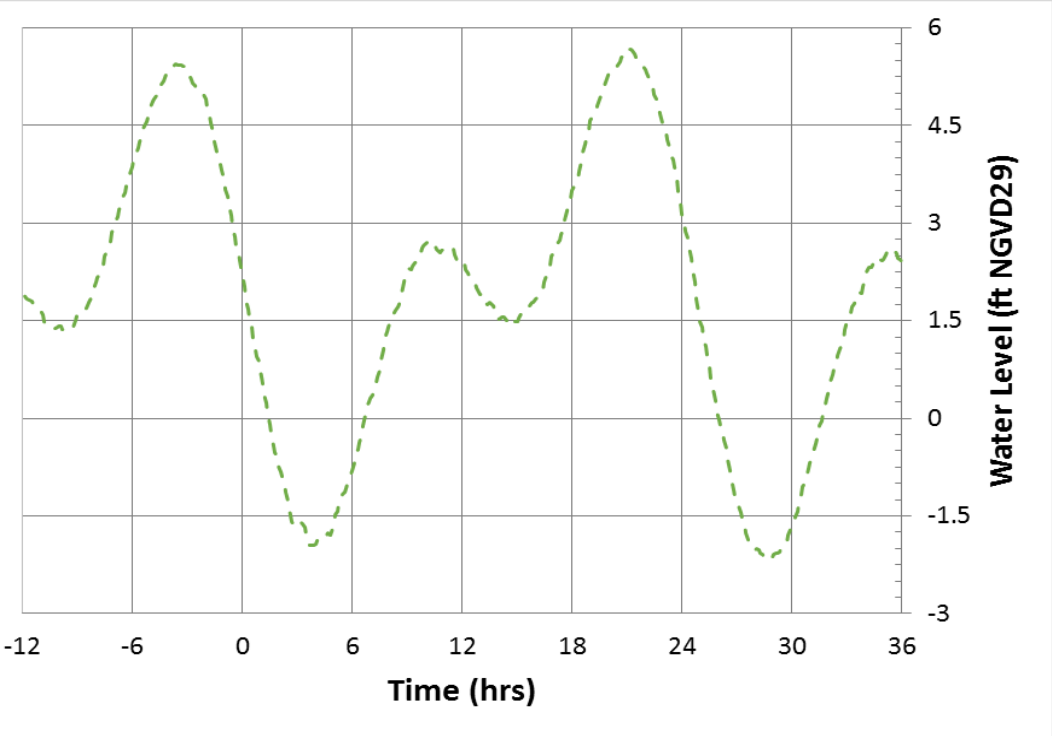

Figure 3-7. Simulation 2 Boundary Conditions

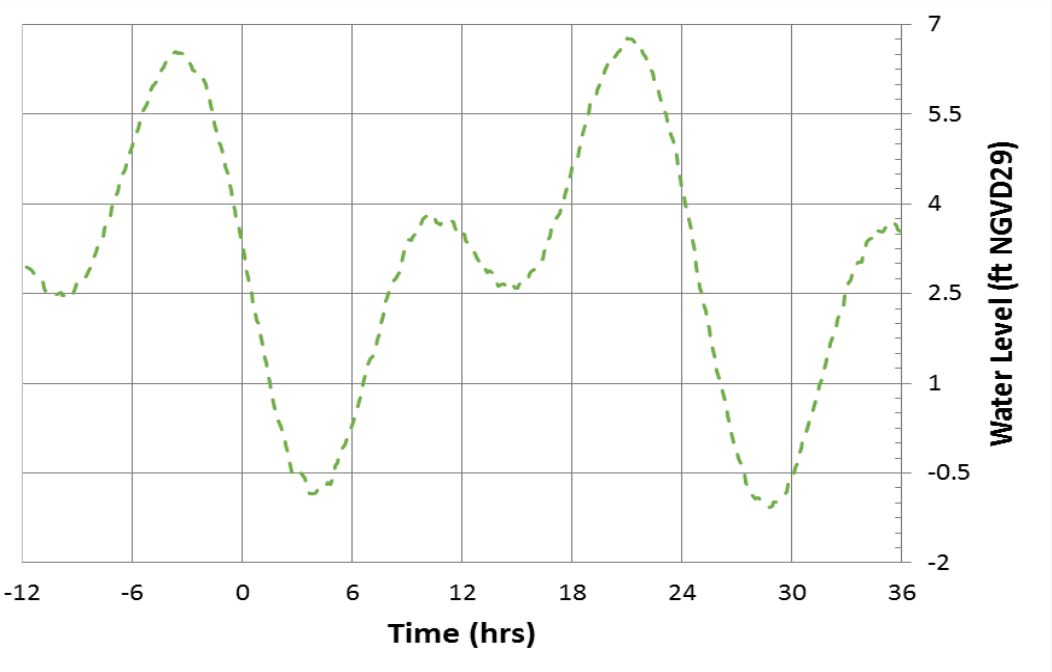

Figure 3-8. Simulation 3 Boundary Conditions

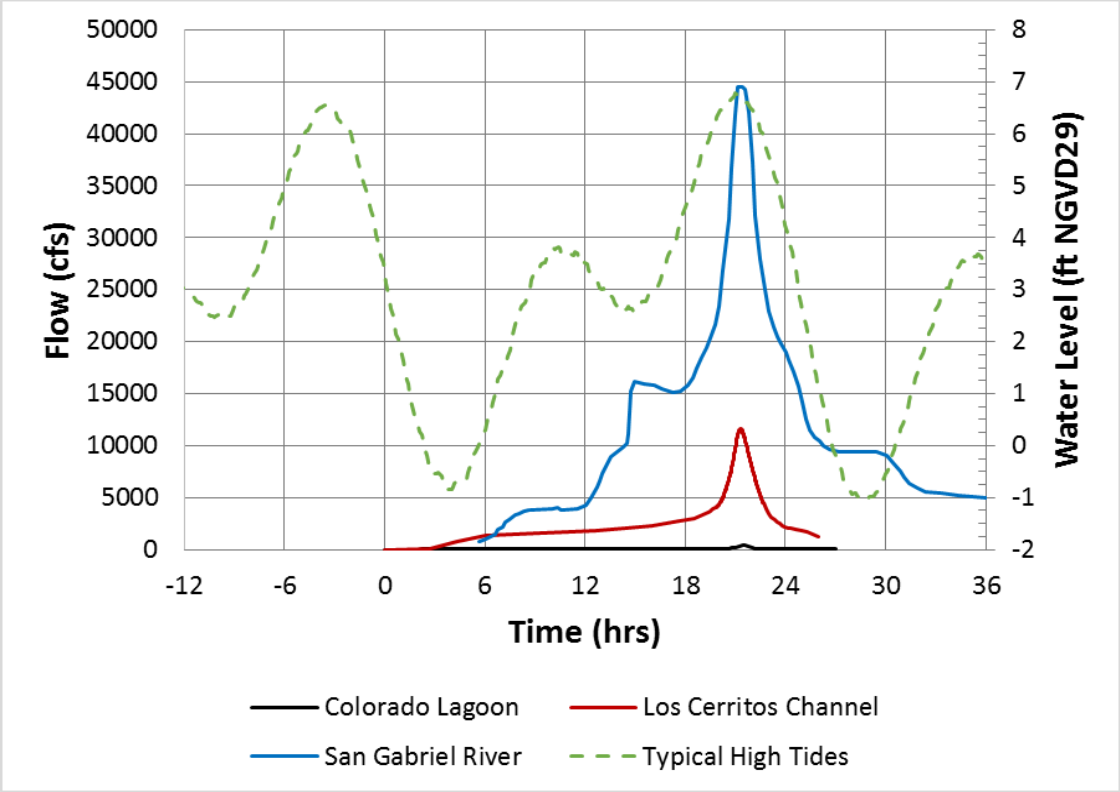

Figure 3-9. Simulation 4 Boundary Conditions

4.0 RESULTS

The results of this study include maps of areas within the SEADIP Planning Area that would possibly be inundated by the scenarios modeled; these maps can be seen in Figure 4-1 through Figure 4-4. Electronic versions (in ArcView Geographic Information System) are being provided to the City.

The area within the SEADIP boundary east of the San Gabriel River was modeled using a different method because it is connected to the River by culverts, and culvert flows are better approximated using a one-dimensional model. The area at that location is in use for industrial oil extraction, and two small wetlands exist. Water levels will rise at the wetlands by several feet during SLR conditions, and with SLR combined with a stormflow event. However, the portion of the site surrounding the wetlands is sufficient high that waters will be contained on-site within the wetlands and they would not expand significantly beyond their existing boundaries.

Areas to be affected with inundation by high water during the high-end sea level rise scenario analyzed herein (2.6 feet of sea level rise during dry weather) include the following sites:

- The PCH Club site east of Pacific Coast Highway (PCH) and north of Los Cerritos Channel;
- Jack Nichol Park west of PCH and north of Los Cerritos Channel;
- The intersection of Loynes Drive and Bellflower Boulevard;
- Azure Way and the Long Beach Bikeway route adjacent to Spinnaker Bay;
- East Elliot Street along the north end of Marine Stadium; and
- The west bound lanes of 2nd Street just east of PCH.

Recommendations for flood protection of these sites consist of evaluating the status of shoreline protection at each site and considering improvements, such as raising the elevation of the shoreline protection structure (e.g. seawall and/or rip-rap) along the perimeter of the adjacent water body. For example, the PCH Club site (the parking lot) may be able to be protected from flooding by raising the edge between land and water along the channel-side of the parking lot by at least one foot. The site is approximately 8.0 feet above North American Vertical Datum (NAVD, 1988) and high water is predicted to reach +9.0 feet NAVD in 2060 with high tide combined with a 50 year stormflow. Raising the entire parking lot may also be worth considering to more fully protect the site and eliminate seawater backing up through any storm drains, particularly for future predicted high waters subsequent in time to 2060. Figure 4-5 shows the condition of the existing shoreline along this location. Existing shore protection consists of large pieces of broken concrete dumped along the shore, with gunnite or grout poured over them. This type of material may be ineffective to adequately protect the shoreline during future predicted high waters. Figure 4-6 shows the elevation of the PCH Club site relative to surrounding areas, with predicted inundation areas outlined in red.

In addition, PCH south of Los Cerritos Channel is at an elevation of approximately +10 feet NAVD 88, so one foot of freeboard exists under the worst case high water scenario analyzed herein. Any increase in water levels above this scenario in the future may episodically threaten PCH in this area. Either raising PCH at this location or the privately-owned land area between PCH and the water may be viable options for the future.

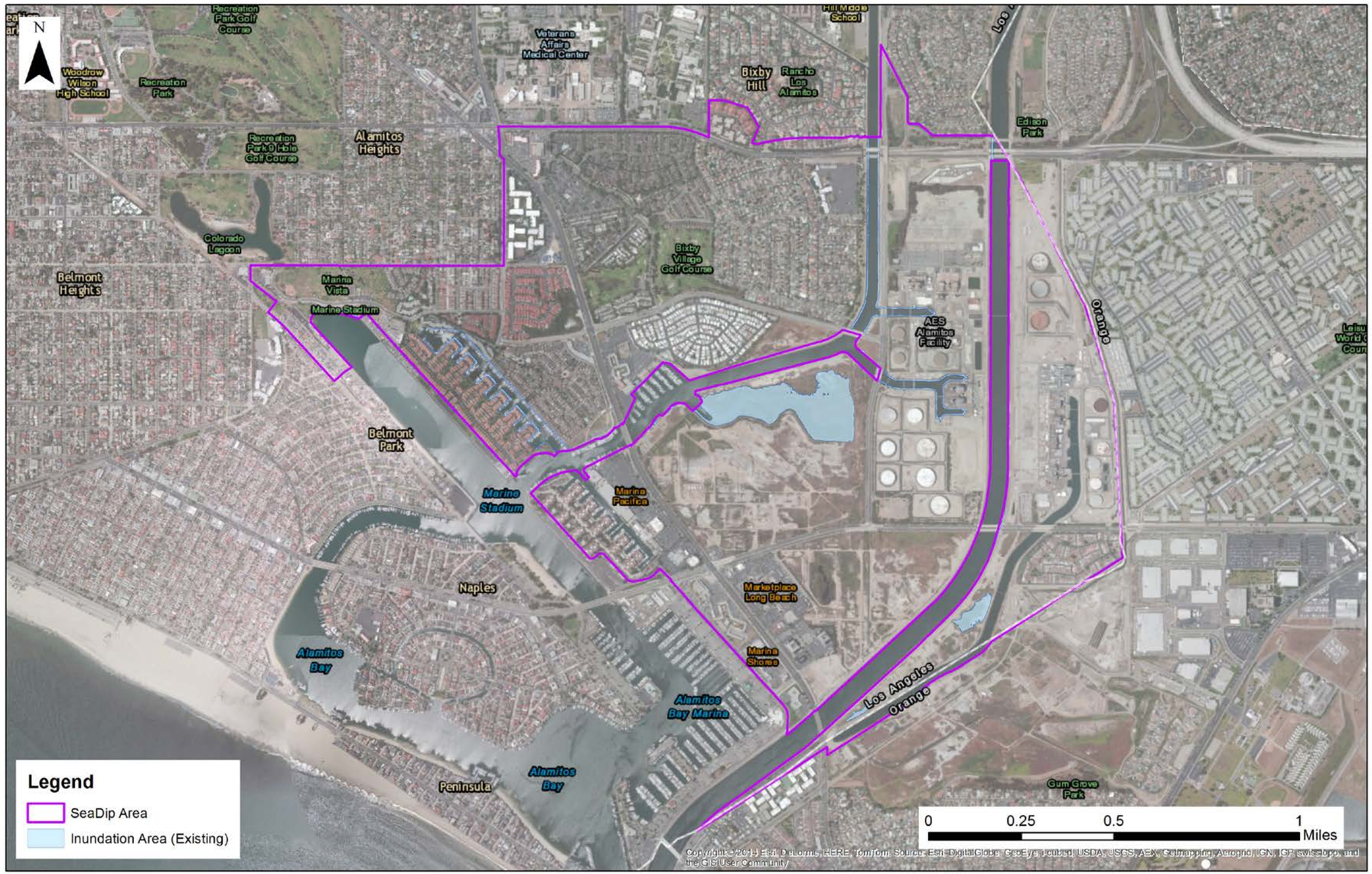

Figure 4-1. SEADIP Planning Area Possibly Inundated Under Existing Conditions

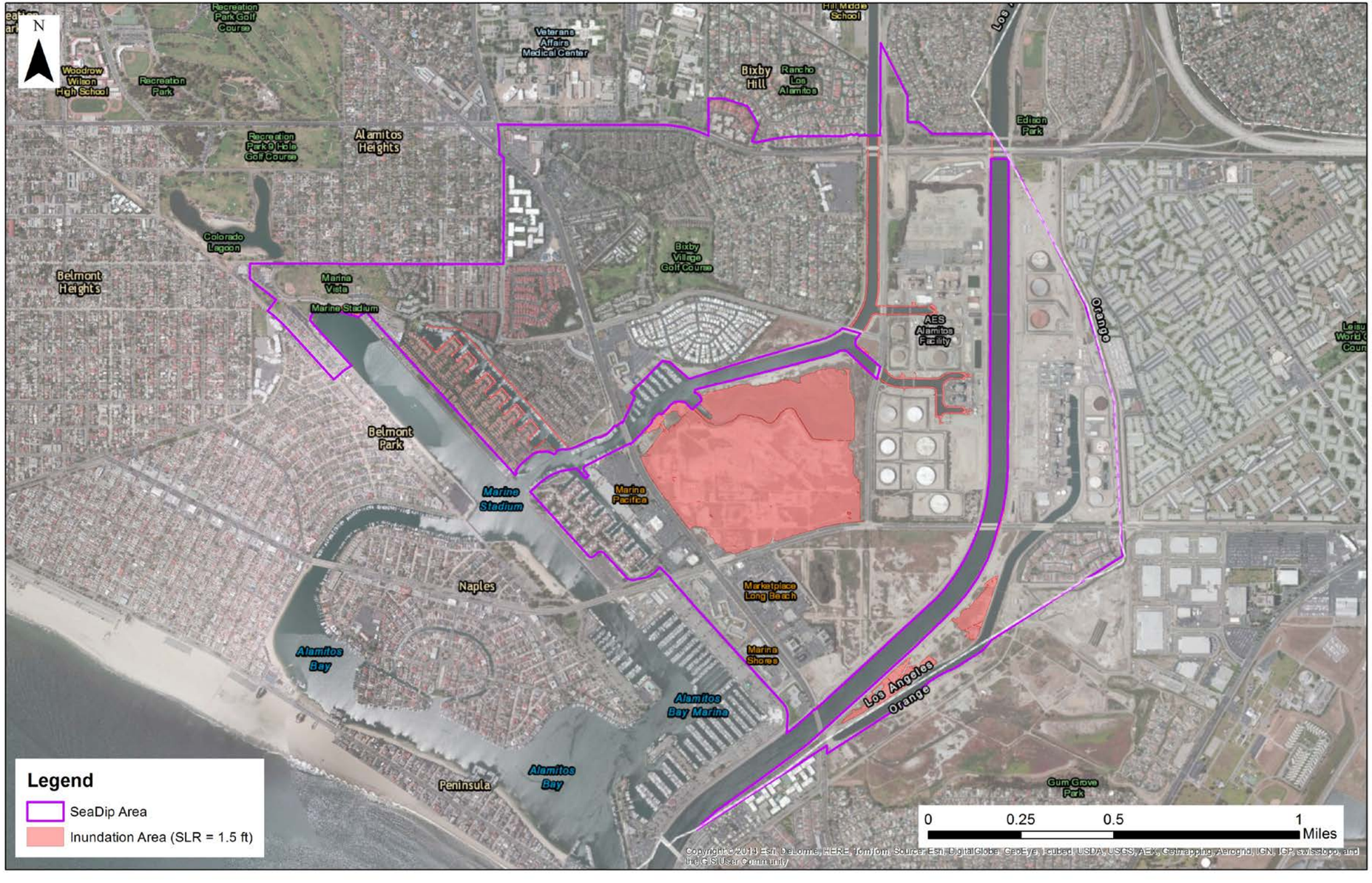

Figure 4-2. SEADIP Planning Area Possibly Inundated Under 1.5 Feet of Sea Level Rise, Dry Conditions

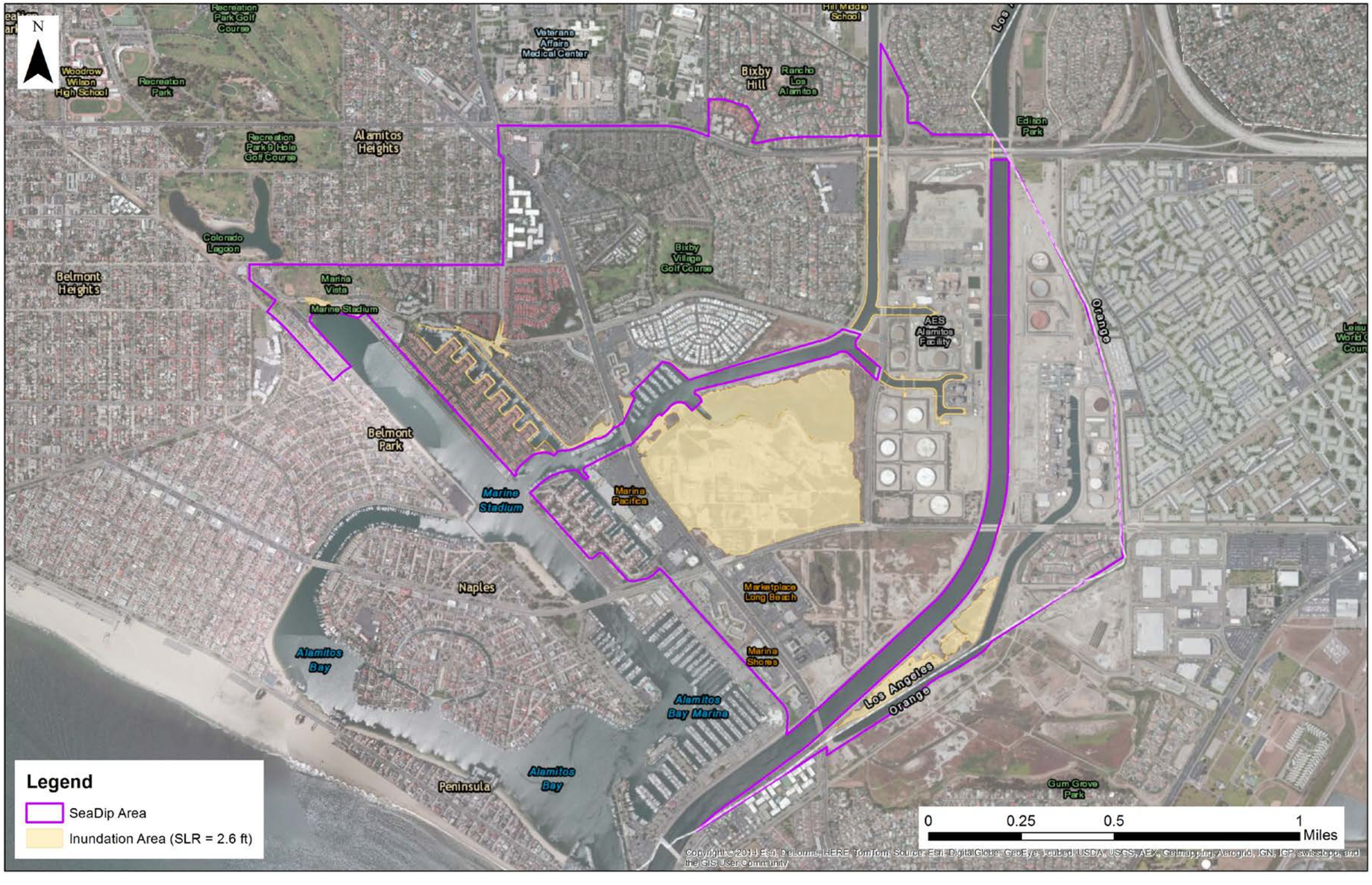

Figure 4-3. SEADIP Planning Areas Possibly Inundated Under 2.6 Feet of Sea Level Rise, Dry Conditions

Figure 4-4. SEADIP Planning Areas Possibly Inundated Under 2.6 Feet of Sea Level Rise and 50-Year Stormflow

Figure 4-5. The Existing Shoreline Condition of the PCH Club Site (Parking Lot) Within the SEADIP Planning Area

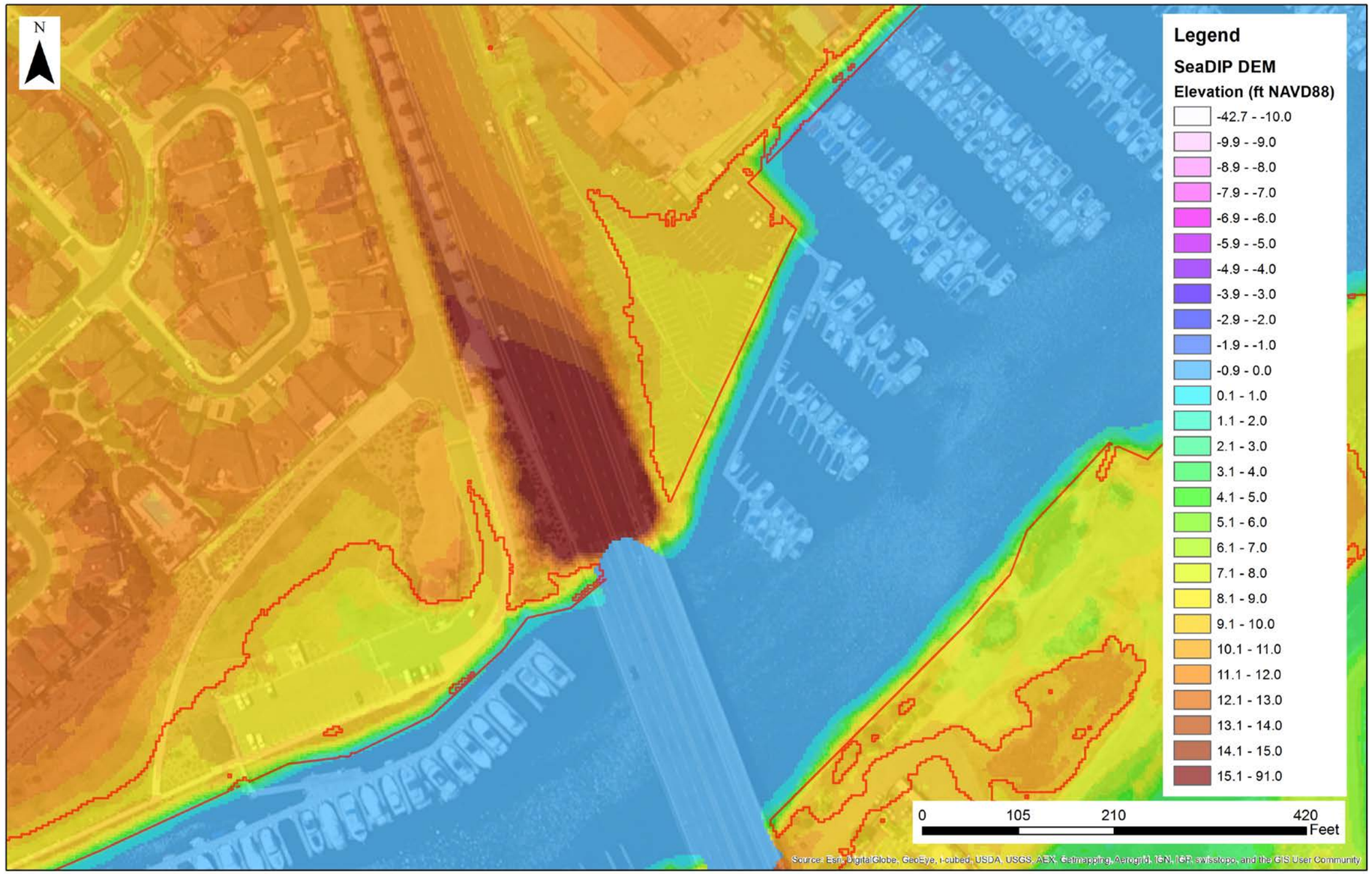

Figure 4-6. The Existing Elevation of the PCH Club Site With Predicted Inundation Areas Outlined in Red

5.0 REFERENCES

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