APPENDIX C

Fluvial and Tidal Hydraulics Report

Buena Vista Lagoon Enhancement Project

Fluvial and Tidal Hydraulics Analyses

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August 29, 2014

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

2-D	Two-dimensional
Alt	Alternative
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources Model
BVLEP	Buena Vista Lagoon Enhancement Project
Caltrans	California Department of Transportation
cfs	cubic feet per second
CH	Coast Highway
CO-CAT	California Climate Action Team
COPC	California Ocean Protection Council
Everest	Everest International Consultants, Inc.
Exist.	Existing
ft	feet
h	horizontal
Hwy	Highway
I-5	Interstate Highway 5
Max	Maximum
MHHW	mean higher high water
MLLW	mean lower low water
MP	Milepost
N	north
NAVD88	North American Datum of 1988
NGVD	National Geodetic Vertical Datum of 1929
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NTCD	North County Transit District
NTDE	National Tidal Datum Epoch
RR	Railroad

S	south or second
SANDAG	San Diego Association of Governments
USACE	United States Army Corps of Engineers
v	vertical
yr	year

1. INTRODUCTION

1.1 BACKGROUND

The Buena Vista Lagoon (Lagoon) is located on the border between the cities of Carlsbad and Oceanside in San Diego County, California. The Lagoon covers an area over 200 acres. Although the majority of the Lagoon is owned and managed by the California Department of Fish and Wildlife (CDFW), other public agencies and private parties own portions of the Lagoon. The portion of the Lagoon owned and managed by CDFW is designated a State Ecological Reserve.

Historically (e.g., pre-1940s), the Lagoon was in a dynamic equilibrium between a tidal-influenced Saltwater system during dry conditions and a river-influenced freshwater system during wet weather. Over time the Lagoon was converted to a fully freshwater system as a result of highway, roadway, and railroad construction as well as installation of a weir at the ocean outlet. The Lagoon has been progressively degrading in terms of benefits and value to biological communities, habitats, and human uses. Without enhancement, it will most likely become a vegetated freshwater marsh or riparian woodland-meadow in the future. This degradation would reduce or eliminate wetland functions and values as well as result in increased vector concerns, water quality impairments, and aesthetic impacts.

The San Diego Association of Governments (SANDAG) is leading an effort to restore the Lagoon. The Buena Vista Lagoon Enhancement Project (BVLEP) would restore over 200 acres of wetland habitat. Infrastructure modifications that may be considered for this project include changes to Carlsbad Boulevard and the creation of a tidal inlet. Infrastructure improvements to existing lagoon crossings that are currently being planned or designed under other projects would be considered in the analyses of the BVLEP. These improvements include the Interstate 5 Bridge and the North County Transit District (NCTD) Railroad Bridge.

The California Department of Transportation (Caltrans) is currently working on the development of a project to improve Interstate 5 (I-5) throughout northern San Diego County. Implementation of this project will entail construction work across and within the coastal salt marsh Lagoons located throughout northern San Diego County, including the Lagoon. At this time, the type of work anticipated includes roadway and embankment widening as well as demolition of the existing I-5 Bridge and subsequent construction of a new I-5 Bridge.

NCTD is currently undertaking a railroad improvement project in northern San Diego County in the cities of Carlsbad and Oceanside. The project, which is known as the Carlsbad Village Double Tracking (CVDT) Project, will replace the existing single track railroad bridge that crosses the Lagoon with a double track railroad bridge. On behalf of NCTD, SANDAG is leading the program management, environmental review, and engineering design of the CVDT Project.

1.2 PURPOSE

The purpose of the fluvial hydraulics summarized in this report was to assess the potential impacts to flooding associated with the various enhancement alternatives. In addition, the results of the fluvial hydraulics were used to support conceptual design of the Carlsbad Boulevard Bridge and embankment prepared by AECOM. The purpose of the tidal hydraulics was to provide the hydrologic information needed to develop the grading necessary to support the target habitat distribution for tidally influenced wetlands habitats. In addition, the results of the tidal hydraulics were used to estimate the rate of littoral sedimentation, which, in turn, was used to develop a maintenance dredging program for the tidal inlet. Finally, the fluvial and tidal hydraulics analyses were used to assess the impact of future sea level rise on flooding and habitat type conversion.

1.3 OBJECTIVES

The following objectives were established to fulfill the purpose summarized above.

- Establish baseline conditions for comparison with enhancement alternatives.
- Conduct fluvial hydraulic modeling under current (Year 2015) sea level condition to estimate flood levels for existing and proposed conditions.
- Conduct tidal hydraulic modeling under current (Year 2015) sea level condition to estimate tidally influenced wetlands habitat distributions.
- Conduct fluvial hydraulic modeling under Year 2050 sea level condition to estimate flood levels for existing and proposed conditions.
- Conduct tidal hydraulic modeling under Year 2050 sea level condition to estimate tidally influenced wetlands habitat distributions.
- Conduct fluvial hydraulic modeling under Year 2100 sea level condition to estimate flood levels for existing and proposed conditions.
- Conduct tidal hydraulic modeling under Year 2100 sea level condition to estimate tidally influenced wetlands habitat distributions.

2. ALTERNATIVES ANALYZED

2.1 OVERVIEW

The enhancement alternatives were developed from past efforts in response to the need to improve and enhance the biologic and hydrologic functions of the lagoon. Each of the alternatives evaluated within this document seeks to enhance existing lagoon functions and services through dredging and grading as well as control of freshwater and saltwater inputs and outputs. The range of alternatives developed reflects differing water regimes as well as resulting habitat distribution. Appropriate infrastructure improvements are also included in the enhancement alternatives, as necessary.

2.2 FRESHWATER ALTERNATIVE

The Freshwater Alternative represents the enhancement configuration that was used to analyze and evaluate the freshwater hydrologic regime. This alternative achieves the enhancement objectives primarily through elimination of the existing exotic vegetation and dredging to remove excess sediment. It was assumed that the existing ocean outlet weir would be replaced with an 80-foot (ft) wide ocean outlet weir in accordance with the weir widening project that the City of Oceanside proposed previously. A plan view of the Freshwater Alternative is presented in Figure 2.1.

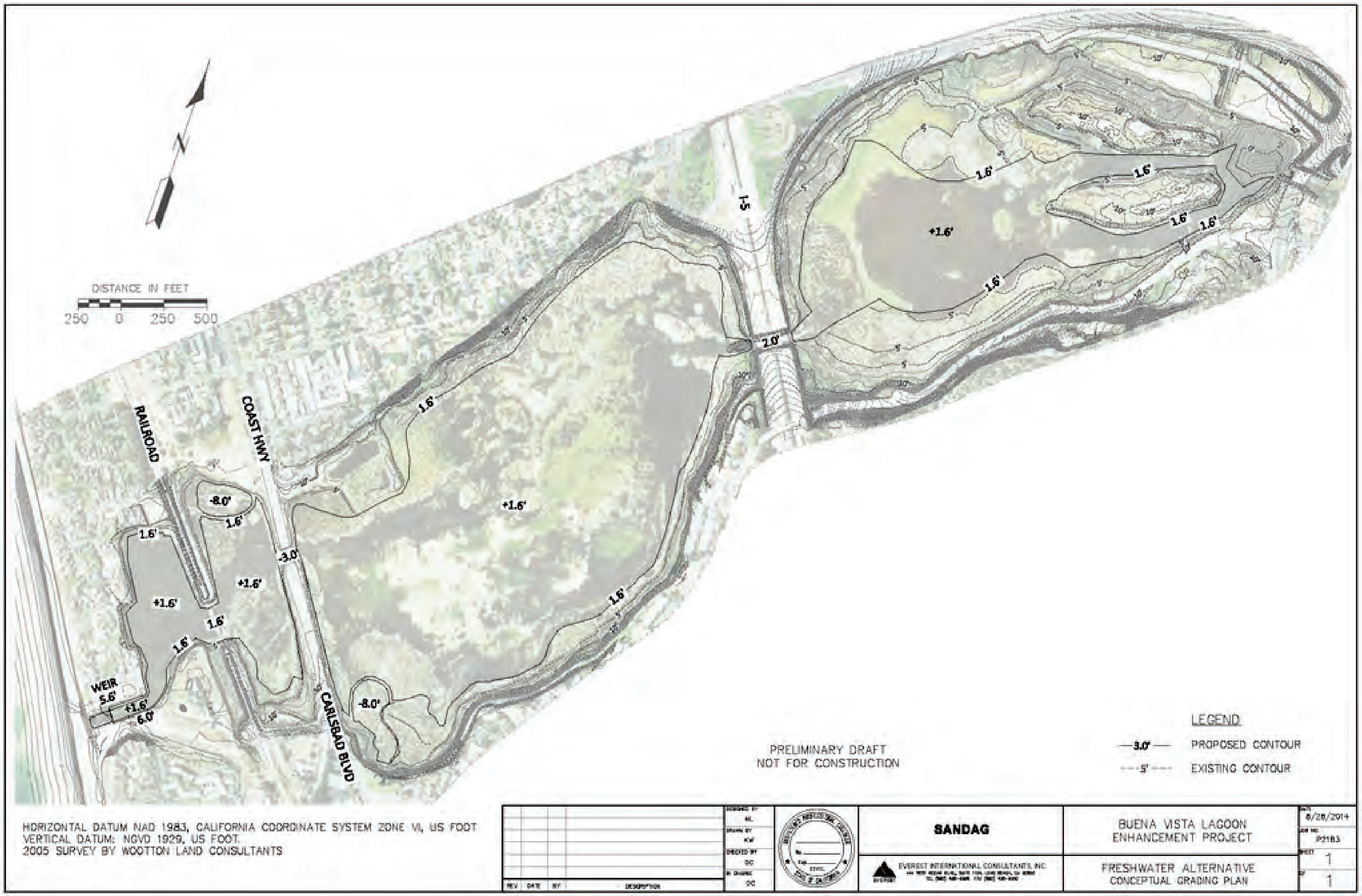

Figure 2.1 Freshwater Alternative Plan View

Prominent features of this alternative include:

- Removal and subsequent disposal of existing exotic vegetation.
- Excavation/dredging of 562,000 cubic yards (CY) of sediment.
- Creation of open freshwater habitat in the I-5 Basin with a general bottom elevation of +1.6 ft relative to the National Geodetic Vertical Datum of 1929 (NGVD).
- Creation of open freshwater habitat in the Coast Highway Basin with a general bottom elevation +1.6 ft NGVD.
- Creation of open freshwater habitat in the Railroad Basin and Weir Basin with a general bottom elevation +1.6 ft NGVD.
- The new I-5 Bridge structure being developed by Caltrans is considered in the analysis. The channel cross section would have the same bottom width and invert elevation as those of the existing channel cross section. The invert elevation would be +2 ft NGVD and the bottom width would be 24 ft. The side slopes would be 1V:1.5H on both sides of the channel.
- The existing Carlsbad Boulevard Bridge is considered in the analysis. The invert elevation would be -3 ft, NGVD. The hydraulic connection would be 29 ft wide with vertical slopes on both sides.
- The new Railroad Bridge structure being developed by NCTD and SANDAG is considered in the analysis. The channel invert elevation would be equal to the invert elevation of the channels upstream and downstream of the hydraulic connection, which would be -2.5 ft, NGVD. The bottom width of the channel would be 90 ft with a slope of 1V:8.5H on the north side and a slope of 1V:11.5H on the south side.
- Replacement of the existing 50-ft wide weir with an 80-ft wide weir at the ocean outlet.
- The proposed pedestrian boardwalk that is being planned is included in the analysis. It would run parallel to the Carlsbad Boulevard, providing a pedestrian crossing over the Lagoon.

2.3 SALTWATER ALTERNATIVE

The Saltwater Alternative represents the enhancement configuration that was used to analyze and evaluate the saltwater hydrologic regime with expanded hydraulic connections This alternative achieved the enhancement objectives primarily through elimination of existing exotic vegetation, dredging to remove excess sediment, and establishment of continuous tidal exchange. A plan view of the Saltwater Alternative is presented in Figure 2.2.

Figure 2.2 Saltwater Alternative Plan View

Prominent features of this alternative include:

- Removal and subsequent disposal of existing exotic vegetation.
- Excavation/dredging of 781,000 CY.
- Creation of open saltwater habitat in the I-5 Basin with a subtidal channel having a bottom elevation of -2.5 ft, NGVD. The three existing islands in the western part of the I-5 Basin would be kept at existing elevations.
- Creation of saltwater habitat in the Coast Highway Basin with a subtidal channel running through the central part of the basin. The invert elevation of the channel would be -2.5 ft, NGVD.
- Creation of open saltwater habitat in the Railroad Basin and Weir Basin with a bottom elevation -2.5 ft, NGVD. This area would serve as a sand trap for littoral sands entering the Lagoon through the newly created tidal inlet.
- The new I-5 Bridge structure being developed by Caltrans is considered in the analysis. The channel cross section would have an invert elevation of -2.5 ft, NGVD. The bottom width of the channel would be 160 ft, with a slope of 1V:2H on the both sides of the channel.
- A new Carlsbad Boulevard Bridge would be built as part of the enhancement project under this alternative. The new bridge would have adequate clearance and channel width to accommodate fluvial and tidal flows. The invert elevation would be level with the invert elevation of the channels upstream and downstream of the hydraulic connection, which would be -2.5 ft, NGVD. The bottom width of the hydraulic connection would be 110 ft with vertical slopes on both sides of the channel.
- The new NCTD Railroad Bridge structure being developed by NCTD and SANDAG is considered in the analysis. The channel invert elevation would be equal to the invert elevation of the channels upstream and downstream of the hydraulic connection, which would be -2.5 ft, NGVD. The bottom width of the channel would be 90 ft with an average slope of 1V:8.5H on the north side and 1V:11.5H on the south side.
- Replacement of the existing 50-ft wide weir with a tidal inlet to provide continuous tidal exchange between the Lagoon and ocean. The tidal inlet would be stabilized with channel guides. The top width of the inlet at an elevation of 6’ ft NGVD would be 100 ft. The inlet channel would be designed with an invert elevation of -2.0 ft, NGVD. The slope of the channel guide would be 1V:2H.
- Tidal inlet maintenance program to keep the Lagoon open to tidal exchange.
- The proposed pedestrian boardwalk that is being planned is included in the analysis. It would run parallel to the Carlsbad Boulevard, providing a pedestrian crossing over the Lagoon.

2.5 HYBRID ALTERNATIVE

Under the Hybrid Alternative, the hydrologic regime of the Lagoon would be changed from the existing freshwater system to a hybrid system influenced by both saltwater and freshwater. A saltwater system would be created west of I-5 and a freshwater system would be created east of I-5. The hydrologic system west of I-5 would be influenced primarily by saltwater entering the system from an open tidal inlet during flood tides as well as freshwater entering the Lagoon just downstream from I-5 and along the boundary of the Lagoon. Under the Hybrid Alternative, water would exit the Lagoon primarily during ebb tides. The hydrologic system east of I-5 would be controlled primarily by freshwater entering the system from upstream and along the boundary of the Lagoon, and outputs via overflow at a new weir to be located under I-5.

There are two options under the Hybrid Alternative (Options A and B) differentiated by the configuration of the Weir Basin. Under Hybrid Alternative, Option A, a channel would be constructed to connect the tidal inlet from the ocean area through the Weir Basin and into the Railroad Basin. Hybrid Alternative, Option B would achieve tidal exchange in the same manner as the Saltwater Alternative with an open tidal inlet connecting the ocean to the Weir Basin. The channel constructed under Hybrid Alternative, Option A would result in a perched water level within the northern portion of the Weir Basin that would have a substantially muted tide range compared with Hybrid Alternative, Option B. Plan views of Option A and Option B of the Hybrid Alternative are presented in Figure 2.3 and Figure 2.4, respectively.

Prominent features of this alternative (common to both Options A and B) include:

- Removal and subsequent disposal of existing exotic vegetation.
- Excavation/dredging of 833,000 CY.
- Enhancement of open freshwater habitat in the I-5 Basin with a general bottom elevation of +1.6 ft relative to the National Geodetic Vertical Datum of 1929 (NGVD).
- Creation of saltwater habitat in the Coast Highway Basin with a subtidal channel running through the central part of the basin. The invert elevation of the channel would be -2.5 ft, NGVD.
- Creation of open saltwater habitat in the Railroad Basin and Weir Basin with a bottom elevation of -2.5 ft, NGVD. This area would serve as a sand trap for littoral sands entering the Lagoon through the newly created tidal inlet.
- The new I-5 Bridge structure being developed by Caltrans is considered in the analysis. The channel cross section would have the same bottom width and invert elevation as those of the existing channel cross section. The invert elevation would be +2 ft, NGVD. The bottom width would be 24 ft. The side slopes would be 1V:1.5H

on both sides of the channel. In addition, a new weir would be constructed under I-5 between the Coast Highway Basin and I-5 Basin to maintain a freshwater hydrologic regime in the I-5 Basin. The crest elevation of the weir would be +5.6 ft, NGVD.

- A new Carlsbad Boulevard Bridge would be built as part of this enhancement alternative. The new bridge would have adequate clearance and channel width to accommodate fluvial and tidal flows. The invert elevation would be level with the invert elevation of the channels upstream and downstream of the hydraulic connection, which would be -2.5 ft, NGVD. The bottom width of the hydraulic connection would be 110 ft with vertical slopes on both sides of the channel.
- The new NCTD Railroad Bridge structure being developed by NCTD and SANDAG is considered in the analysis. The channel invert elevation would be equal to the invert elevation of the channels upstream and downstream of the hydraulic connection, which would be -2.5 ft, NGVD. The bottom width of the channel would be 90 ft with an average slope of 1V:8.5H on the north side and 1V:11.5H on the south side.
- Replacement of the existing 50-ft wide weir with an ocean inlet/outlet to provide continuous tidal exchange between the Lagoon and ocean. The tidal inlet would be stabilized with channel guides. The top width of the inlet at an elevation of 6 ft, NGVD would be 100 ft. The inlet channel would be designed with an invert elevation of -2.0 ft, NGVD. The slope of the channel guide would be 1V:2H.
- Tidal inlet maintenance program to keep the Lagoon open to tidal exchange.
- The proposed pedestrian boardwalk that is being planned is included in the analysis. It would run parallel to the Carlsbad Boulevard, providing a pedestrian crossing over the Lagoon.

Additional Feature for Option A:

- Creation of a channel in the Weir Basin by building a channel guide along the north side of the channel across the Weir Basin. The southern edge of the channel would defined by the southern bank of the Weir Basin. The channel conveys fluvial and tidal flows between the Railroad Basin and tidal inlet. The crest elevation of the channel guide would be +2.3 ft, NGVD.

Figure 2.3 Hybrid Alternative Option A Plan View

Figure 2.4 Hybrid Alternative Option B Plan View

3. STUDY APPROACH

3.1 OVERVIEW

A comprehensive study approach was developed to achieve the objectives identified in Chapter 1. The study approach involved the use of a hydrodynamic model to estimate the water surface elevations and water velocities associated with extreme storm events (*e.g.,* 100-year return period storm event) and small storm events (*e.g.,* 10-year return period storm event). The two-dimensional numerical hydrodynamic model known as TUFLOW was used to conduct the numerical modeling (BMT 2013). A set of scenarios was developed to guide the numerical modeling analysis. The scenarios developed to achieve the study objectives are described in the section below.

3.2 MODELING SCENARIOS

A total of 94 scenarios were developed to achieve the study objectives. These 94 scenarios were developed for various combinations of lagoon condition, sea level, flood flow, lagoon water level, and hydraulic constriction conditions aimed at achieving different objectives either directly or via comparison to other scenarios. The lagoon, sea level, flood flow, lagoon water level, and hydraulic constriction conditions are described below.

3.2.1 Lagoon Condition

Existing Condition

The existing lagoon condition was represented by the existing lagoon contours developed from a 2005 bathymetric survey. The existing lagoon condition and model setup are presented in Chapter 4.

No-Project Condition

The no-project condition was used to analyze hydraulic conditions in future when no maintenance and development would happen to the existing lagoon. The assumption for future no-project scenario is that the Lagoon would be filled with fluvial sediment to a level equal to the crest elevation of the existing weir at +5.6 ft, NGVD. The no-project condition and model setup are presented in Chapter 4.

Enhancement Alternatives

The following four enhancement alternatives were analyzed. These alternatives are described in Chapter 2.

- Freshwater Alternative
- Saltwater Alternative
- Hybrid Alternative Option A
- Hybrid Alternative Option B

3.2.2 Sea Level Condition

Three mean sea level conditions were considered for the analysis. The three mean sea level conditions were taken as Year 2015, Year 2050, and Year 2100. For each of the three mean sea level conditions, two tide series were developed to analyze various conditions for the enhancement project.

Mean Tide Series

The Year 2015 was selected to represent the mean sea level condition at the completion of project construction (*i.e.,* post-construction condition). Given the fact that very little sea level rise as occurred over the past 14 years and little sea level rise is expected over the next year, the mean sea level for 2015 was taken as the mean tide range represented at the closest NOAA tide gauge station (Scripps Pier, La Jolla) during the latest tidal epoch (1983-2001).

The high end of the mean sea level range projections for Year 2050 and Year 2100 identified in the March 2013 sea level rise guidance developed by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) were selected for consideration of sea level rise (CO-CAT 2013). The mean sea level increases for Year 2050 and Year 2100 are 2.0 ft and 5.5 ft, respectively. The time series for these sea level conditions are presented in Chapter 4.

Long-term Tide Series

The tidal series used for the tidal hydraulics analyses was developed to reflect the long-term fluctuation of tidal conditions. It is important that the tidal series used to assess the tidal response in the Lagoon represent long-term conditions since the habitat distribution in the Lagoon would likely become established based on the long-term trends. Therefore, a water level series was selected to represent the long-term, tidal characteristics off the coast of the Lagoon.

A 30-day segment of the historical water level data at the NOAA Scripps Pier station was selected to represent the long-term tides off the coast of the Lagoon. This 30-day segment was shown to be statistically similar to long-term data and determined to be sufficient to represent the long-term tidal characteristics. This 30-day tide series is termed the Tidal Epoch Analysis (TEA) tide series for Year 2015. The TEA tide series for Year 2050 and 2100 are assumed to have mean sea level increases of 2.0 ft and 5.5 ft, respectively. The TEA tide time series are presented in Chapter 4.

3.2.3 Flood Flows

Five flood flow conditions were considered in conducting the fluvial hydraulic analyses. Fluvial modeling was performed with the 100-year storm event to estimate the water surface elevations within the Lagoon for the purpose of determining the impact of the enhancement project on flood conditions. In addition, fluvial modeling was conducted with the 2-year, 5-year, 10-year, and 50-year storm events, providing additional information for water surface elevations in the vicinity of the Lagoon under the enhancement alternatives. The flood flow hydrographs for these five events are discussed in Chapter 4.

3.2.4 Water Levels

Three different water level conditions were utilized to represent the initial condition (*i.e.,* at the beginning of a storm) for conducting the fluvial hydraulic modeling. Under Existing Lagoon conditions, the water level in the Lagoon is generally governed by the invert elevation of the weir located at the Lagoon outlet. For existing Lagoon condition scenarios utilized to determine the impact of flood flows on water surface elevations, a water elevation of +5.6 ft, NGVD29 was utilized to represent the initial Lagoon water level, as this elevation matches the invert elevation of the existing weir. Based on a review of historical conditions, it was assumed that water elevations lower than +4.0 ft NGVD29 would not be likely to occur. For the Saltwater Alternative, the water level in the Lagoon would not be controlled by the weir, but, rather, would vary with the tide. To represent high water velocity conditions under the Saltwater Alternative, a tidal time series varying between mean higher high water and mean lower low water was utilized with the peak of the flood flow hydrograph timed to occur when the tidal flow is ebbing. The tidal series and the timing between the flood flows and tide water levels are presented in Chapter 4.

3.2.5 Hydraulic Constrictions

The fluvial hydraulic model consists of the ocean area, Buena Vista Lagoon as represented by four basins (Weir Basin, Railroad Basin, Coast Highway Basin, and I-5 Basin), and four hydraulic constrictions. The four hydraulic constrictions from downstream to upstream are: (i) ocean outlet (weir) or tidal inlet, (ii) Railroad Embankment and Bridge, (iii) Carlsbad Boulevard Roadway and Bridge, and (iv) I-5 Roadway and Bridge. The bridges were represented in either the existing condition or proposed condition. The proposed conditions for each bridge were provided by SANDAG, AECOM, and Caltrans for the Railroad Bridge, Carlsbad Boulevard Bridge, and I-5 Bridge, respectively. The hydraulic constrictions utilized for the fluvial hydraulic modeling are described in Chapter 4.

3.2.6 Tidal Inlet Condition

Conceptual tidal inlet configurations were developed for an inlet system with no jetties at Buena Vista Lagoon under three wetland enhancement alternatives. The three inlet cross sections were developed to approximate the evolution of the tidal inlet dimensions over time (Everest 2014). The inlet invert varies over time from a post dredged condition (A - Open) to a pre-dredge condition (C - Closed). These tidal inlet configurations are shown in Table 3.1 and Figure 3.1.

Table 3.1 Tidal Inlet Configurations

CONDITION	MAINTENANCE SCHEDULE (MONTHS)	INVERT (FT, NGVD)
A – Open	0	-2.0
B – Transitional	6 – 12	-0.5
C - Closed	16.4	+2.3

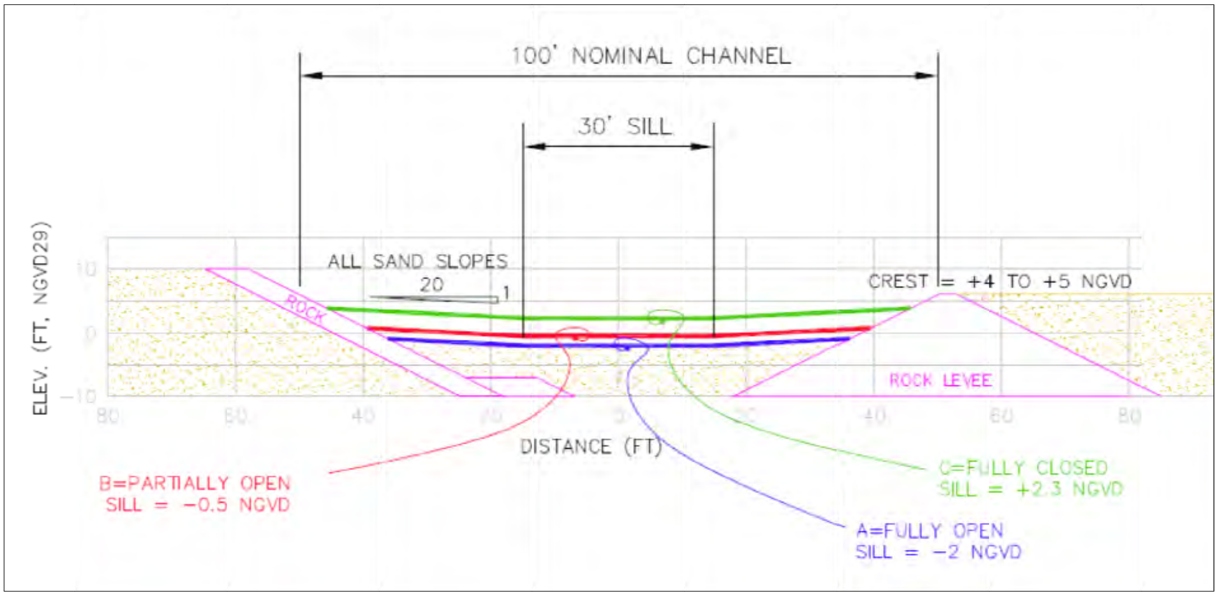

Figure 3.1 Tidal Inlet Configuration (Cross Section Looking Inland)

3.3 MODELING SCENARIO SUMMARY

More than 150 model runs were conducted for the fluvial and tidal hydraulic analyses. Many of the runs were conducted as iterations, such as simulations to achieve the desired habitat distribution for the Saltwater Alternative, and to test performance of hydraulic connections (*e.g.,* proposed Carlsbad Boulevard Bridge configuration). There were 78 final modeling scenarios for which results were evaluated for the fluvial and tidal hydraulic analyses. These 78 modeling scenarios are summarized in Table 3.2. The table includes the Lagoon, sea level, flood flow return period, initial water level, and hydraulic constriction conditions associated with each scenario. The table includes the primary objective of each scenario along with the type of primary model result that will be used to achieve the objective.

Table 3.2 Modeling Scenarios

Inlet proposed = 80 feet wide for fresh water/100 feet wide for salt water and hybrid
Proposed Coast Highway Bridge includes the boardwalk
2015 Sea Level = 1983-2001 Tidal Epoch sea level
2050 Sea Level = +2 ft
2100 Sea Level = +5.5 ft

BVLEP = Buena Vista Lagoon Enhancement Project
WSE = Water Surface Elevation
Mean-Hi = mean tide with timing to get high water surface elevation
Mean-Lo = mean tide with timing to get high water velocity
TEA = Tidal Epoch Analysis tide used to estimate habitat distribution

Lagoon Condition	Scenario Number	Sea Level Year	Flood Flow	Tide	Hydraulic Constriction Conditions							Objective
					Outlet/Inlet	Railroad Bridge	Railroad Channel	Coast Highway Bridge	Coastal Highway Channel	I-5 Bridge	I-5 Channel	
No Project	1	2050	100	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	2	2050	100	Mean-Lo	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. velocity
	3	2100	100	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	4	2100	100	Mean-Lo	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. velocity
	5	2100	None	TEA	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Estimate salt water input
Existing Conditions	6	2015	2	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	7	2015	5	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	8	2015	10	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	9	2015	50	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	10	2015	100	Mean-Hi	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. WSE
	11	2015	100	Mean-Lo	Existing Weir	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Existing Bridge	Existing Channel	Establish max. velocity
Freshwater Alternative	12	2015	2	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	13	2015	5	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	14	2015	10	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	15	2015	50	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	16	2015	100	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	17	2015	100	Mean-Lo	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. velocity
	18	2050	100	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	19	2050	100	Mean-Lo	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. velocity
	20	2100	100	Mean-Hi	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. WSE
	21	2100	100	Mean-Lo	80' Fixed Weir	Proposed Bridge	Proposed Channel	Existing Bridge	Existing Channel	Proposed Bridge	Existing Channel	Establish max. velocity

Table 3.2 Modeling Scenarios

Inlet proposed = 80 feet wide for fresh water/100 feet wide for salt water and hybrid
Proposed Coast Highway Bridge includes the boardwalk
2015 Sea Level = 1983-2001 Tidal Epoch sea level
2050 Sea Level = +2 ft
2100 Sea Level = +5.5 ft

BVLEP = Buena Vista Lagoon Enhancement Project
WSE = Water Surface Elevation
Mean-Hi = mean tide with timing to get high water surface elevation
Mean-Lo = mean tide with timing to get high water velocity
TEA = Tidal Epoch Analysis tide used to estimate habitat distribution

Lagoon Condition	Scenario Number	Sea Level Year	Flood Flow	Tide	Hydraulic Constriction Conditions							Objective
					Outlet/Inlet	Railroad Bridge	Railroad Channel	Coast Highway Bridge	Coastal Highway Channel	I-5 Bridge	I-5 Channel	
Saltwater Alternative	22	2015	2	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	23	2015	5	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	24	2015	10	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	25	2015	50	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	26	2015	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	27	2015	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. velocity
	28	2015	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	29	2015	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	30	2015	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	31	2050	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	32	2050	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. velocity
	33	2050	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	34	2050	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	35	2050	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	36	2100	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. WSE
	37	2100	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Establish max. velocity
	38	2100	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	39	2100	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.
	40	2100	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Optimized Channel	Proposed Bridge	Optimized Channel	Establish habitat dist.

Table 3.2 Modeling Scenarios

Inlet proposed = 80 feet wide for fresh water/100 feet wide for salt water and hybrid
Proposed Coast Highway Bridge includes the boardwalk
2015 Sea Level = 1983-2001 Tidal Epoch sea level
2050 Sea Level = +2 ft
2100 Sea Level = +5.5 ft

BVLEP = Buena Vista Lagoon Enhancement Project
WSE = Water Surface Elevation
Mean-Hi = mean tide with timing to get high water surface elevation
Mean-Lo = mean tide with timing to get high water velocity
TEA = Tidal Epoch Analysis tide used to estimate habitat distribution

Lagoon Condition	Scenario Number	Sea Level Year	Flood Flow	Tide	Hydraulic Constriction Conditions							Objective
					Outlet/Inlet	Railroad Bridge	Railroad Channel	Coast Highway Bridge	Coastal Highway Channel	I-5 Bridge	I-5 Channel	
Hybrid Alternative B	41	2015	2	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	42	2015	5	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	43	2015	10	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	44	2015	50	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	45	2015	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	46	2015	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. velocity
	47	2015	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	48	2015	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	49	2015	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	50	2050	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	51	2050	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. velocity
	52	2050	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	53	2050	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	54	2050	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	55	2100	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	56	2100	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. velocity
	57	2100	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	58	2100	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	59	2100	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.

Table 3.2 Modeling Scenarios

Inlet proposed = 80 feet wide for fresh water/100 feet wide for salt water and hybrid
Proposed Coast Highway Bridge includes the boardwalk
2015 Sea Level = 1983-2001 Tidal Epoch sea level
2050 Sea Level = +2 ft
2100 Sea Level = +5.5 ft

BVLEP = Buena Vista Lagoon Enhancement Project
WSE = Water Surface Elevation
Mean-Hi = mean tide with timing to get high water surface elevation
Mean-Lo = mean tide with timing to get high water velocity
TEA = Tidal Epoch Analysis tide used to estimate habitat distribution

Lagoon Condition	Scenario Number	Sea Level Year	Flood Flow	Tide	Hydraulic Constriction Conditions							Objective
					Outlet/Inlet	Railroad Bridge	Railroad Channel	Coast Highway Bridge	Coastal Highway Channel	I-5 Bridge	I-5 Channel	
Hybrid Alternative A	60	2015	2	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	61	2015	5	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	62	2015	10	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	63	2015	50	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	64	2015	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	65	2015	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. velocity
	66	2015	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	67	2015	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	68	2015	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	69	2050	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	70	2050	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. velocity
	71	2050	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	72	2050	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	73	2050	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	74	2100	100	Mean-Hi	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. WSE
	75	2100	100	Mean-Lo	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish max. velocity
	76	2100	None	TEA	Open	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	77	2100	None	TEA	Transition	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.
	78	2100	None	TEA	Closed	Proposed Bridge	Proposed Channel	Proposed Bridge	Proposed Channel	Proposed Bridge	Existing Channel w/Weir	Establish habitat dist.

4. MODEL DEVELOPMENT

4.1 OVERVIEW

The two-dimensional numerical hydrodynamic model known as TUFLOW was used to conduct the numerical modeling. TUFLOW is a finite difference numerical model designed to model tidal and flood hydraulics for rivers, estuaries, coastal bays, floodplains and urban areas. TUFLOW was used to simulate flows through the Lagoon under flood events from Buena Vista Creek and ocean tides entering the lagoon. TUFLOW model grids were developed for Existing Conditions, No-Project, and four enhancement alternatives with features as described in Chapter 2. Model grids of the study area for the fluvial hydraulics analysis were developed with grid cell size of 20 ft x 20 ft. For tidal hydraulics, 25 ft x 25 ft grid size model grids were used. Time steps for model simulation runs ranged from 1 second to 3 seconds.

4.2 EXISTING CONDITIONS

The Lagoon topography for Existing Conditions was based on a bathymetric survey conducted in 2005. Figure 4.1 shows the TUFLOW model grid developed with this bathymetry and topography. The model grid was setup based on the existing hydraulic connections as summarized in Table 4.1.

Table 4.1 Existing Conditions Hydraulic Connections

INFRASTRUCTURE	INVERT WIDTH (FT)	INVERT ELEVATION (FT, NGVD)	CHANNEL SIDE SLOPE (H:V)
Weir	50	+5.6	N/A
NCTD Railroad Bridge	200	+3.0	18:1 (S), 4.5:1 (N)
Carlsbad Boulevard Bridge	29	-3.0	Vertical
I-5 Bridge	36	+2.0	1.5:1

H:V = horizontal to vertical, S = south side, N = north side

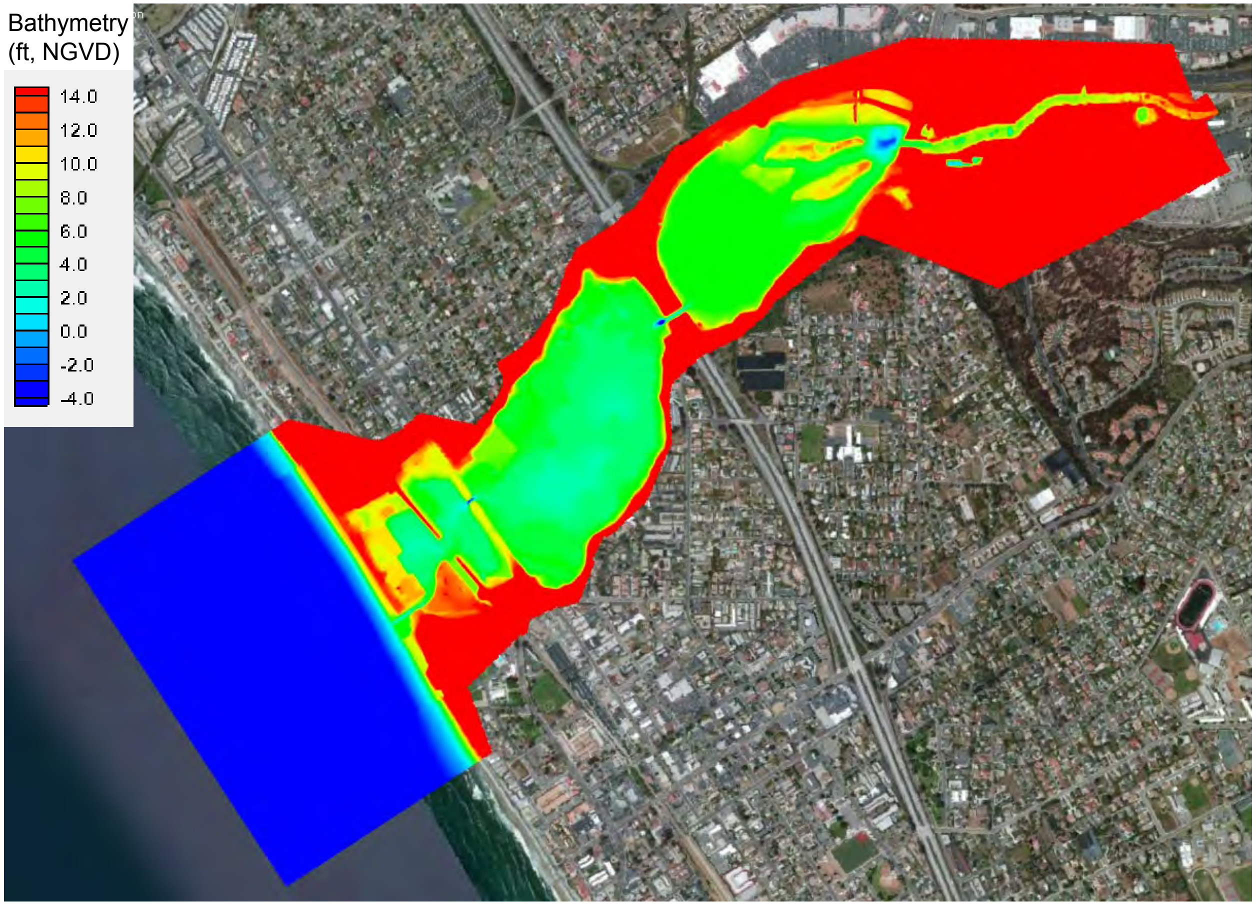

Figure 4.1 TUFLOW Model Domain and Bathymetry for Existing Conditions

4.3 FRESHWATER ALTERNATIVE

The TUFLOW model grid for Freshwater Alternative is shown in Figure 4.2. The proposed Lagoon grading shown in Chapter 2 was used to prepare the TUFLOW model grid shown in the figure. The Freshwater Alternative model grid was setup based on the hydraulic connections summarized in Table 4.2. In addition, it included a proposed pedestrian boardwalk that would be constructed parallel to the Carlsbad Boulevard. It can be seen from Table 4.2 that the hydraulic connection at I-5 Bridge is the same as that of the existing I-5 Bridge (Table 4.1), although a new I-5 Bridge structure is assumed to be in place for the Freshwater Alternative. As part of the I-5 Widening Project Caltrans intends to build a new, longer bridge but the existing embankment would remain in place from a functional standpoint. Consequently, it is expected that water flow under the I-5 Bridge would have a similar pattern as that of Existing Conditions.

Table 4.2 Freshwater Alternative Hydraulic Connections

INFRASTRUCTURE	INVERT WIDTH (FT)	INVERT ELEVATION (FT, NGVD)	CHANNEL SIDE SLOPE (H:V)
Weir	80	+5.6	N/A
NCTD Railroad Bridge	90	-2.5	11.5:1 (S), 8.5:1 (N)
Carlsbad Boulevard Bridge	29	-3.0	Vertical
I-5 Bridge	36	+2.0	1.5:1

H:V = horizontal to vertical, S = south side, N = north side

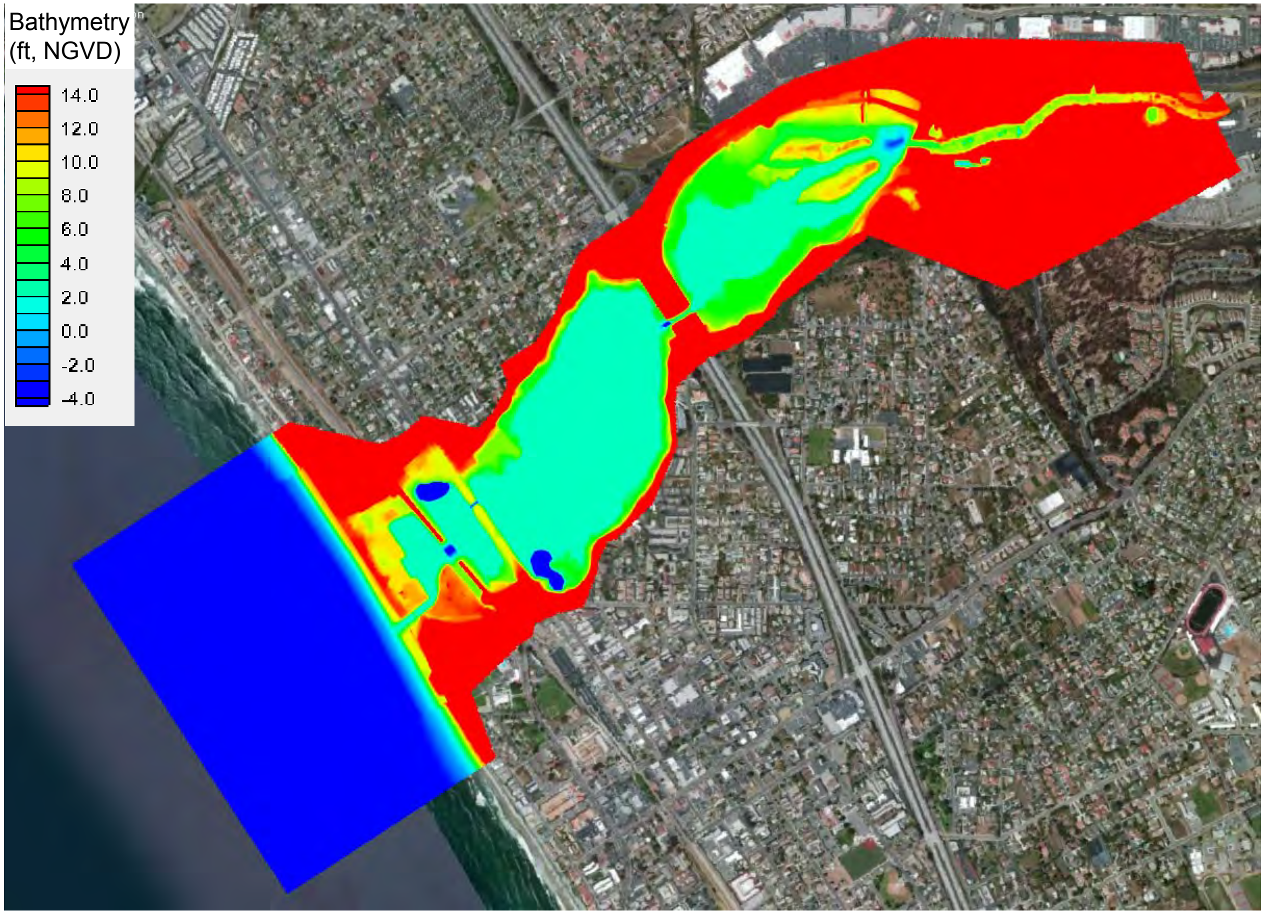

Figure 4.2 TUFLOW Model Domain and Bathymetry for Freshwater Alternative

4.4 SALTWATER ALTERNATIVE

The TUFLOW model domain and bathymetry for Saltwater Alternative are shown in

Figure 4.3. The proposed Lagoon grading shown in Chapter 2 was used to prepare the TUFLOW model grid shown in the figure. The Saltwater Alternative model grid was setup based on the hydraulic connections that are summarized in Table 4.3. In addition, it included a proposed pedestrian boardwalk that would be constructed parallel to the Carlsbad Boulevard. The tidal inlet invert elevations would vary from -2.0 ft, NGVD to +2.3 ft, NGVD. The transitional condition of the tidal inlet with an invert elevation of -0.5 ft, NGVD was used in the analyses as this condition represents the most prevailing and average condition of the tidal inlet in a maintenance dredging cycle. The open and closed conditions were also used in tidal hydraulics analyses in order to estimate the possible ranges of inundation frequencies and corresponding habitat distributions in a full maintenance dredging cycle.

Table 4.3 Saltwater Alternative Hydraulic Connections

STRUCTURE	INVERT WIDTH (FT)	INVERT ELEVATION (FT, NGVD)	CHANNEL SIDE SLOPE (H:V)
Tidal Inlet	100 (top width)	-2.0, -0.5, +2.3	2:1
NCTD Railroad Bridge	90	-2.5	11.5:1 (S), 8.5:1 (N)
Carlsbad Boulevard Bridge	110	-2.5	Vertical
I-5 Bridge	160	-2.5	2:1

H:V = horizontal to vertical, S = south side, N = north side

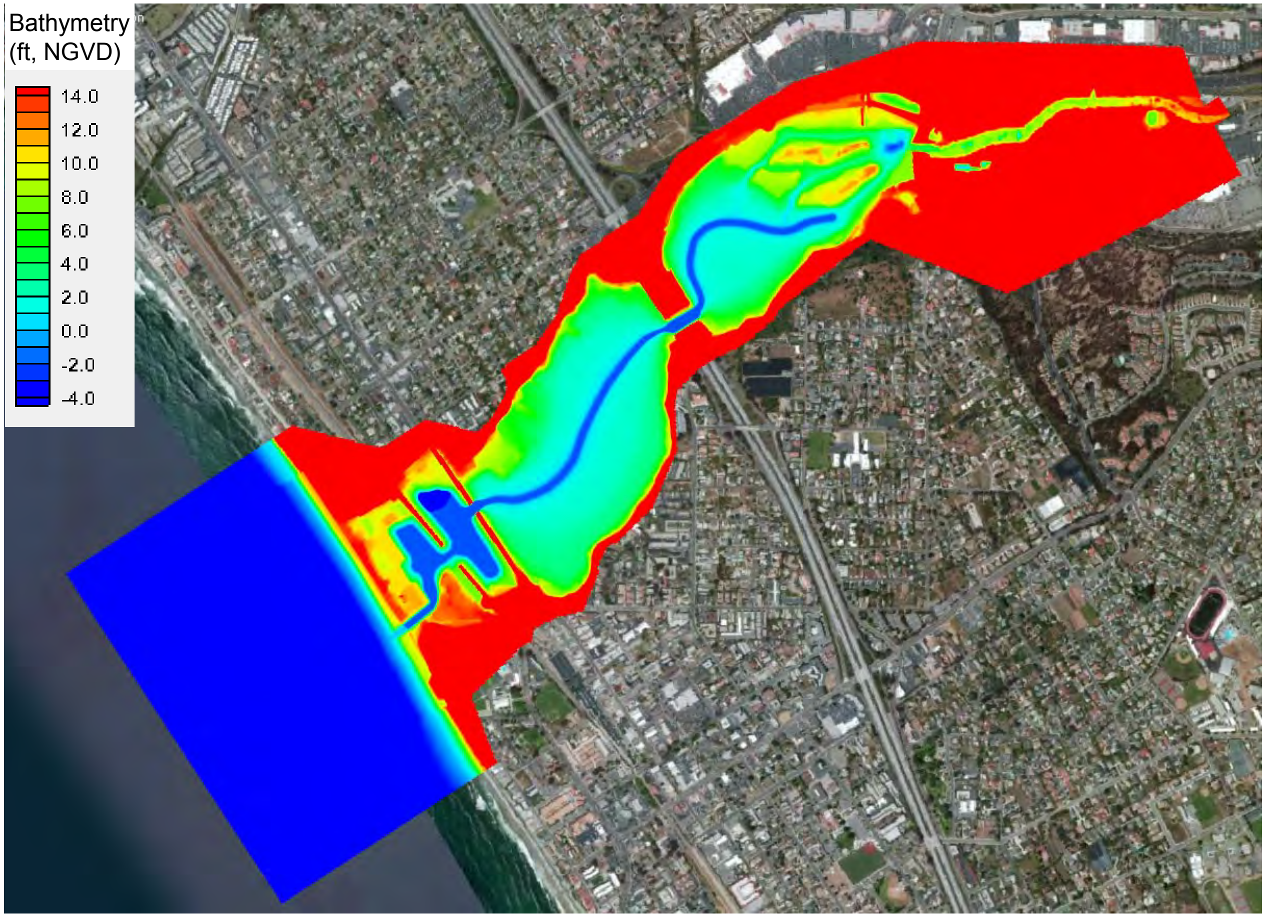

Figure 4.3 TUFLOW Model Domain and Bathymetry for Saltwater Alternative

4.5 HYBRID ALTERNATIVE OPTION A (HYBRID A)

The TUFLOW model domain and bathymetry for Hybrid A is shown in Figure 4.4. The proposed Lagoon grading shown in Chapter 2 was used to prepare the TUFLOW model grid shown in the figure. The Saltwater Alternative model grid was setup based on the hydraulic connections summarized in Table 4.4. In addition, it included a proposed pedestrian boardwalk that would be constructed parallel to the Carlsbad Boulevard. The tidal inlet invert elevations would vary from -2.0 ft, NGVD to +2.3 ft, NGVD. The transitional condition of the tidal inlet with an invert elevation of -0.5 ft, NGVD was used in the analyses as this condition represents the most prevailing and average condition of the tidal inlet in a maintenance dredging cycle. The open and closed conditions were also used in tidal hydraulics analyses in order to estimate the possible ranges of inundation frequencies and corresponding habitat distributions in a full maintenance dredging cycle.

Table 4.4 Hybrid A Hydraulic Connections

STRUCTURE	INVERT WIDTH (FT)	INVERT ELEVATION (FT, NGVD)	CHANNEL SIDE SLOPE (H:V)
Ocean Inlet/Outlet	100 (top width)	-2.0, -0.5, +2.3	2:1
Weir Basin Channel Guide	N/A	+2.3	2:1
NCTD Railroad Bridge	90	-2.5	11.5:1 (S), 8.5:1 (N)
Carlsbad Boulevard Bridge	110	-6.0	Vertical
I-5 Weir	N/A	+5.6	N/A
I-5 Bridge	36	+2.0	1.5:1

H:V = horizontal to vertical, S = south side, N = north side

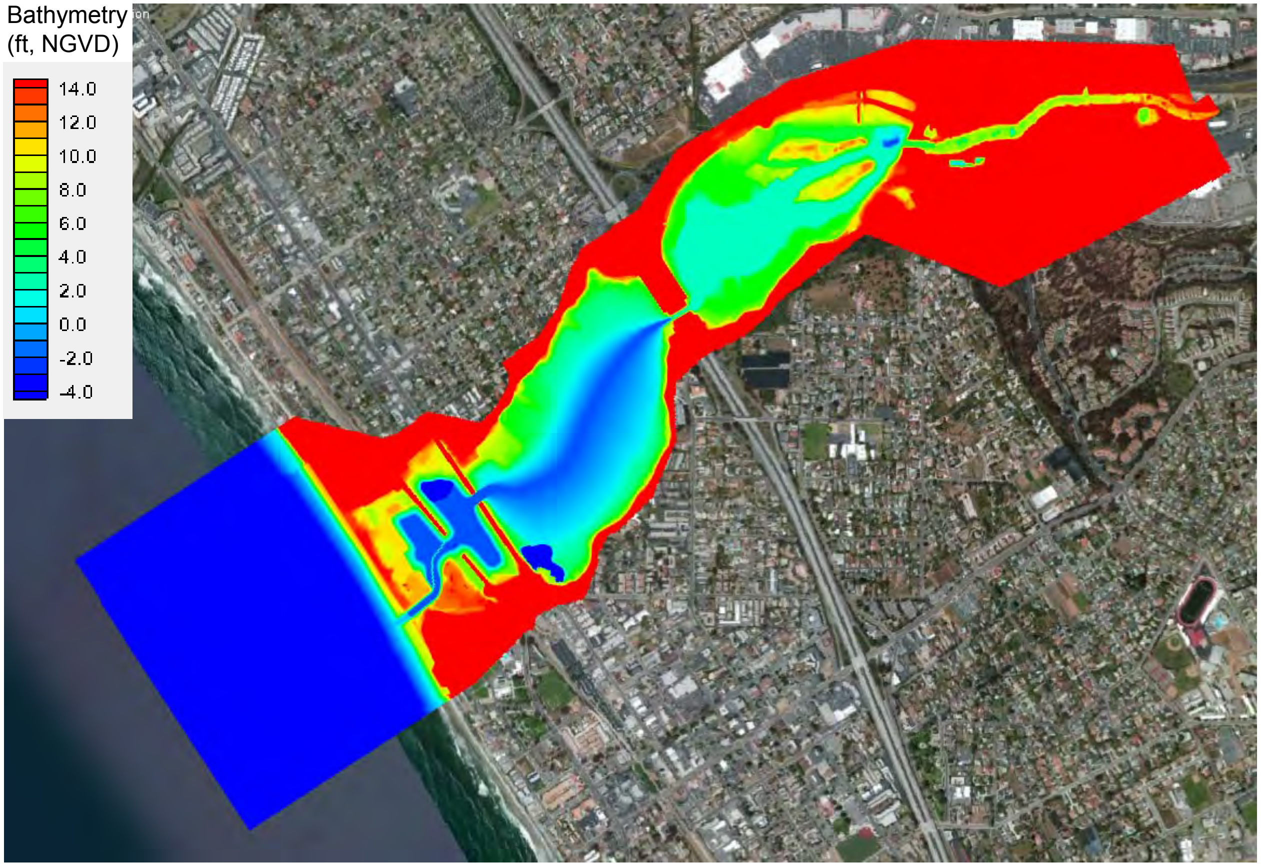

Figure 4.4 TUFLOW Model Domain and Bathymetry for Hybrid A

4.6 HYBRID ALTERNATIVE OPTION B (HYBRID B)

The TUFLOW model domain and bathymetry for Hybrid B is shown in Figure 4.5. The proposed Lagoon grading shown in Chapter 2 was used to prepare the TUFLOW model grid shown in the figure. The Hybrid B model grid was setup based on the hydraulic connections summarized in Table 4.5. In addition, it included a proposed pedestrian boardwalk that would be constructed parallel to the Carlsbad Boulevard. As indicated in Table 4.5, Hybrid B differs from Hybrid A in that it does not include the channel guide in the Weir Basin. The tidal inlet invert elevations would vary from -2.0 ft, NGVD to +2.3 ft, NGVD. The transitional condition of the tidal inlet with an invert elevation of -0.5 ft, NGVD was used in the analyses as this condition represents the most prevailing and average condition of the tidal inlet in a maintenance dredging cycle. The open and closed conditions were also used in tidal hydraulics analyses in order to estimate the possible ranges of inundation frequencies and corresponding habitat distributions in a full maintenance dredging cycle.

Table 4.5 Hybrid B Hydraulic Connections

STRUCTURE	INVERT WIDTH (FT)	INVERT ELEVATION (FT, NGVD)	CHANNEL SIDE SLOPE (H:V)
Ocean Inlet/Outlet	100 (top width)	-2.0, -0.5, +2.3	2:1
NCTD Railroad Bridge	90	-2.5	11.5:1 (S), 8.5:1 (N)
Carlsbad Boulevard Bridge	110	-6.0	Vertical
I-5 Weir	N/A	+5.6	N/A
I-5 Bridge	36	+2.0	1.5:1

H:V = horizontal to vertical, S = south side, N = north side

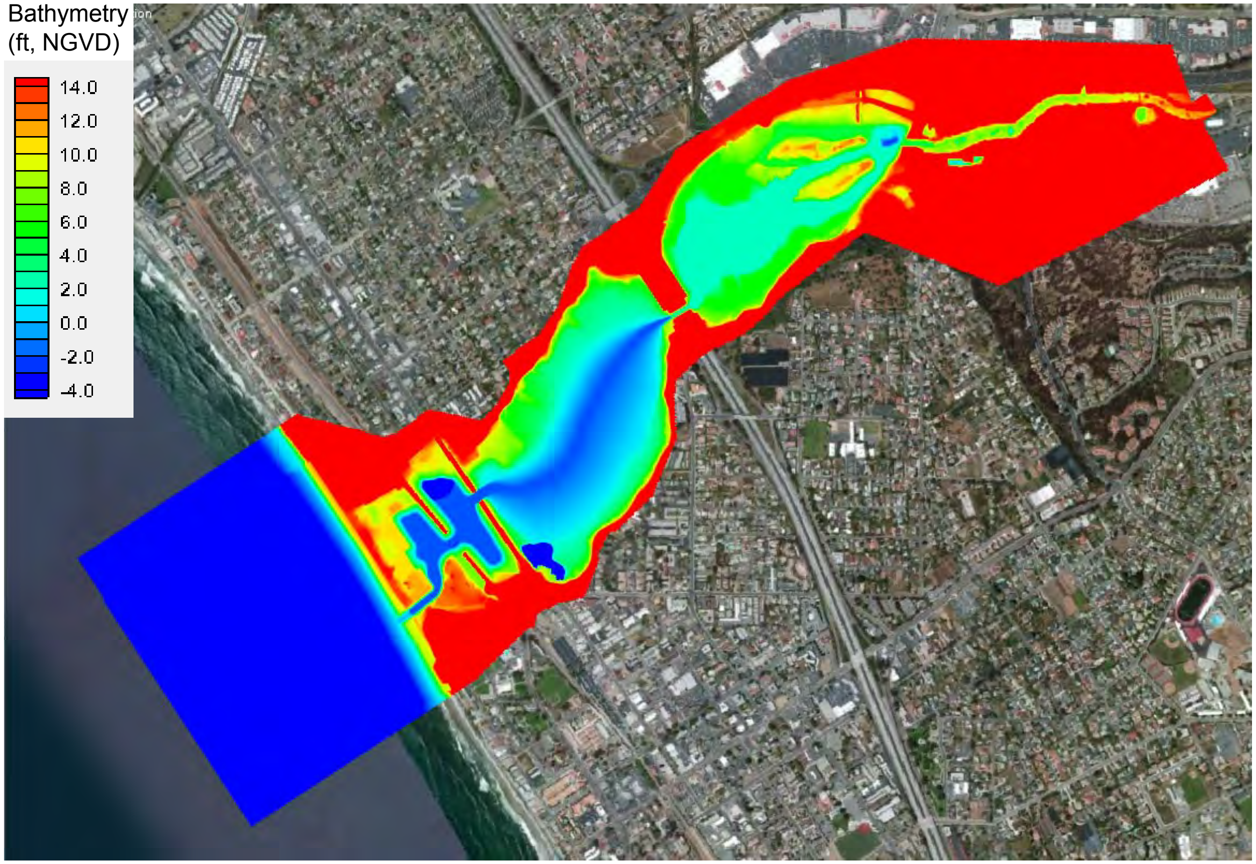

Figure 4.5 TUFLOW Model Domain and Bathymetry for Hybrid B

5. FLUVIAL HYDRAULICS

5.1 OVERVIEW

A fluvial hydraulic analysis was performed for Existing Conditions, No-Project, and four enhancement alternatives using TUFLOW. The four alternatives include:

1. Freshwater Alternative
2. Saltwater Alternative
3. Hybrid Alternative Option A (Hybrid A)
4. Hybrid Alternative Option B (Hybrid B)

In each case, simulations were conducted using the TUFLOW model grid developed according to proposed grading plans (see Chapter 4) to evaluate the impacts of storm events of various magnitudes. Flows from Buena Vista Creek during storm events were specified as input at the upstream end of the model. Tidal influence was included in the analysis as a boundary condition at the downstream end of the Lagoon. Results from TUFLOW simulations were analyzed to determine the maximum water elevations (flood elevations) and flow velocities at different basins under flood events of various magnitudes.

5.2 FLOOD HYDROGRAPH

As input to the fluvial hydraulic analysis, flood hydrographs were specified as a boundary condition at the upstream end of the Buena Vista Lagoon. The flood hydrographs used in the model were developed in 2003 for the Buena Vista Lagoon Restoration Feasibility Analysis Project (Everest 2004). Flow conditions of the Creek for the 2- 5-, 10-, 50- and 100-year return period storms were generated from watershed modeling using the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) modeling system developed by the EPA (2001). The BASINS analysis included considerations for land uses, topography, soil characteristics, precipitation, evaporation, etc., in developing flow hydrographs for the upstream end of the Lagoon. In addition, the hydrographs were adjusted such that the peak flows match with the FEMA peak flow values (FEMA 2012). Figure 5.1 shows the flood hydrographs for the 2- 5-, 10-, 50- and 100-year return period storms. It can be seen that the maximum flow for the 100-year return period storm is 8,500 cfs. For a 5-year return period storm, the maximum flow is about 1,000 cfs.

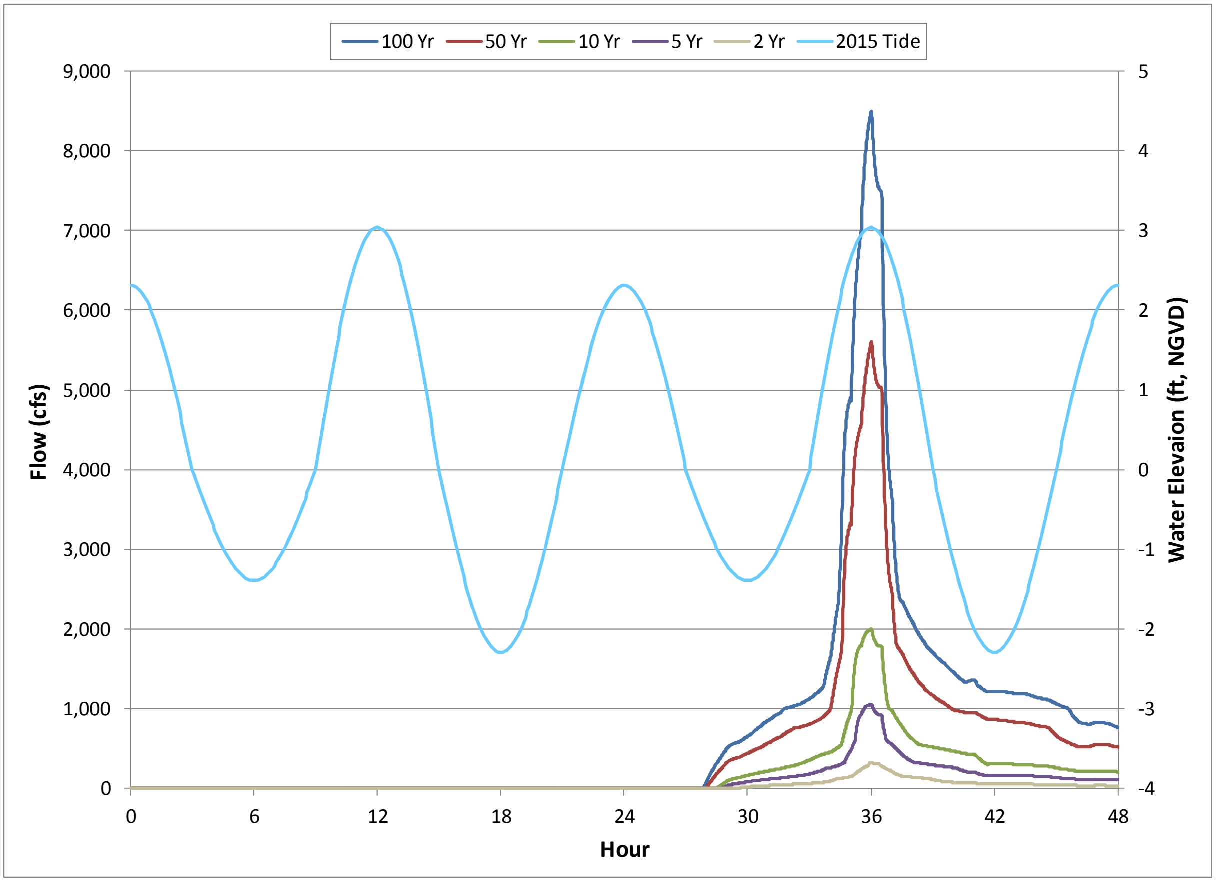

Figure 5.1 Flood and Mean Tide Hydrographs

5.3 TIDAL HYDROGRAPH

The tidal influence to the Lagoon is simulated with a mean tide specified as a boundary condition at the downstream end of the TUFLOW model grid. The tide data used for modeling was based on historical water level data collected at the NOAA Scripps Pier Station (Station 9410230) in La Jolla. The tidal benchmarks and tidal datum at this station are shown in Table 5.1. Figure 5.1 shows the mean tide time series which was developed by fitting a sinusoidal curve to consecutive MHHW, MLLW, MHW, and MLW water surface elevations, and repeating for the modeling duration. To simulate the maximum flood impact in the Lagoon, model test runs were performed to identify the optimum timing with respect to when MHHW occurs and when the peak flow enters the Lagoon. In most cases, the maximum flood impact occurs with MHHW occurring at the same time the peak flow enters the Lagoon, as depicted in Figure 5.1.

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Table 5.1 Tidal Benchmarks and Tidal Datum at NOAA Station 9410230 (NOAA 2011)

TIDE	ELEVATION (FT, MLLW)	ELEVATION (FT, NGVD)
Highest Observed Water Level (1/11/2005)	+7.66	+5.37
Mean Higher High Water (MHHW)	+5.33	+3.04
Mean High Water (MHW)	+4.60	+2.31
Mean Sea Level (MSL)	+2.73	+0.44
Mean Low Water (MLW)	+0.91	-1.39
North American Vertical Datum-1988 (NAVD88)	+0.19	-2.11
Mean Lower Low Water (MLLW)	0.00	-2.29
Lowest Observed Water Level (12/171933)	-2.87	-5.16

Source: NOAA

5.4 SEA LEVEL RISE

One of the purposes of this study was to conduct an analysis to evaluate the impact of mean sea level rise on flood impacts and tidal flow characteristics. This was done by evaluating the sea level rise impact for the Year 2050 and Year 2100. The projected rise of the mean sea levels are respectively 2.0 feet and 5.5 feet in Year 2050 and Year 2100, based on the guidance of the California Ocean Protection Council (OPCC, 2013). These 2.0-ft and 5.5-ft increases were added to the mean tide elevations (shown in Figure 5.1), and the resulting mean tide elevations for Year 2050 and Year 2100 are shown in Figure 5.2. These tides were specified as the downstream boundary conditions for the model scenarios for Year 2050 and Year 2100.

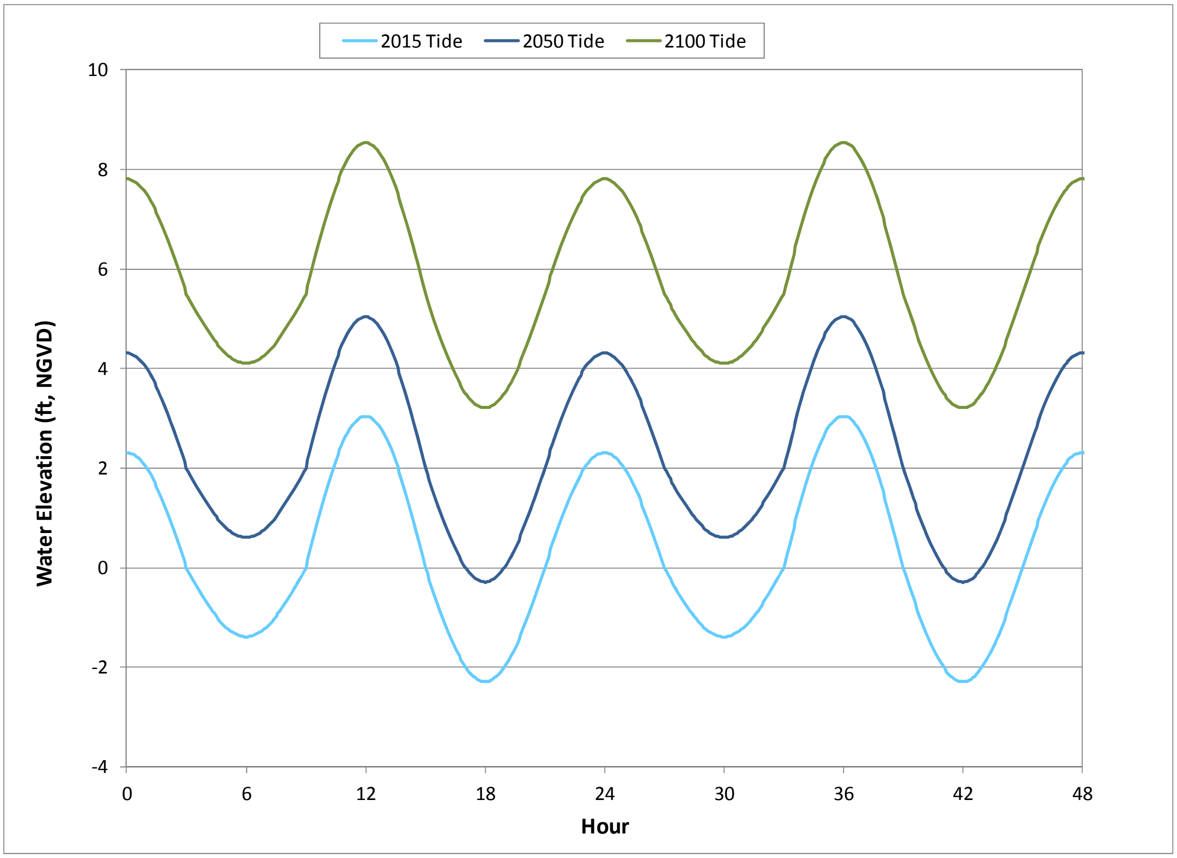


Figure 5.2 Projected Mean Tide Elevation Time Series for Year 2050 and Year 2100

5.5 RESULTS – WATER ELEVATIONS

Water elevations output from TUFLOW for Existing Conditions and the four enhancement alternatives were analyzed to evaluate potential flood impacts of storm events of various magnitudes. Water elevation results are presented first in plan view by alternative as 100-year flood maximum water elevations throughout the project area for Year 2015 mean sea level conditions, Year 2050 mean sea level conditions, and Year 2100 mean sea level conditions. Then maximum water elevation profiles for storm events of various magnitudes (*e.g.,* 2-yr, 5-yr, 10-yr, 50-yr and 100-yr return periods) and for current (Year 2015) and future (Year 2050 and Year 2100) mean sea level conditions are provided along the center line of the Lagoon that runs from the upstream boundary to the Lagoon inlet/outlet. This provides information on flood levels in the basins. Last, a comparison of maximum water elevations for all alternatives is summarized in tabular form at the end of this section.

5.5.1 Existing Conditions

Figure 5.3 shows the maximum water elevations of the project area during a 100-year storm event under existing conditions. Figure 5.4 shows the maximum water elevation profiles experienced along the entire Lagoon for different return periods.

5.5.2 No-Project Conditions

The No-Project Conditions flood impacts were evaluated for Year 2050 and Year 2100. Figure 5.5 and Figure 5.7 show the maximum water elevations of the project area during a 100-year storm event under mean sea level rise conditions in Year 2050 and Year 2100. For comparison, the maximum water elevation profiles experienced along the entire Lagoon for the two mean sea level rise conditions are presented in Figure 5.7.

5.5.3 Freshwater Alternative

Figure 5.8 shows the maximum water elevations of the project area during a 100-year storm event under Year 2015 mean sea level conditions. Figure 5.9 and Figure 5.10 show the maximum water elevations during the same storm under mean sea level conditions in Year 2050 and Year 2100. To compare maximum water elevations of different storm events and mean sea level conditions, the maximum water elevation profiles experienced along the entire Lagoon for storm events of different return periods and sea level conditions are plotted in Figure 5.11.

5.5.4 Saltwater Alternative

Figure 5.12 shows the maximum water elevations of the project area during a 100-year storm event under Year 2015 mean sea level conditions. Figure 5.13 and Figure 5.14 show the maximum water elevations during the same storm under mean sea level conditions in Year 2050 and Year 2100. To compare maximum water elevations of different storm events and mean sea level conditions, the maximum water elevation profiles experienced along the entire Lagoon for storm events of different return periods and mean sea level conditions are plotted in Figure 5.15.

5.5.5 Hybrid Alternative Option A

Figure 5.16 shows the maximum water elevations of the project area during a 100-year storm event under Year 2015 mean sea level conditions. Figure 5.17 and Figure 5.18 show the maximum water elevations during the same storm under mean sea level rise conditions in Year 2050 and Year 2100. To compare maximum water elevations of different storm events and mean sea level conditions, the maximum water elevation profiles experienced along the entire Lagoon for storm events of different return periods and mean sea level conditions are plotted in Figure 5.19.

Figure 5.3 Maximum Water Elevations under Existing Conditions during a 100-Year Storm in Year 2015

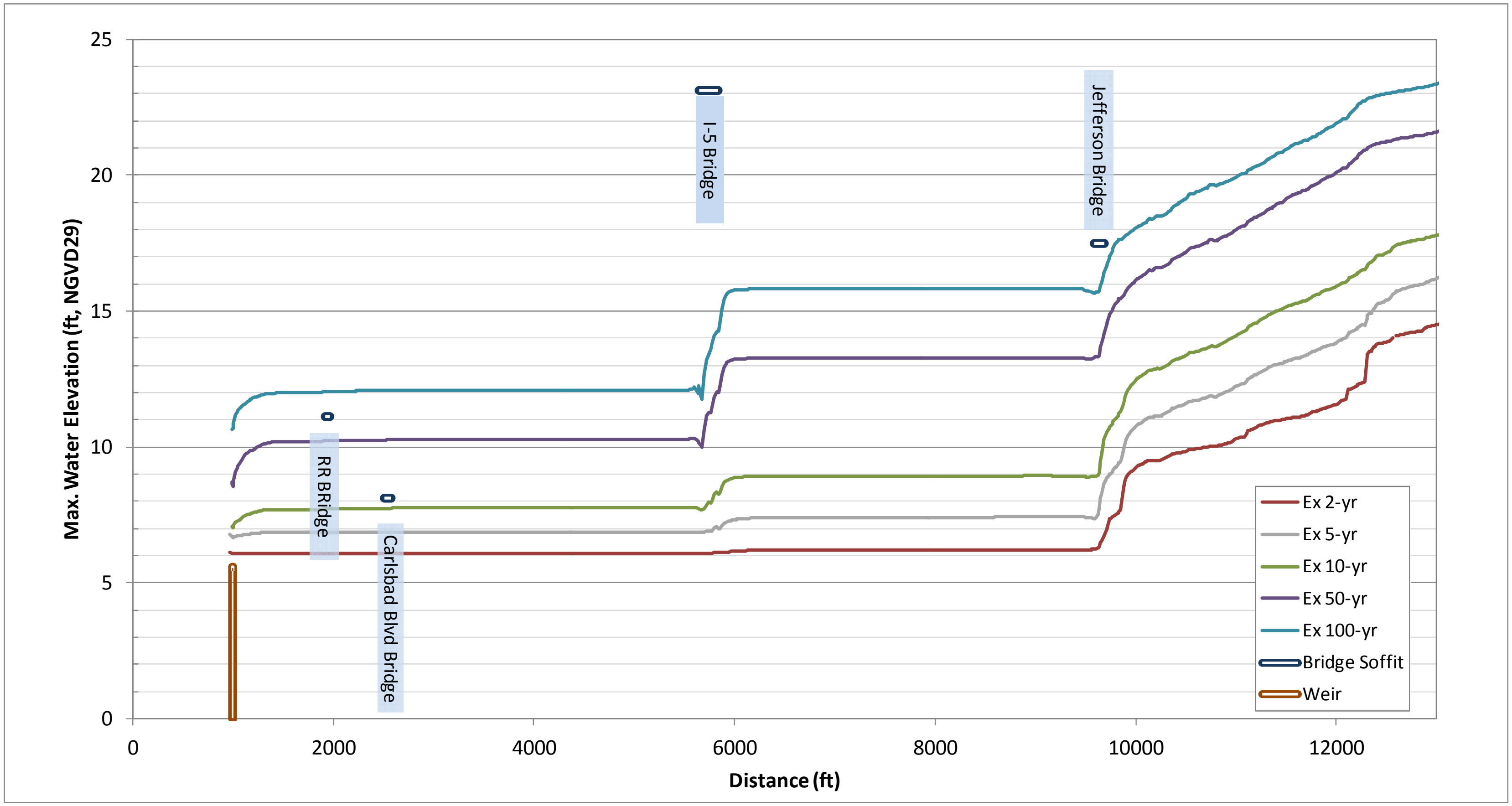


Figure 5.4 Maximum Water Elevation Profiles under Existing Conditions

Figure 5.5 Maximum Water Elevations under No-Project Conditions during a 100-Year Storm in Year 2050

Figure 5.6 Maximum Water Elevations under No-Project Conditions during a 100-Year Storm in Year 2100

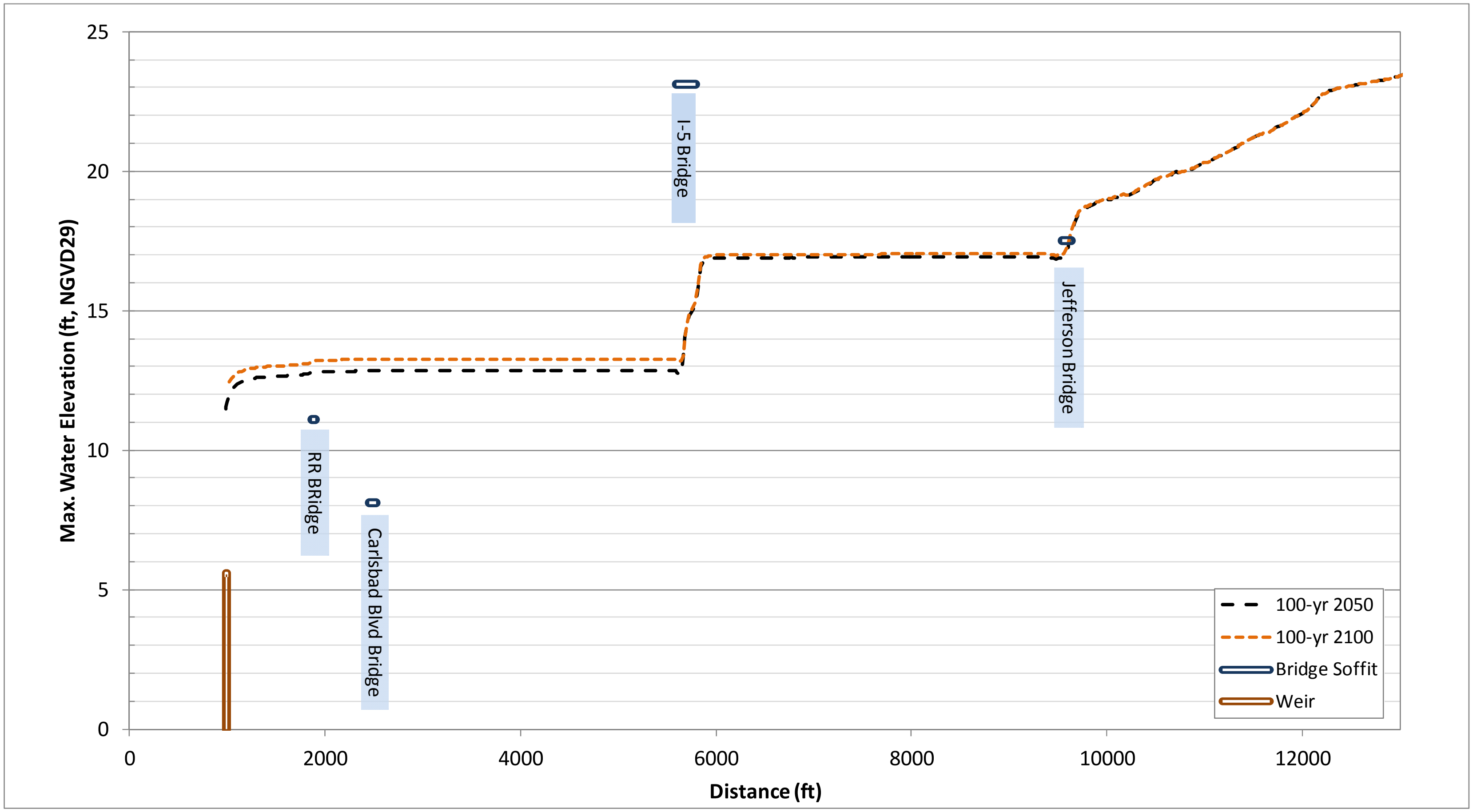


Figure 5.7 Maximum Water Elevation Profiles under No-Project Conditions

Figure 5.8 Maximum Water Elevations under Freshwater Alternative during a 100-Year Storm in Year 2015

Figure 5.9 Maximum Water Elevations under Freshwater Alternative during a 100-Year Storm in Year 2050

Figure 5.10 Maximum Water Elevations under Freshwater Alternative during a 100-Year Storm in Year 2100

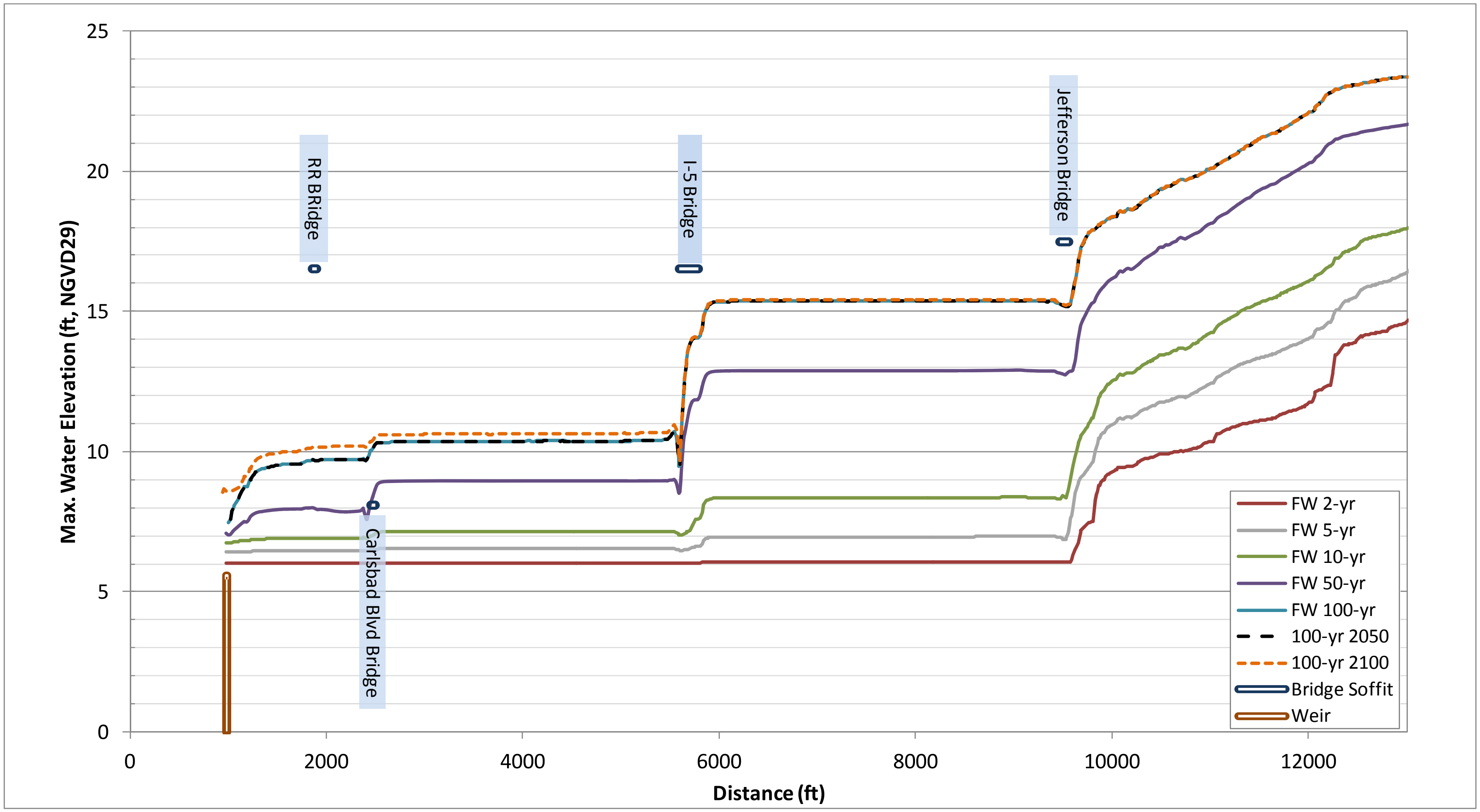


Figure 5.11 Maximum Water Elevation Profiles under Freshwater Alternative

Figure 5.12 Maximum Water Elevations under Saltwater Alternative during a 100-Year Storm in Year 2015

Figure 5.13 Maximum Water Elevations under Saltwater Alternative during a 100-Year Storm in Year 2050

Figure 5.14 Maximum Water Elevations under Saltwater Alternative during a 100-Year Storm in Year 2100

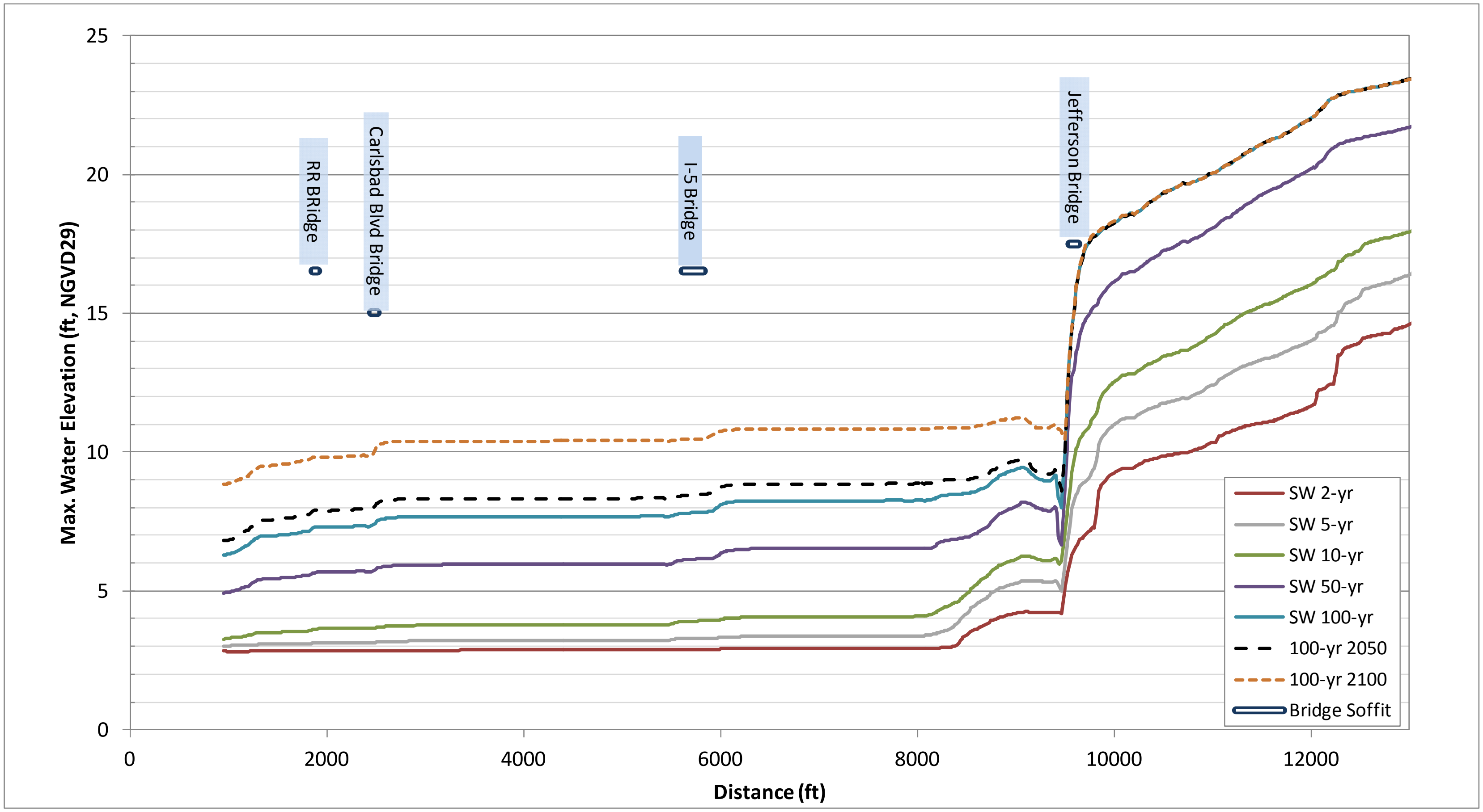


Figure 5.15 Maximum Water Elevation Profiles under Saltwater Alternative

Figure 5.16 Maximum Water Elevations under Hybrid A during a 100-Year Storm in Year 2015

Figure 5.17 Maximum Water Elevations under Hybrid A during a 100-Year Storm in Year 2050

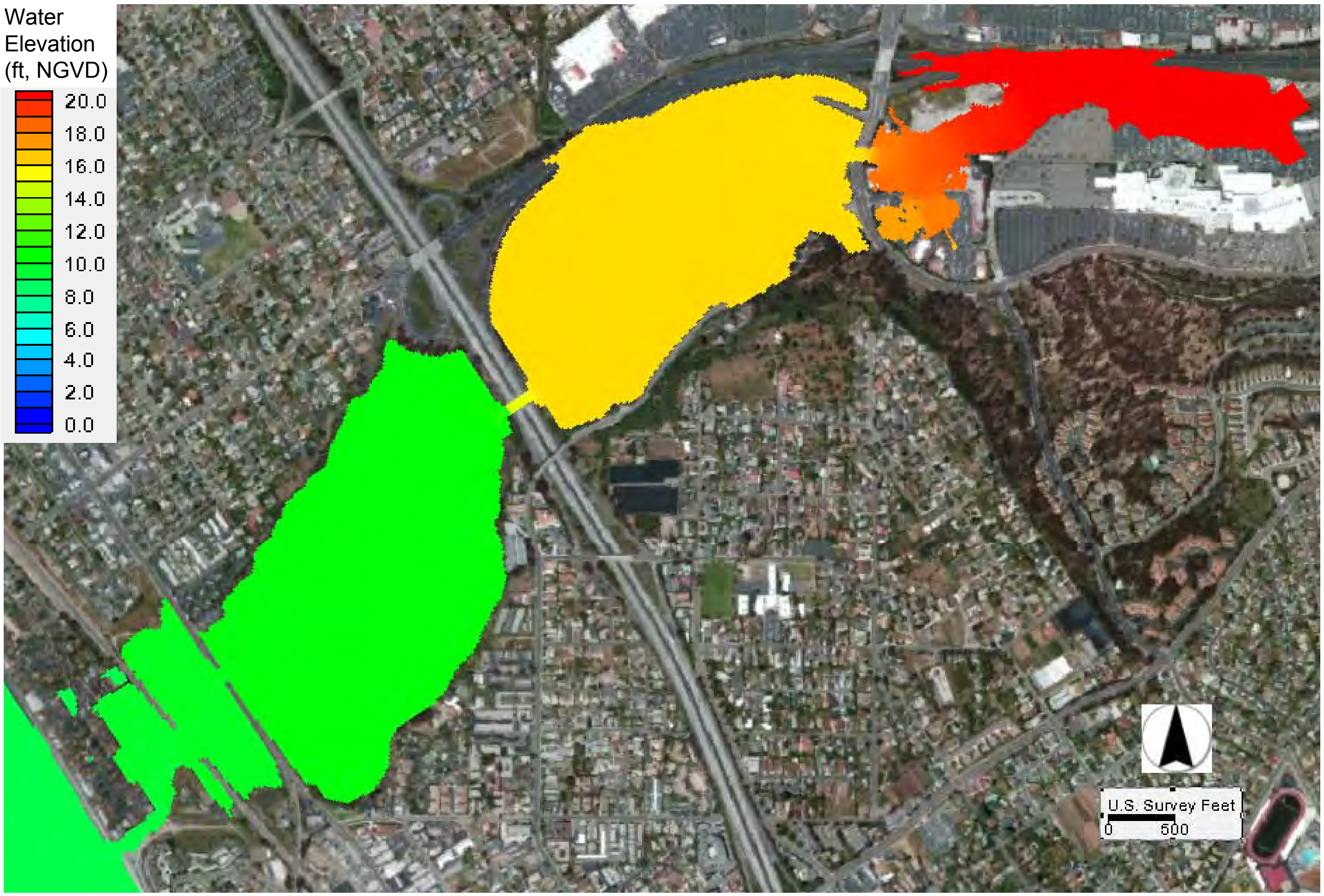


Figure 5.18 Maximum Water Elevations under Hybrid A during a 100-Year Storm in Year 2100

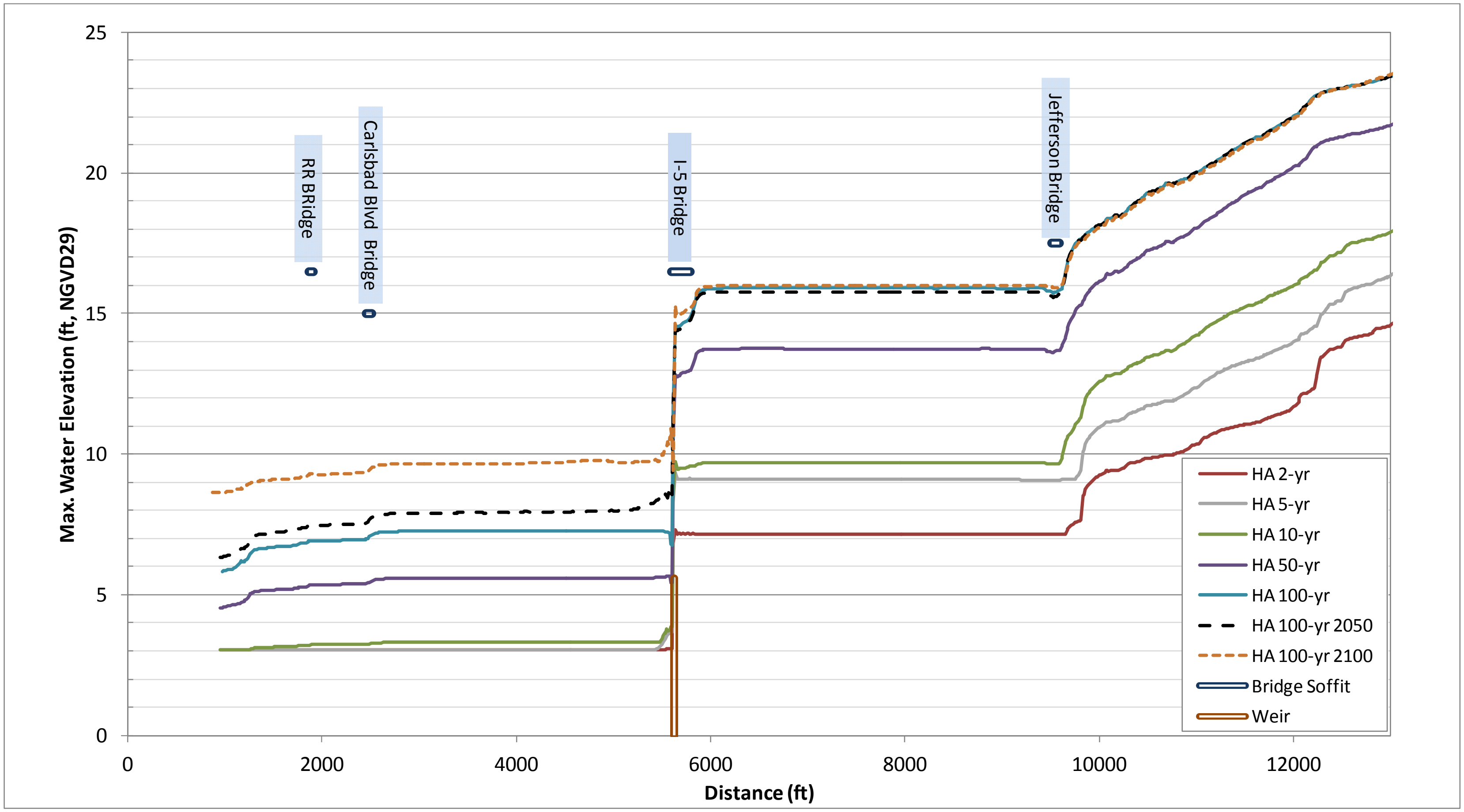


Figure 5.19 Maximum Water Elevation Profiles under Hybrid A

5.5.6 Hybrid Alternative Option B

Figure 5.20 shows the maximum water elevations of the project area during a 100-year storm event under Year 2015 mean sea level conditions. Figure 5.21 and Figure 5.22 show the maximum water elevations during the same storm under mean sea level rise conditions in Year 2050 and Year 2100. To compare maximum water elevations of different storm events and mean sea level conditions, the maximum water elevation profiles experienced along the entire Lagoon for storm events of different return periods and mean sea level conditions are plotted in Figure 5.23.

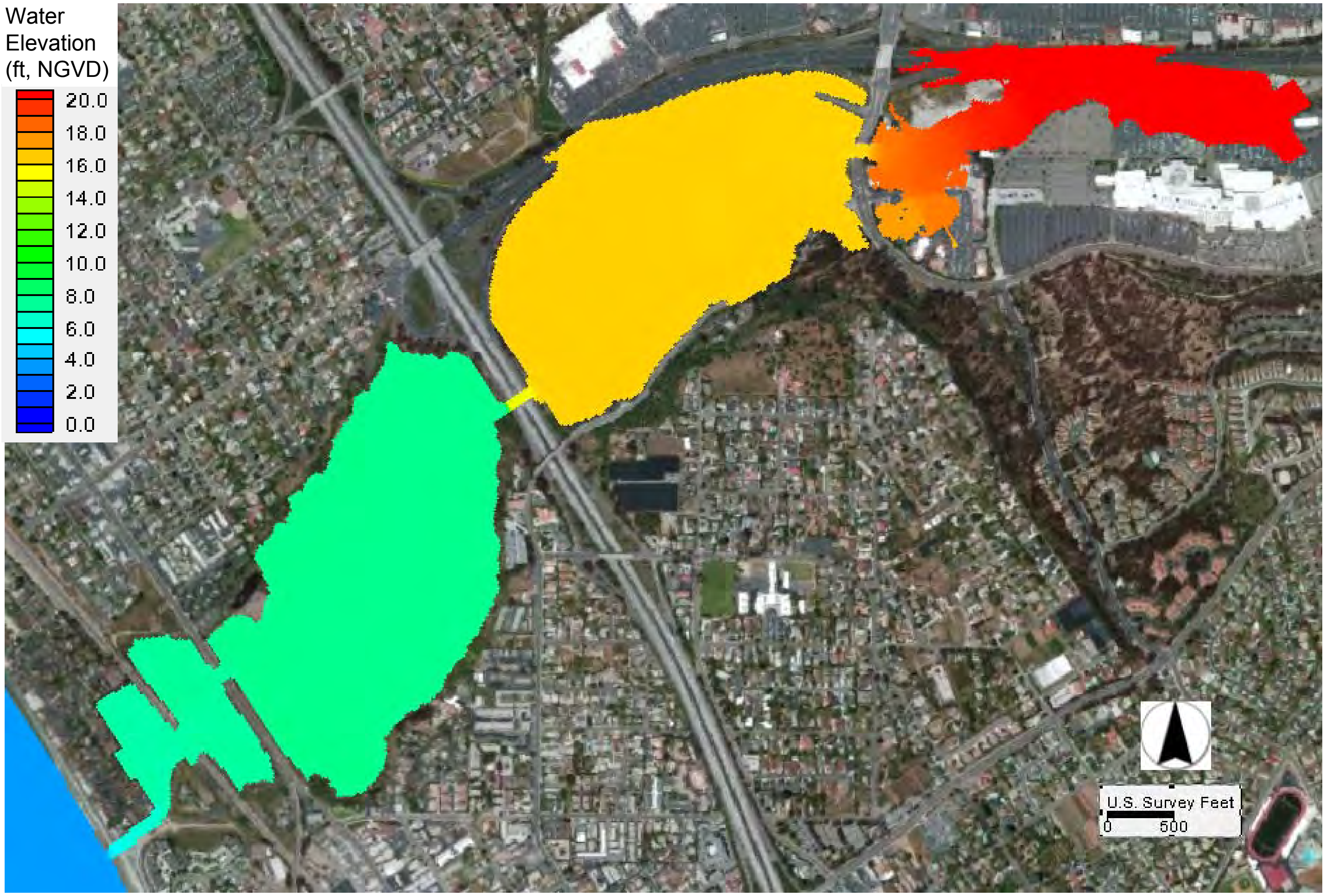


Figure 5.20 Maximum Water Elevations under Hybrid B during a 100-Year Storm in Year 2015

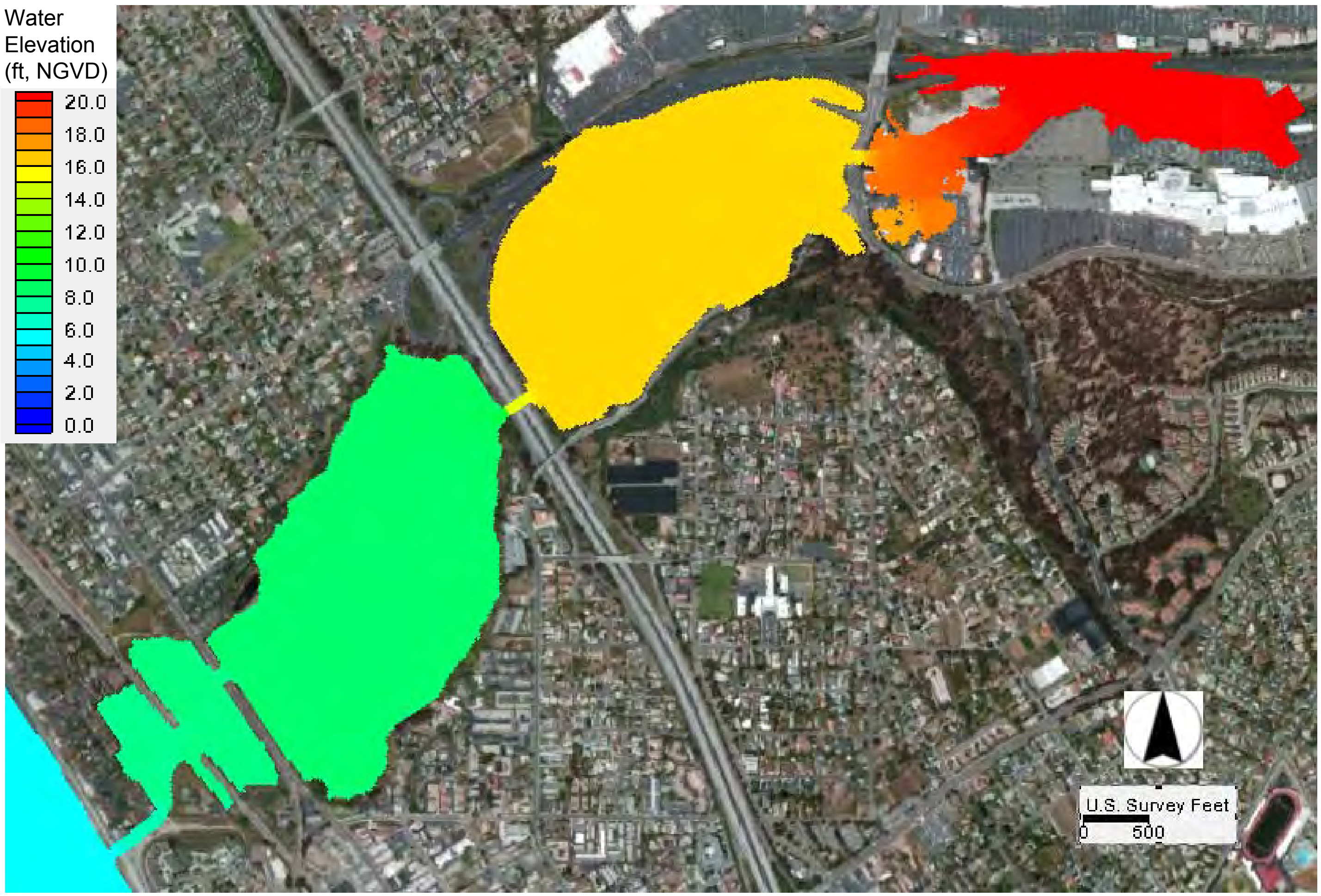


Figure 5.21 Maximum Water Elevations under Hybrid B during a 100-Year Storm in Year 2050

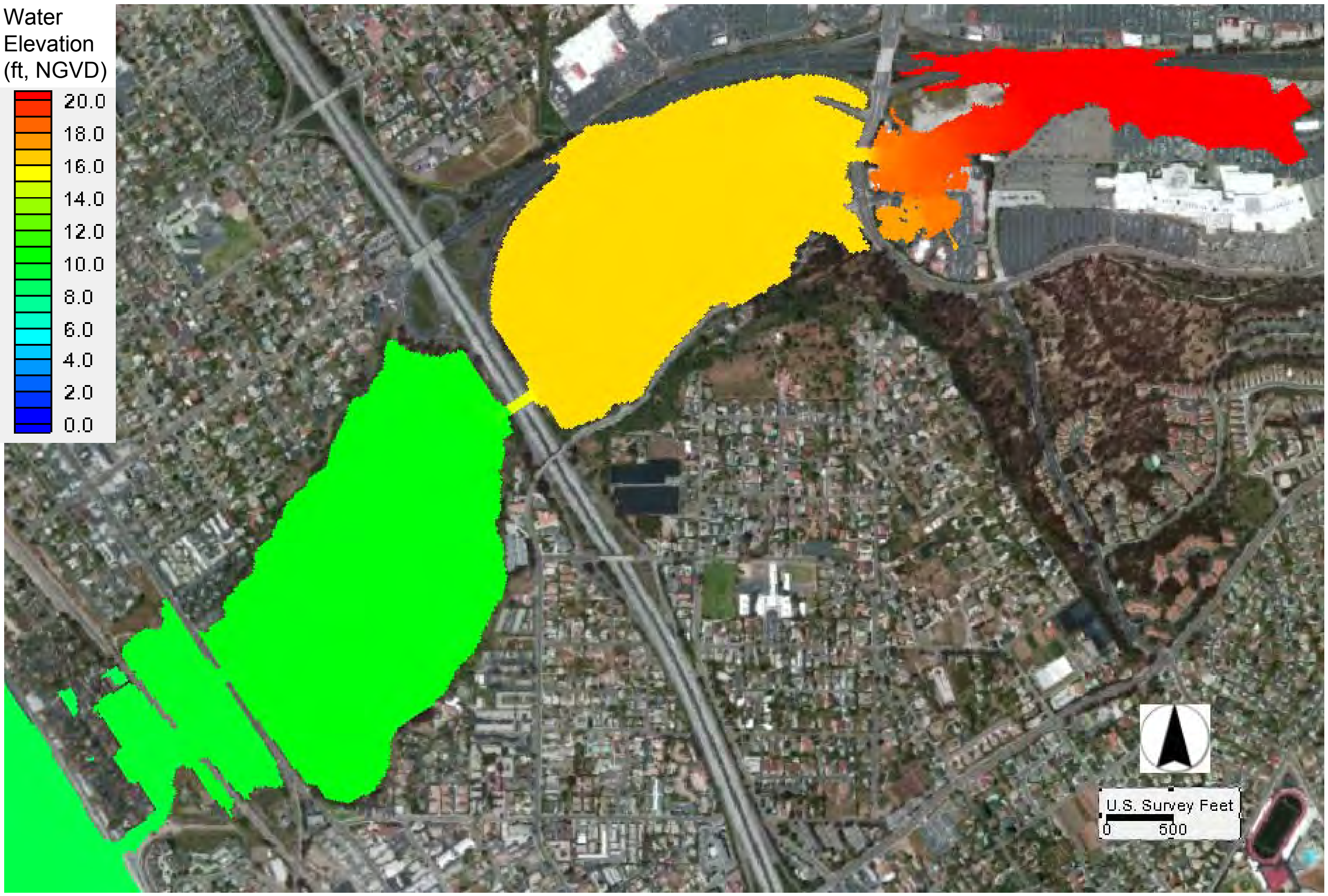


Figure 5.22 Maximum Water Elevations under Hybrid B during a 100-Year Storm in Year 2100

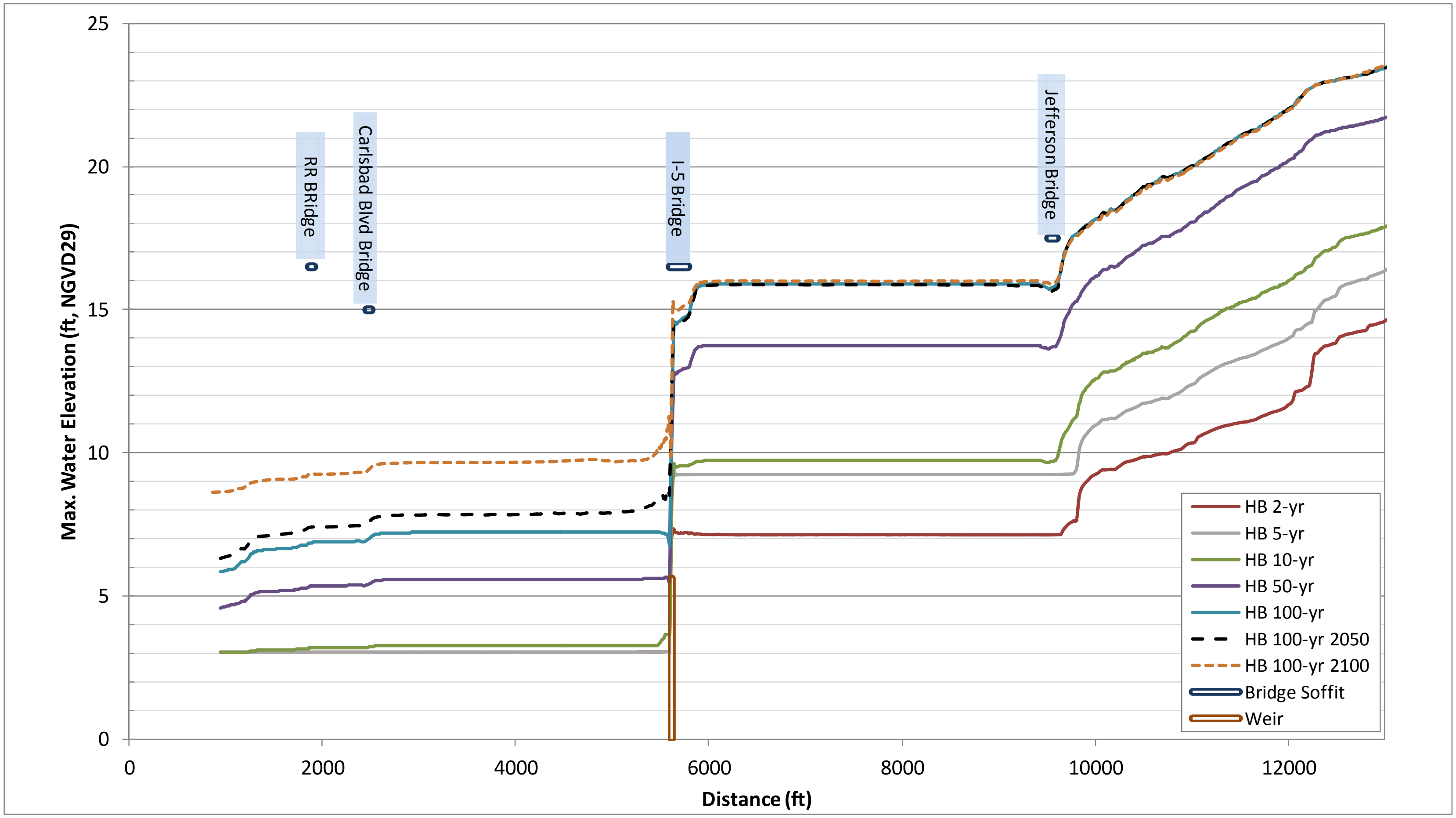


Figure 5.23 Maximum Water Elevation Profiles under Hybrid B

5.5.7 Alternative Comparison – Water Elevations

2015 Sea Level Conditions

To compare the flooding results under Existing Conditions and the four enhancement alternatives, the maximum water elevation results for each enhancement alternative are summarized in Table 5.2 for each basin for storm events of different return periods. This information is also shown graphically in Figure 5.24, which shows the maximum water elevations of the project area during a 100-year storm event under Existing Conditions and the four enhancement alternatives.

Under the 100-yr storm event, the maximum water elevations in all four basins occur under Existing Conditions, although the maximum water elevations under the Hybrid Alternative (Hybrid A and Hybrid B) are the same within the I-5 Basin. Under the 50-yr, 10-yr, 5-yr, and 2-yr storm events, the maximum water elevations in the Weir Basin, Railroad Basin, and Coast Highway Basin also occur under Existing Conditions. However, under the 50-yr, 10-yr, 5-yr, and 2-yr storm events, the maximum water elevations in the I-5 Basin occur under the Hybrid Alternative (Hybrid A and Hybrid B).

Under the 100-yr, 50-yr, 10-yr, and 5-yr storm events, the lowest flood elevations in the Weir Basin, Railroad Basin, and Coast Highway Basin occur under the Hybrid Alternative (Hybrid A and Hybrid B). Under the 2-yr storm event, the lowest flood elevations in the Weir Basin, Railroad Basin, and Coast Highway Basin occur under the Saltwater Alternative, although the results are fairly close to the Hybrid Alternative (Hybrid A and Hybrid B). The lowest flood elevations in the I-5 Basin occur under the Saltwater Alternative. This trend is the same under all storm events. This shows the effect of an open tidal inlet on reducing flood elevations by allowing flood waters to drain from the Lagoon to the ocean.

The results indicate that all four enhancement alternatives would improve flood conditions for the 100-yr storm event, except within the I-5 Basin under the Hybrid Alternative (Hybrid A and Hybrid B), which would result in no increase in water elevation. The Saltwater Alternative would yield the most improvement for the 100-yr storm event within the I-5 Basin, while the Hybrid Alternative (Hybrid A and Hybrid B) would yield the most improvement for the 100-yr storm event within the other three basins. For smaller storm events, the results indicate that the Saltwater Alternative would yield the most improvement within the I-5 Basin, while the Hybrid Alternative (Hybrid A and Hybrid B) would yield the most improvement within the other three basins, except under the 2-yr storm event for which the Saltwater Alternative would yield the most improvement.

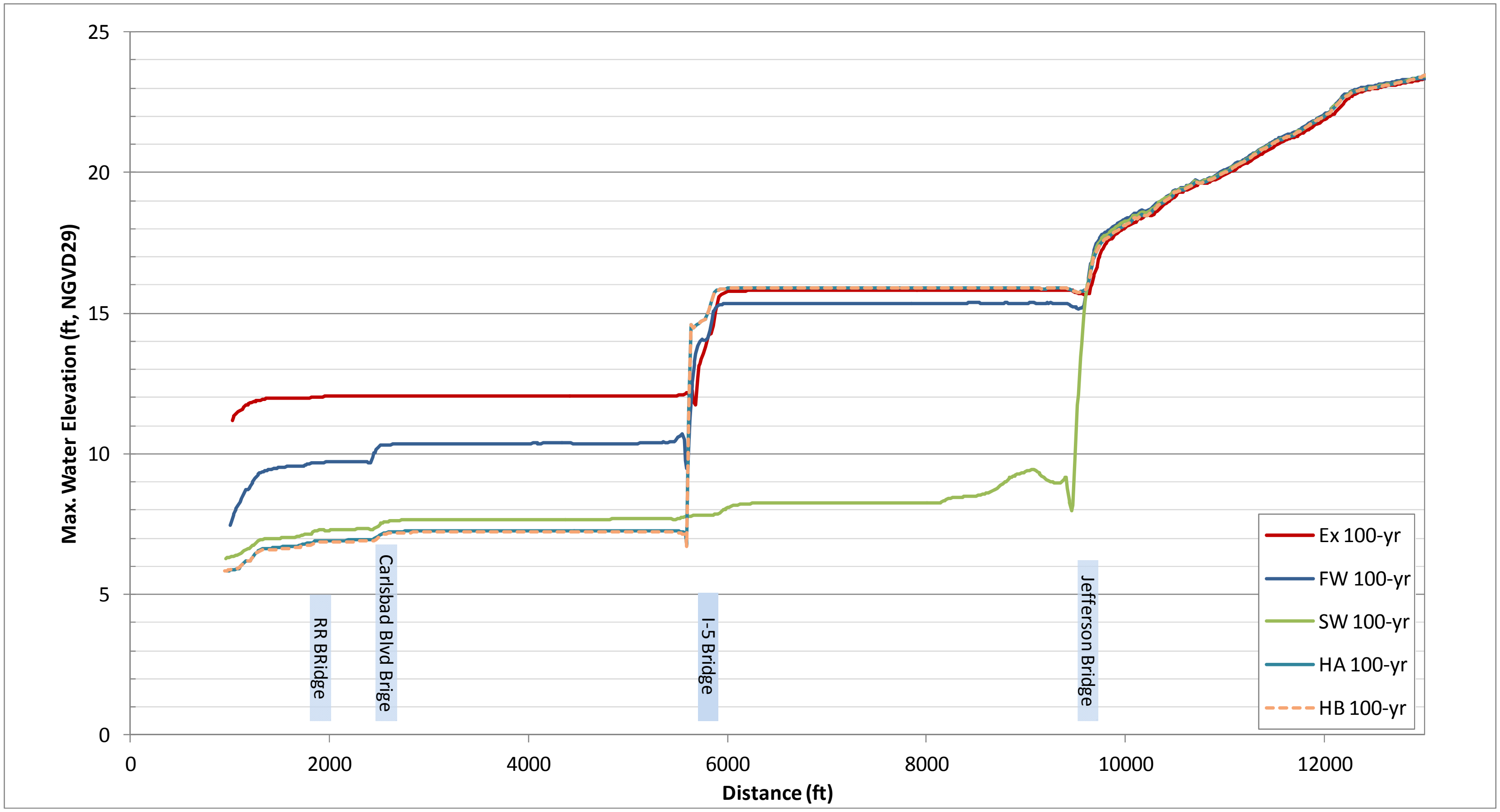


Figure 5.24 Maximum Water Elevation Profiles Comparison

Table 5.2 Comparison of Fluvial Results Under 2015 Mean Sea Level Conditions

STORM RETURN PERIOD (YEAR)	ALTERNATIVE	MAXIMUM WATER ELEVATION (FT, NGVD)			
		WEIR BASIN	RAILROAD BASIN	COAST HIGHWAY BASIN	I-5 BASIN
100	Existing Conditions	12.0	12.1	12.1	15.8
	Freshwater Alternative	9.6	9.7	10.4	15.4
	Saltwater Alternative	7.0	7.3	7.7	8.2
	Hybrid A	6.6	6.8	7.1	15.9
	Hybrid B	6.6	6.8	7.1	15.9
50	Existing Conditions	10.2	10.2	10.3	13.3
	Freshwater Alternative	8.0	7.9	9.0	12.9
	Saltwater Alternative	5.4	5.7	6.0	6.5
	Hybrid A	5.2	5.4	5.6	13.7
	Hybrid B	5.2	5.4	5.6	13.8
10	Existing Conditions	7.7	7.7	7.8	8.9
	Freshwater Alternative	6.9	6.9	7.1	8.4
	Saltwater Alternative	3.5	3.6	3.8	4.0
	Hybrid A	3.1	3.2	3.3	9.7
	Hybrid B	3.1	3.2	3.3	9.7
5	Existing Conditions	6.9	6.9	6.9	7.4
	Freshwater Alternative	6.5	6.5	6.5	7.0
	Saltwater Alternative	3.1	3.1	3.2	3.3
	Hybrid A	3.0	3.0	3.0	9.1
	Hybrid B	3.0	3.0	3.0	9.2
2	Existing Conditions	6.1	6.1	6.1	6.2
	Freshwater Alternative	6.0	6.0	6.0	6.0
	Saltwater Alternative	2.8	2.8	2.9	2.9
	Hybrid A	3.0	3.0	3.0	7.1
	Hybrid B	3.0	3.0	3.0	7.1

Sea Level Rise Conditions

To assess the impact of increases in mean sea level on the flood results, the fluvial modeling results under the three different mean sea level conditions for each of the four enhancement alternatives are summarized in Table 5.3 for each basin for the 100-yr storm event. The results show that as mean sea level rises in the future the water levels in the Lagoon during a 100-yr storm event would increase relative to the water levels expected during the same magnitude flood occurring during Year 2015. The highest flood water levels during the 100-yr storm event would be associated with the No-Project Condition. The enhancement alternatives would improve the flood performance of the Lagoon within all four basins under the 100-yr storm event in comparison to the No-Project Condition. The least increase in water elevations within the I-5 Basin would occur under the Saltwater Alternative, while the least increase in the other three basin would occur under the Hybrid Alternative (Hybrid A and Hybrid B).

Table 5.3 Comparison of Fluvial Results Under Year 2015, Year 2050, and Year 2100 Mean Sea Level Conditions for the 100-yr Storm Event

Sea Level Conditions	Alternative	Maximum Water Elevation (ft, NGVD)			
		Weir Basin	Railroad Basin	Coast Highway Basin	I-5 Basin
2015	Existing Conditions	12.1	12.1	12.1	15.8
	Freshwater Alternative	9.6	9.7	10.4	15.4
	Saltwater Alternative	7.0	7.3	7.7	8.2
	Hybrid A	6.6	6.8	7.1	15.9
	Hybrid B	6.6	6.8	7.1	15.9
2050	No-Project Conditions	12.7	12.8	12.9	16.9
	Freshwater Alternative	9.6	9.7	10.4	15.4
	Saltwater Alternative	7.5	7.9	8.3	8.8
	Hybrid A	7.1	7.4	7.9	16.0
	Hybrid B	7.1	7.4	7.9	16.0
2100	No-Project Conditions	13.1	13.2	13.3	17.0
	Freshwater Alternative	10.0	10.2	10.6	15.4
	Saltwater Alternative	9.5	9.8	10.4	10.8
	Hybrid A	9.1	9.3	9.7	16.0
	Hybrid B	9.1	9.3	9.7	16.0

5.6 RESULTS – VELOCITIES

In addition to water elevations, the TUFLOW model was used to evaluate flow velocities in the project area for Existing Conditions and the four enhancement alternatives. The fluvial velocities were studied to evaluate the erosion potential in the Lagoon during storm events as well as to provide velocities at the bridge or weir crossings for the proposed alternatives such that adequate erosion control measures can be developed in the future. Maximum velocities were plotted for the study area under Existing Conditions and the four enhancement alternatives during the 100-year storm event.

5.6.1 Existing Conditions

Figure 5.25 shows the maximum water elevations of the project area during a 100-year storm event under Existing Conditions for Year 2015 mean sea level conditions.

5.6.2 No-Project Conditions

Figure 5.26 and Figure 5.27 show the maximum velocities of the project area during a 100-year storm event under Year 2050 and Year 2100 mean sea level rise conditions, respectively.

5.6.3 Freshwater Alternative

Figure 5.28 shows the maximum water velocities of the project area during a 100-year storm event in Year 2015. Figure 5.29 and Figure 5.30 show the maximum water velocities during a 100-year storm under Year 2050 and Year 2100 mean sea level rise conditions, respectively.

5.6.4 Saltwater Alternative

Figure 5.31 shows the maximum water velocities of the project area during a 100-year storm event in Year 2015. Figure 5.32 and Figure 5.33 show the maximum water velocities during a 100-year storm under Year 2050 and Year 2100 mean sea level rise conditions, respectively.

5.6.5 Hybrid Alternative Option A

Figure 5.34 shows the maximum water velocities of the project area during a 100-year storm event in Year 2015. Figure 5.35 and Figure 5.36 show the maximum water velocities during a 100-year storm under Year 2050 and Year 2100 mean sea level rise conditions, respectively.

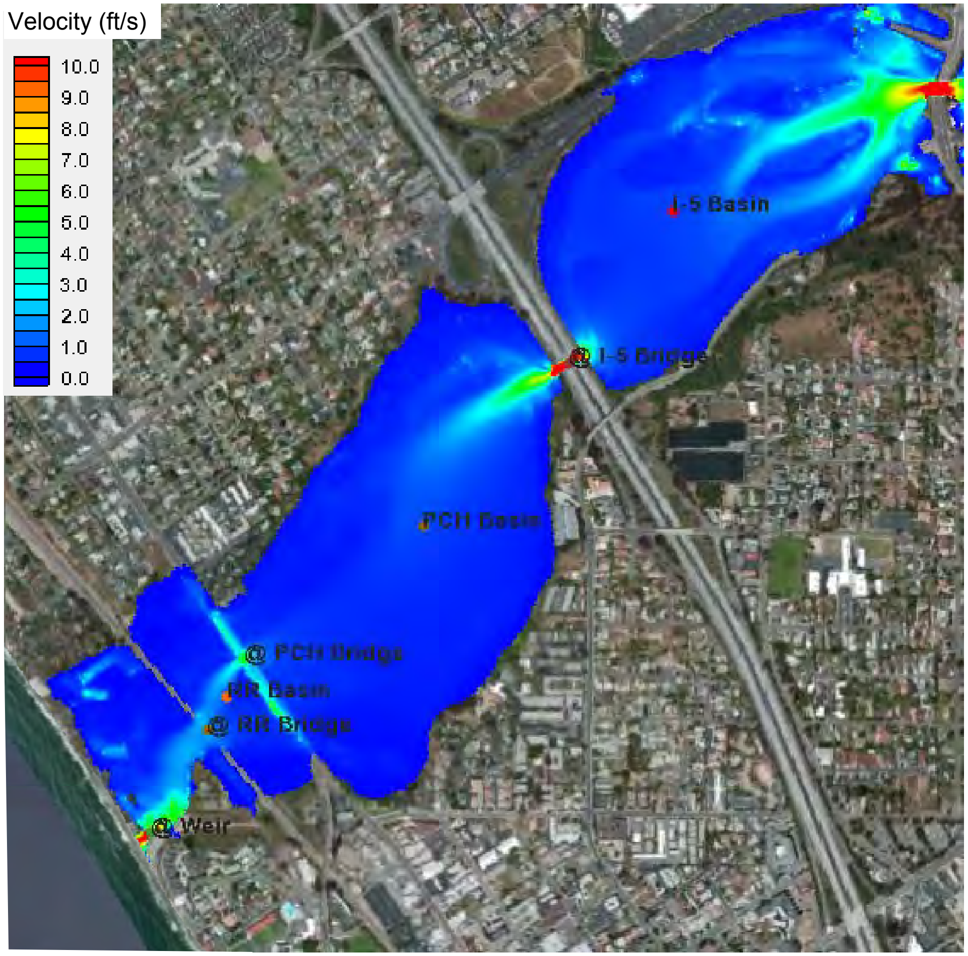


Figure 5.25 Maximum Water Velocities under Existing Conditions during a 100-Year Storm in Year 2015

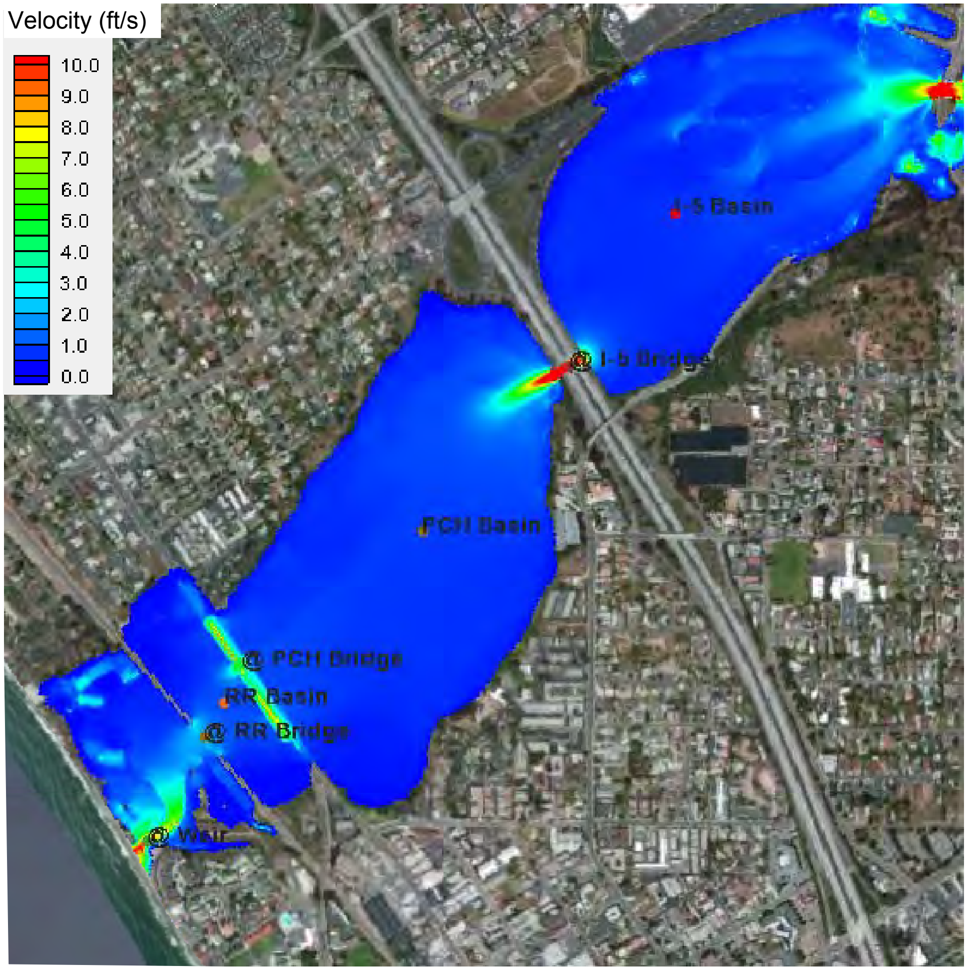


Figure 5.26 Maximum Water Velocities under No-Project Conditions during a 100-Year Storm in Year 2050

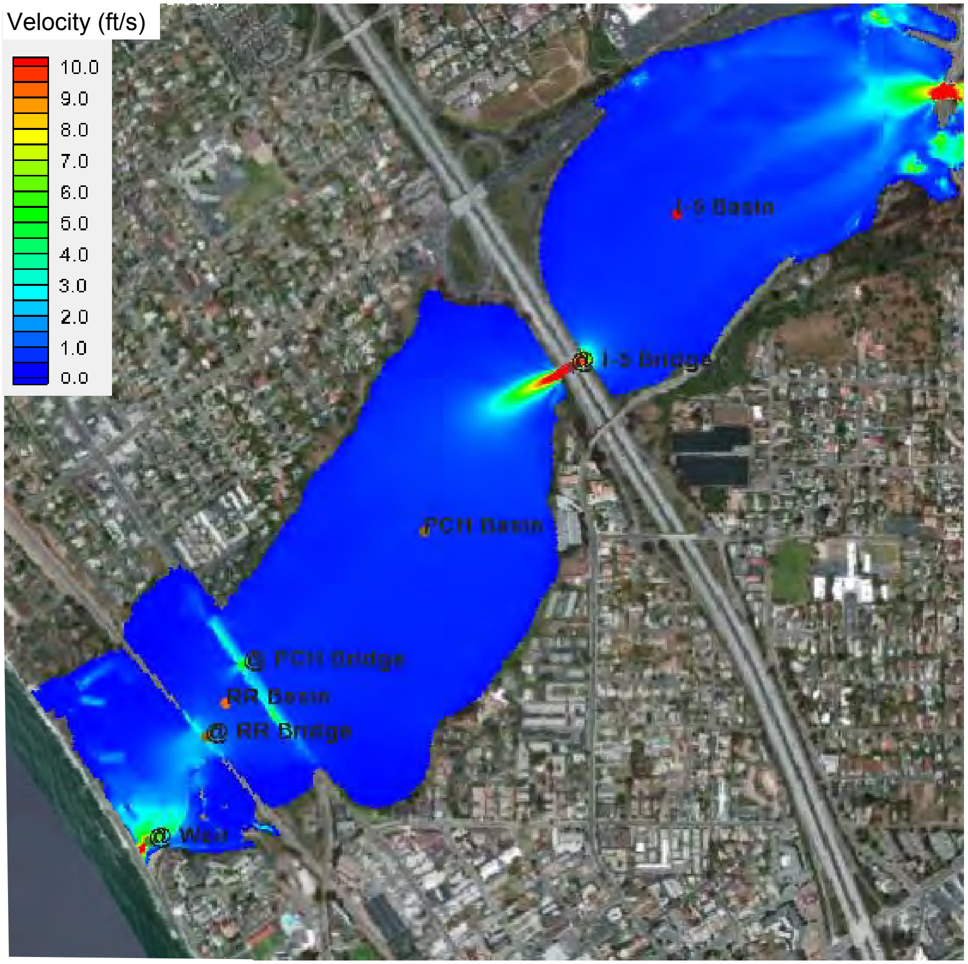


Figure 5.27 Maximum Water Velocities under No-Project Conditions during a 100-Year Storm in Year 2100

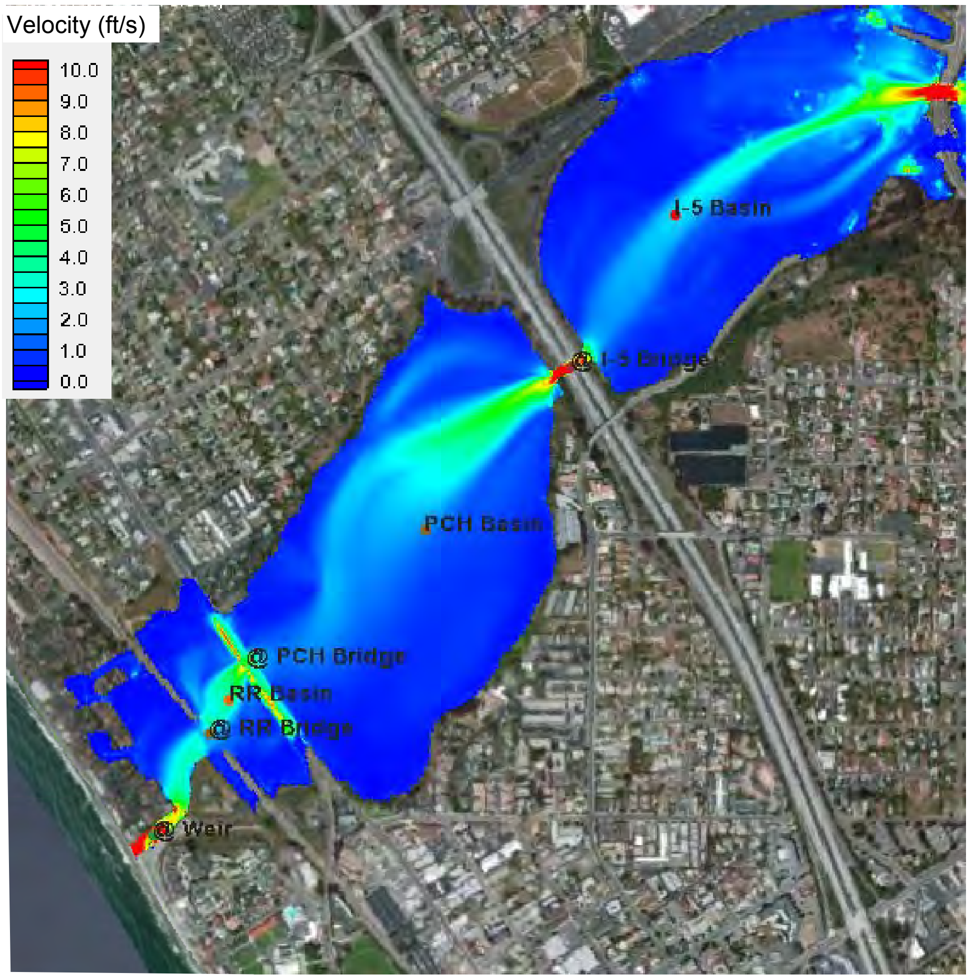


Figure 5.28 Maximum Water Velocities under Freshwater Alternative during a 100-Year Storm in Year 2015

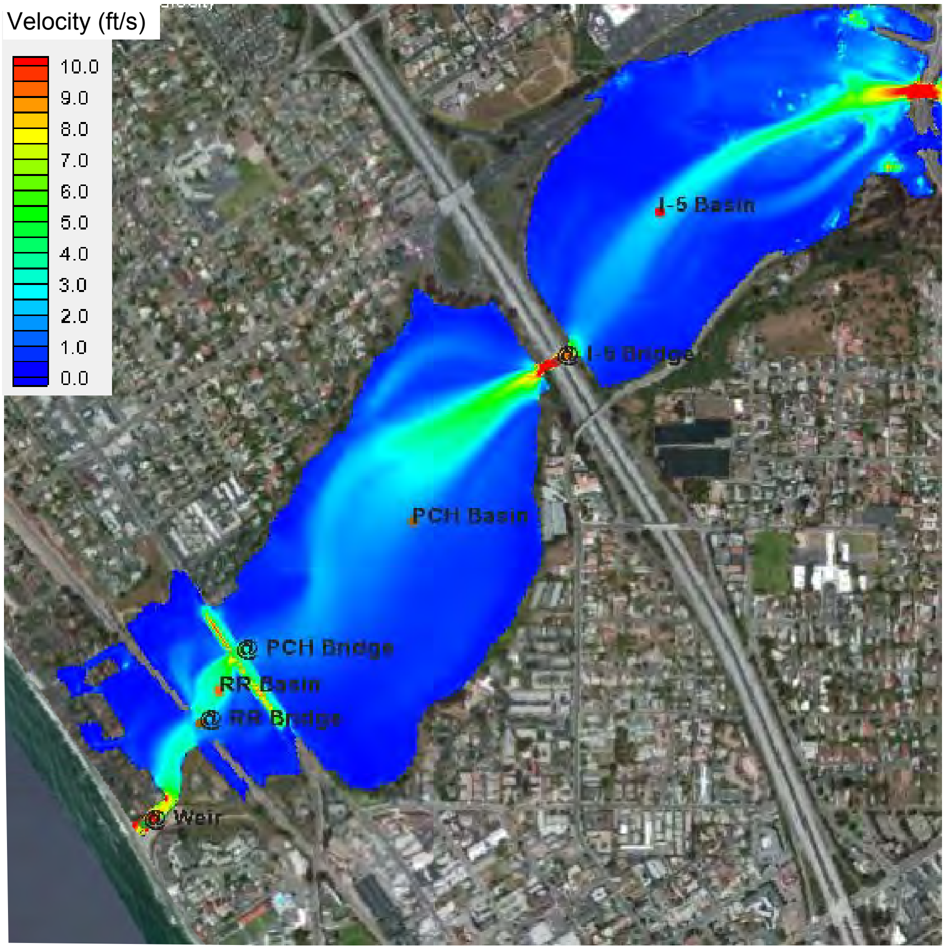


Figure 5.29 Maximum Water Velocities under Freshwater Alternative during a 100-Year Storm in Year 2050

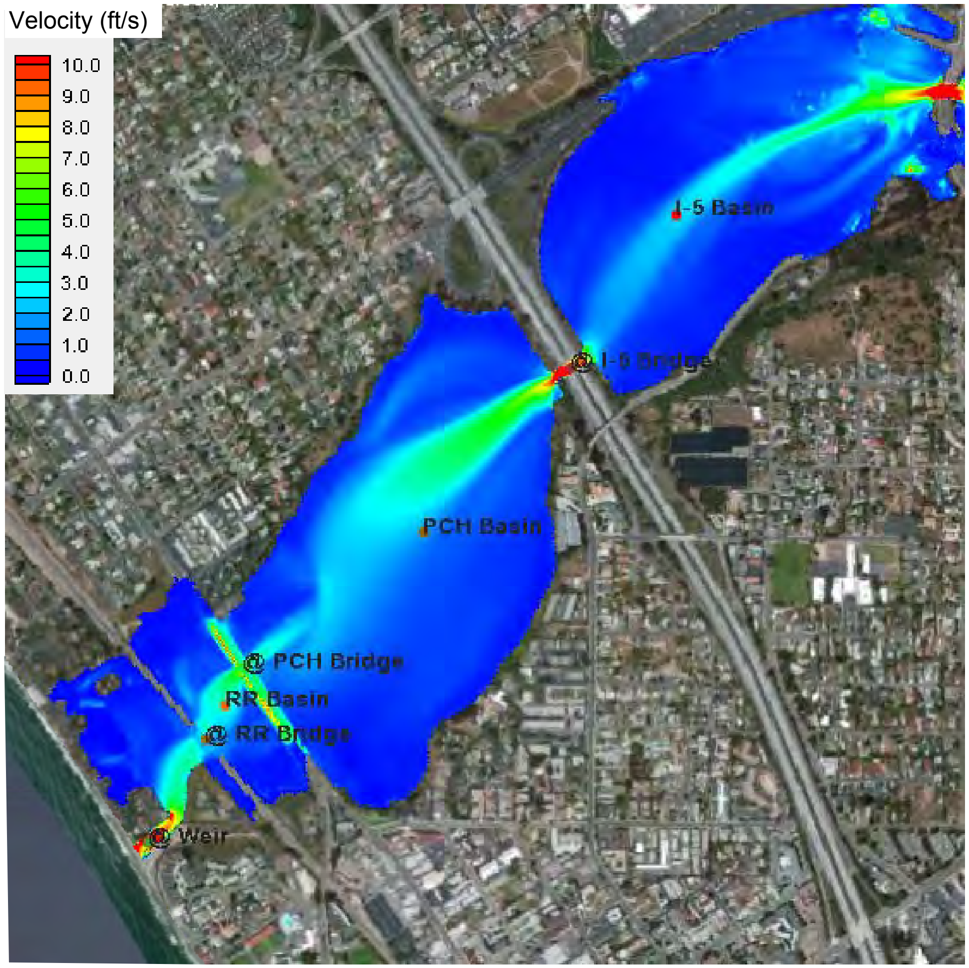


Figure 5.30 Maximum Water Velocities under Freshwater Alternative during a 100-Year Storm in Year 2100

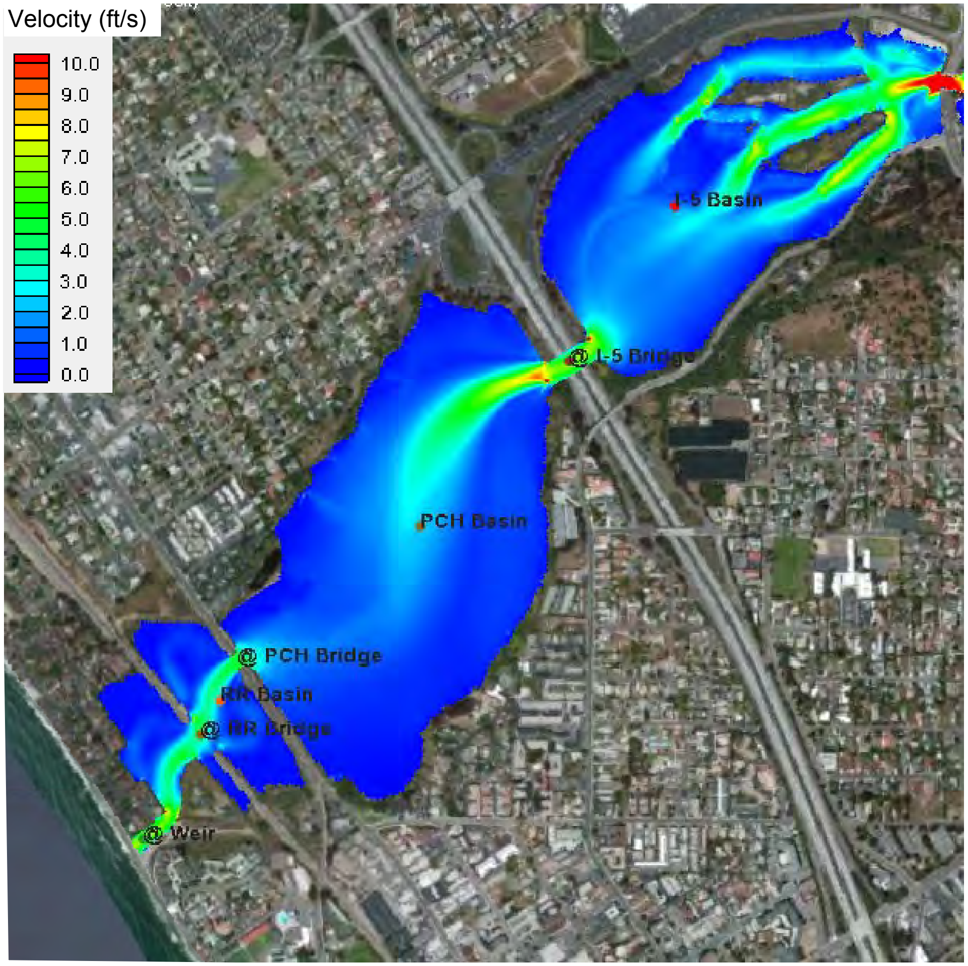


Figure 5.31 Maximum Water Velocities under Saltwater Alternative during a 100-Year Storm in Year 2015

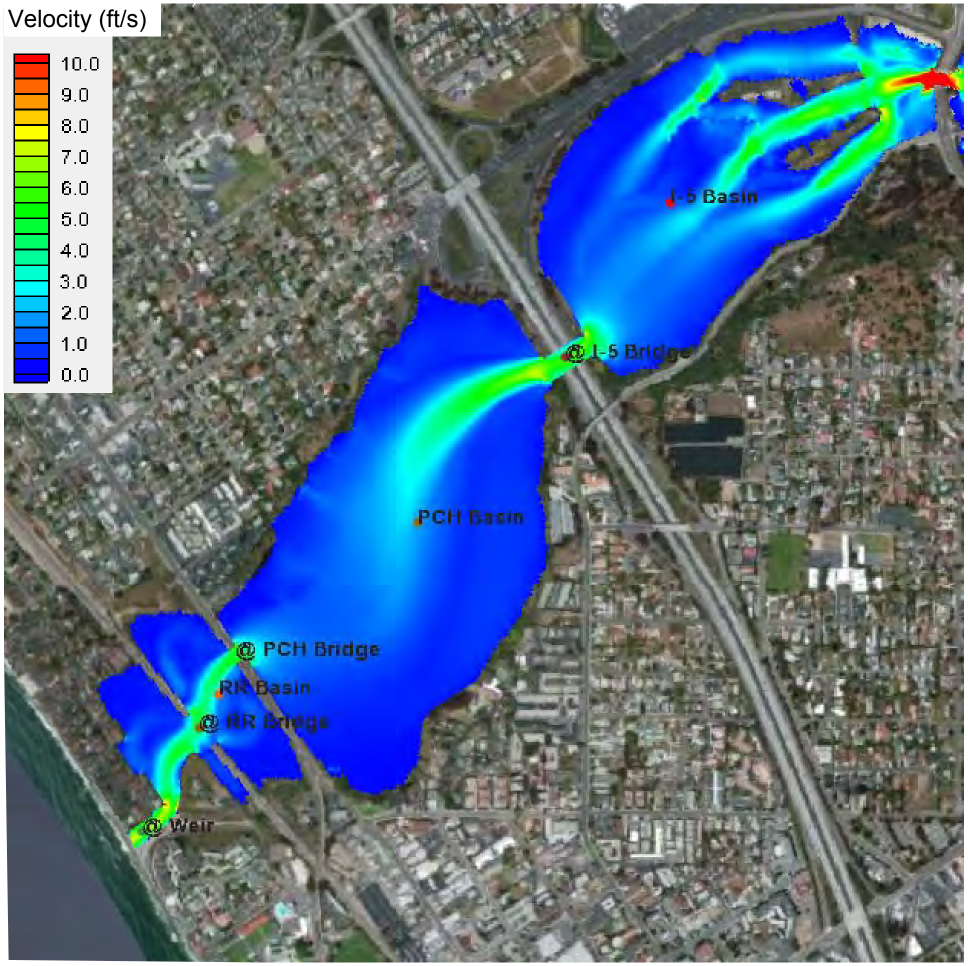


Figure 5.32 Maximum Water Velocities under Saltwater Alternative during a 100-Year Storm in Year 2050

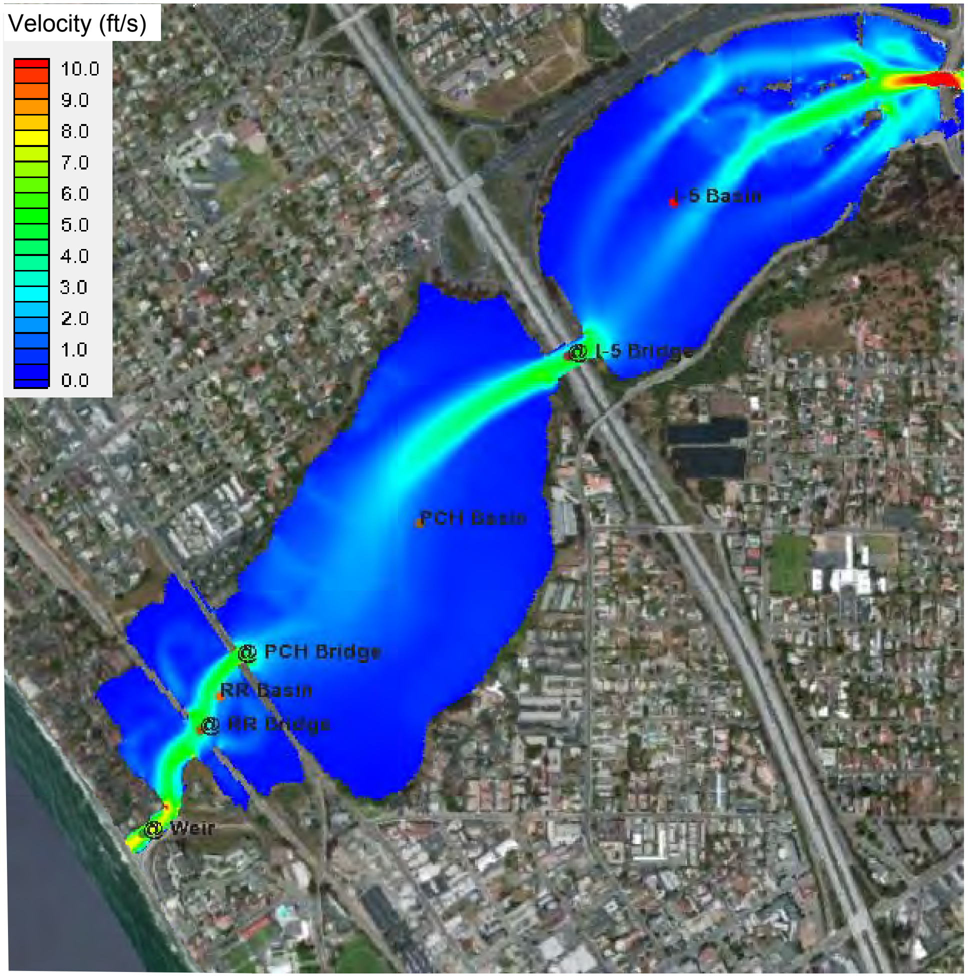


Figure 5.33 Maximum Water Velocities under Saltwater Alternative during a 100-Year Storm in Year 2100

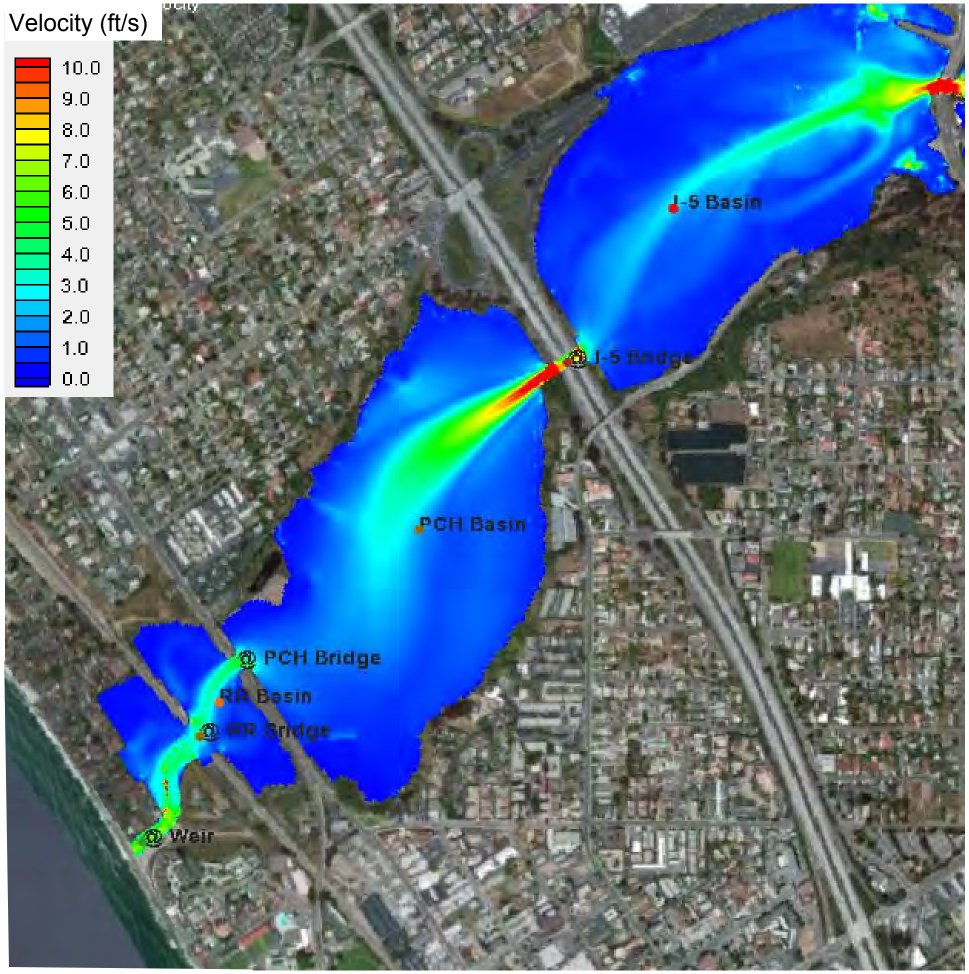


Figure 5.34 Maximum Water Velocities under Hybrid A during a 100-Year Storm in Year 2015

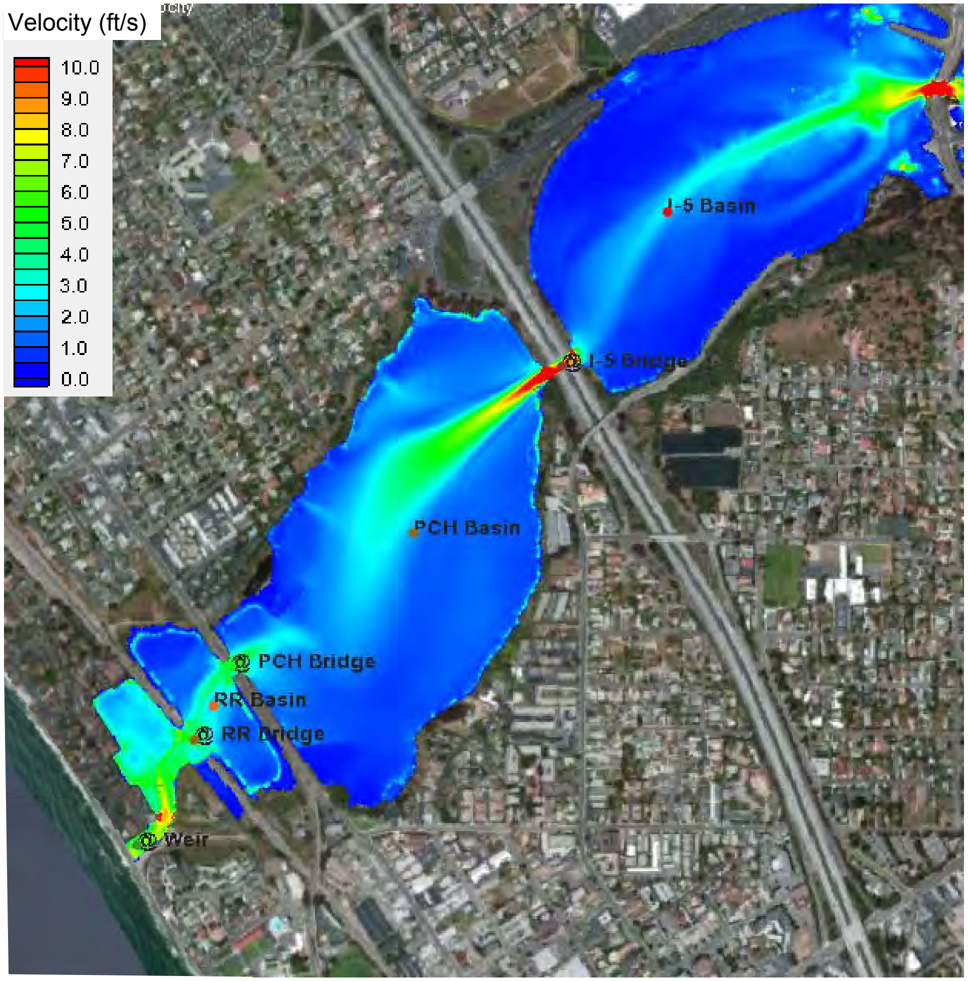


Figure 5.35 Maximum Water Velocities under Hybrid A during a 100-Year Storm in Year 2050

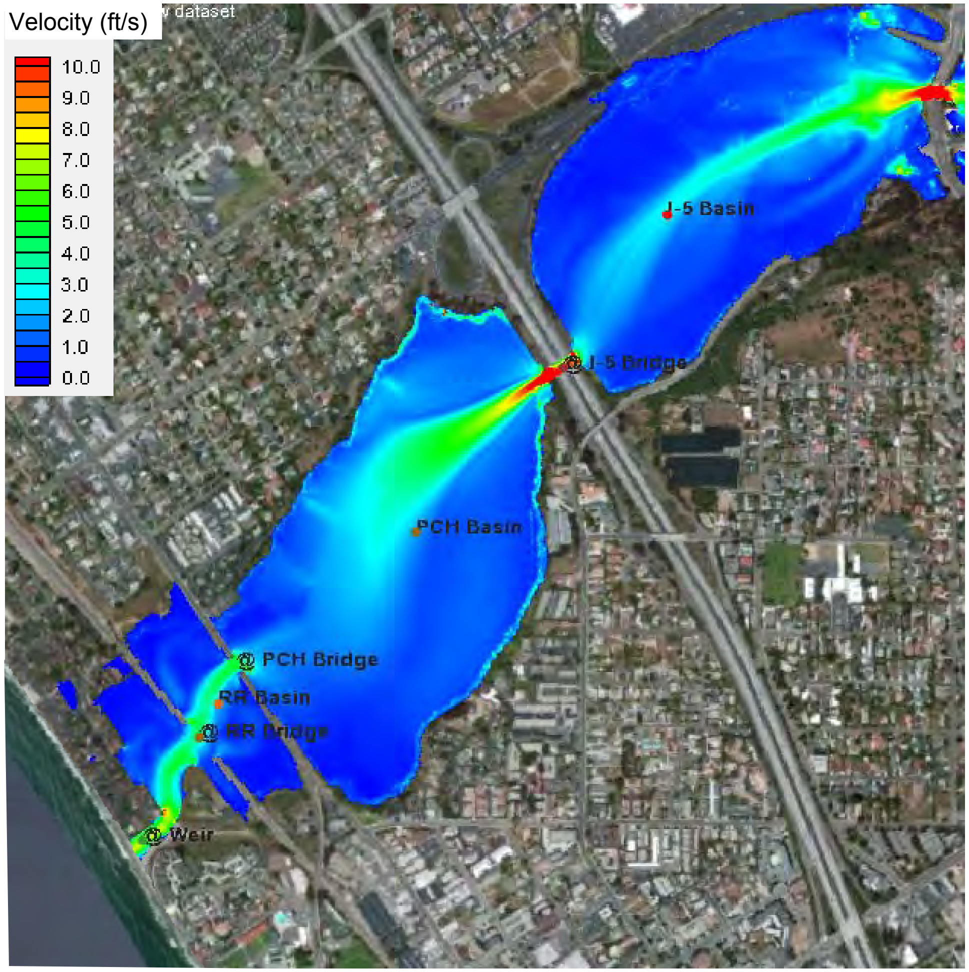


Figure 5.36 Maximum Water Velocities under Hybrid A during a 100-Year Storm in Year 2100

5.6.6 Hybrid Alternative Option B

Figure 5.37 shows the maximum water velocities of the project area during a 100-year storm event in Year 2015. Figure 5.38 and Figure 5.39 show the maximum water velocities during a 100-year storm under Year 2050 and Year 2100 mean sea level rise conditions, respectively.

5.7 SUMMARY

Water Elevations

The fluvial hydraulic analysis results show that the impact of storm events in the Lagoon varies depending on the storm magnitudes, dimensions of the hydraulic connections between the basins, and the connection between the Lagoon and ocean. Based on the results of the analysis, flood conditions would generally be improved with implementation of any one of the enhancement alternatives since flood elevations under the enhancement alternatives are lower than or equal to flood elevations under Existing Conditions. Overall, the Saltwater Alternative would result in the most improvement to flood conditions and the Freshwater Alternative would result in the least improvement. From a basin standpoint, the Saltwater Alternative would yield the greatest improvement for the I-5 Basin while the Hybrid Alternative would yield the greatest improvement for the other three basins.

Velocities

The fluvial hydraulic analysis water velocity results revealed that the velocities in the basins would be below 1 ft/s, except in the defined channel running through the basins. This suggests that erosion would be limited to the channel and would likely only occur during large storm events. The predicted velocities are higher at the hydraulic connections with velocities exceeding 3 ft/s, thereby indicating a potential for erosion. Slope protection will be required in these areas to protect the side slopes and bridge infrastructure from erosion.

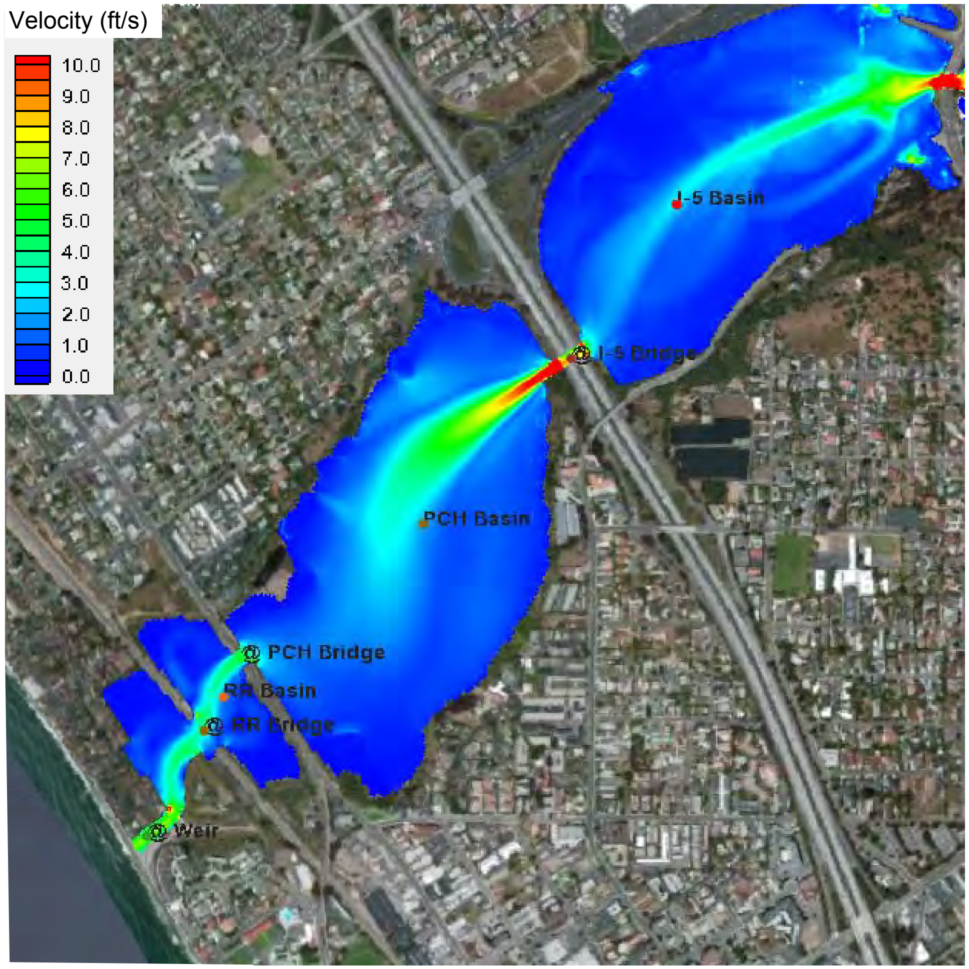


Figure 5.37 Maximum Water Velocities under Hybrid B during a 100-Year Storm in Year 2015

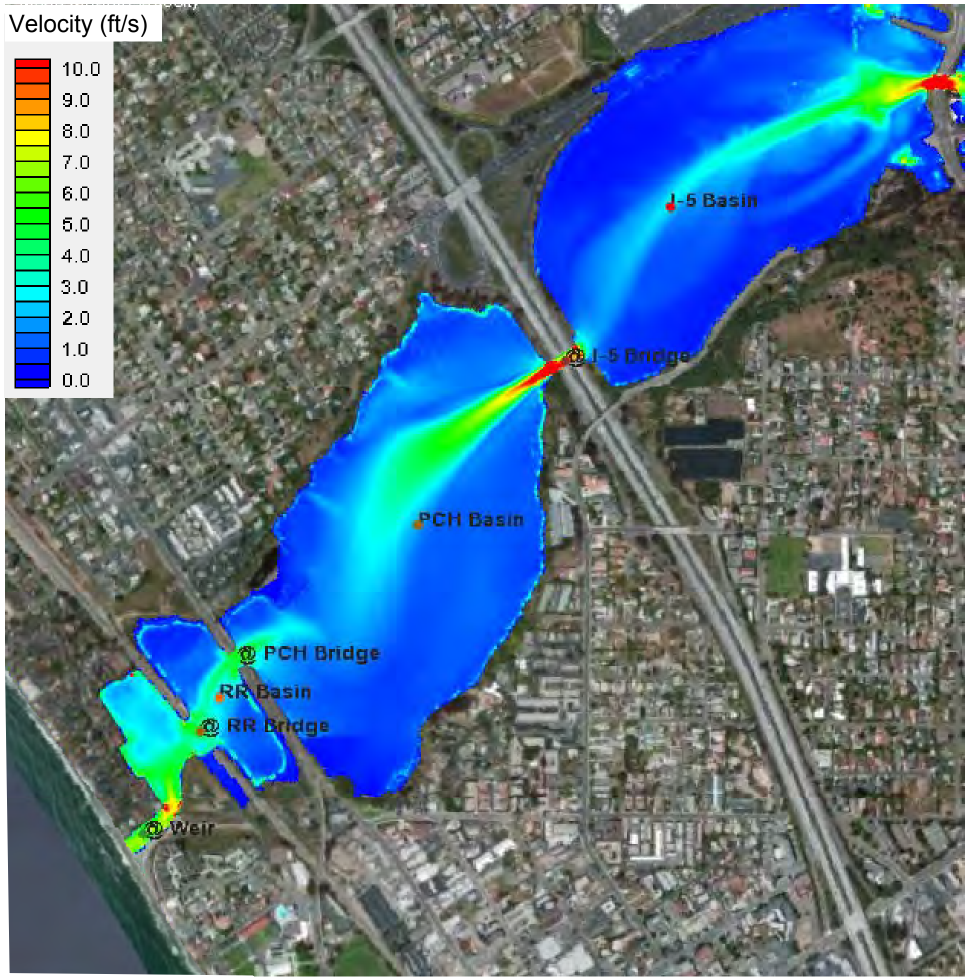


Figure 5.38 Maximum Water Velocities under Hybrid B during a 100-Year Storm in Year 2050

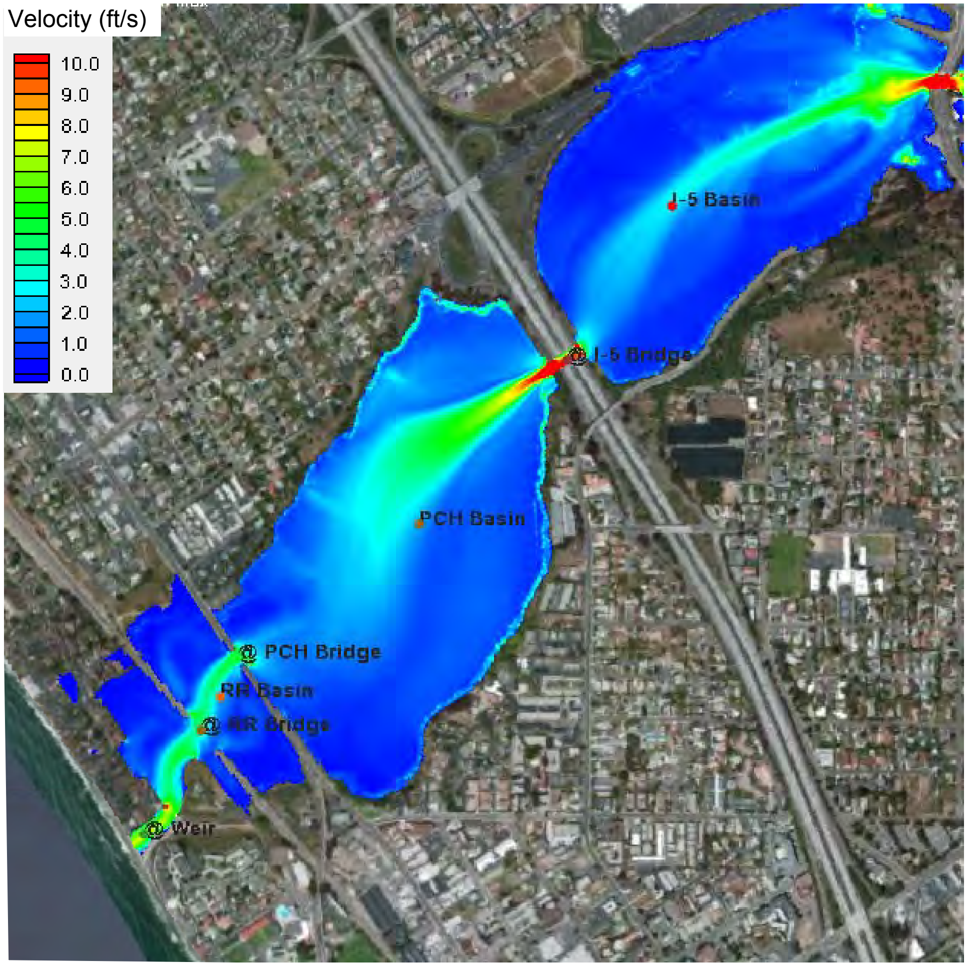


Figure 5.39 Maximum Water Velocities under Hybrid B during a 100-Year Storm in Year 2100

6. TIDAL HYDRAULICS ANALYSIS

6.1 OVERVIEW

The tidal hydraulics analysis was conducted using the TUFLOW numerical model to simulate 30-day representative tidal series to determine the tidal response of water levels and velocities in the Lagoon, as summarized in Section 6.2. The tidal response was used to determine the inundation frequency. The inundation frequency, discussed in Section 6.3, was used to estimate the habitat distribution within the Lagoon, which is described in Section 6.4.

The tidal hydraulics analysis was performed for the following three alternatives:

1. Saltwater Alternative
2. Hybrid Alternative Option A (Hybrid A)
3. Hybrid Alternative Option B (Hybrid B)

In each case, simulations were conducted using the TUFLOW model grid developed according to proposed grading plans (see Chapter 4) to determine the inundation frequency. No flow from Buena Vista Creek was specified as input at the upstream end of the model. Tidal influence in the form of a long-term tidal series was included in the analysis as a boundary condition at the downstream end of the Lagoon. Three inlet conditions were considered in these runs to estimate tidal responses that vary from a post-dredge to a pre-dredge tidal inlet. The results from the TUFLOW simulations were analyzed to determine the inundation frequencies at the four basins for Year 2015, Year 2050, and Year 2100 mean sea level conditions.

6.2 TIDAL EPOCH ANALYSIS (TEA) TIDAL SERIES

The tidal series used for the inlet stability and tidal hydraulics analyses was developed to reflect the long-term fluctuation of tidal conditions. It is important that the tidal series used to assess the tidal response in the Lagoon represent long-term conditions since the habitat distribution in the Lagoon will become established based on the long-term trends. Therefore, a water level series was selected to represent the long-term, tidal characteristics off the coast of the Lagoon.

Tides off the coast of the Lagoon are mixed, semidiurnal with two daily highs and lows. The tidal datums at the NOAA Scripps Pier station (9410230) in La Jolla are shown in Table 5.1. This information is based on an analysis of water level data collected by NOAA for the latest

National Tidal Datum Epoch (NTDE) that covers 1983-2001 (NOAA 2011). The tidal range and datums recorded at La Jolla adequately represents the tides off the Lagoon given the geographic proximity to the Lagoon.

A 30-day segment of the historical water level data at the NOAA Scripps Pier station, shown in Figure 6.1, was selected to represent the long-term ocean tides off the coast of the Lagoon. This 30-day segment shown to be statistically similar to long-term data and determined to be sufficient to represent the long-term tidal characteristics. This water level series is referred to as Tidal Epoch Analysis (TEA) Tidal series.

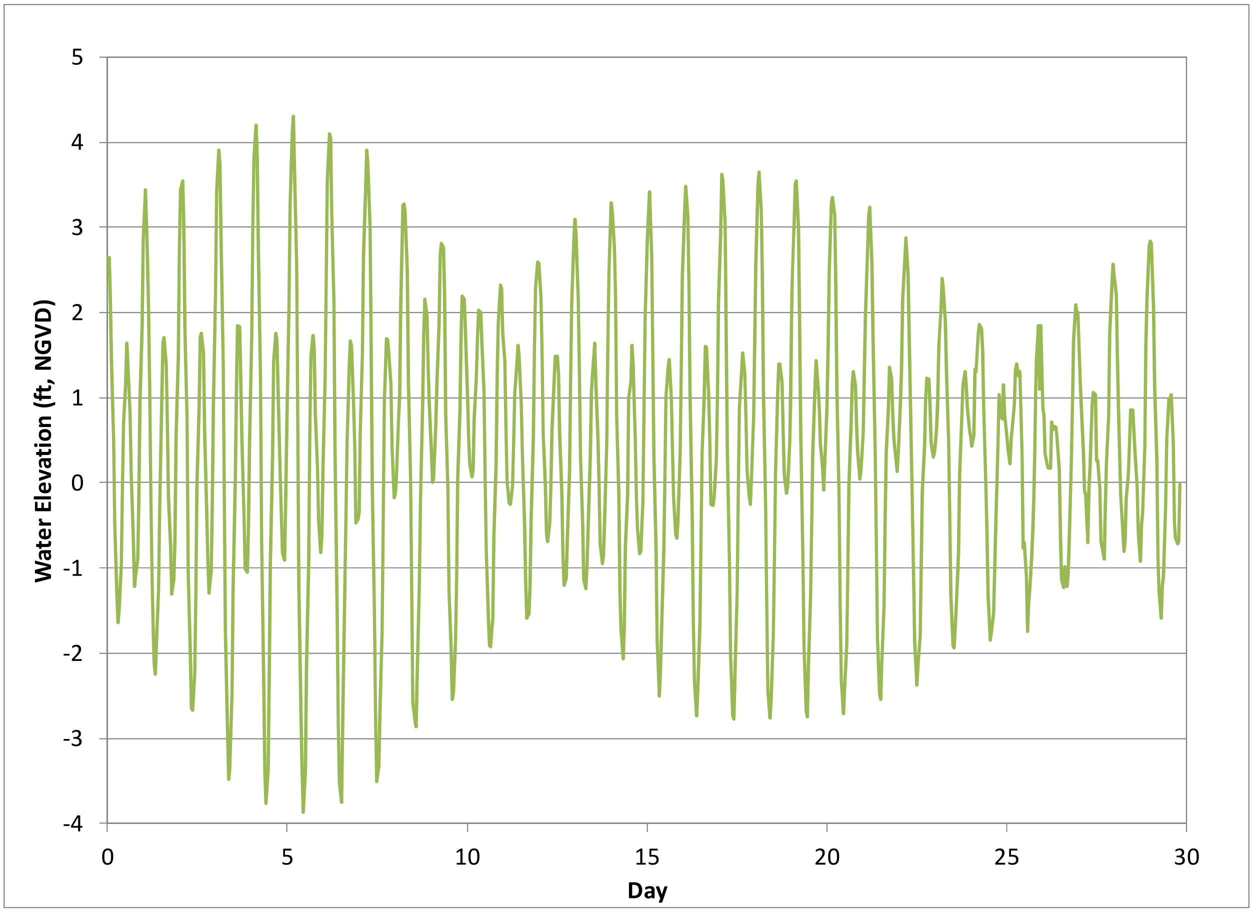


Figure 6.1 TEA Tidal Series

6.2.1 Sea Level Rise

For the evaluation of habitat distribution in future sea level rise conditions, the TEA tidal series for future sea level rise conditions were developed. As mentioned in Section 5.4, the projected rise of the mean sea levels are respectively 2.0 feet and 5.5 feet in Year 2050 and Year 2100, based on the guidance of the California Ocean Protection Council (COPC, 2013).

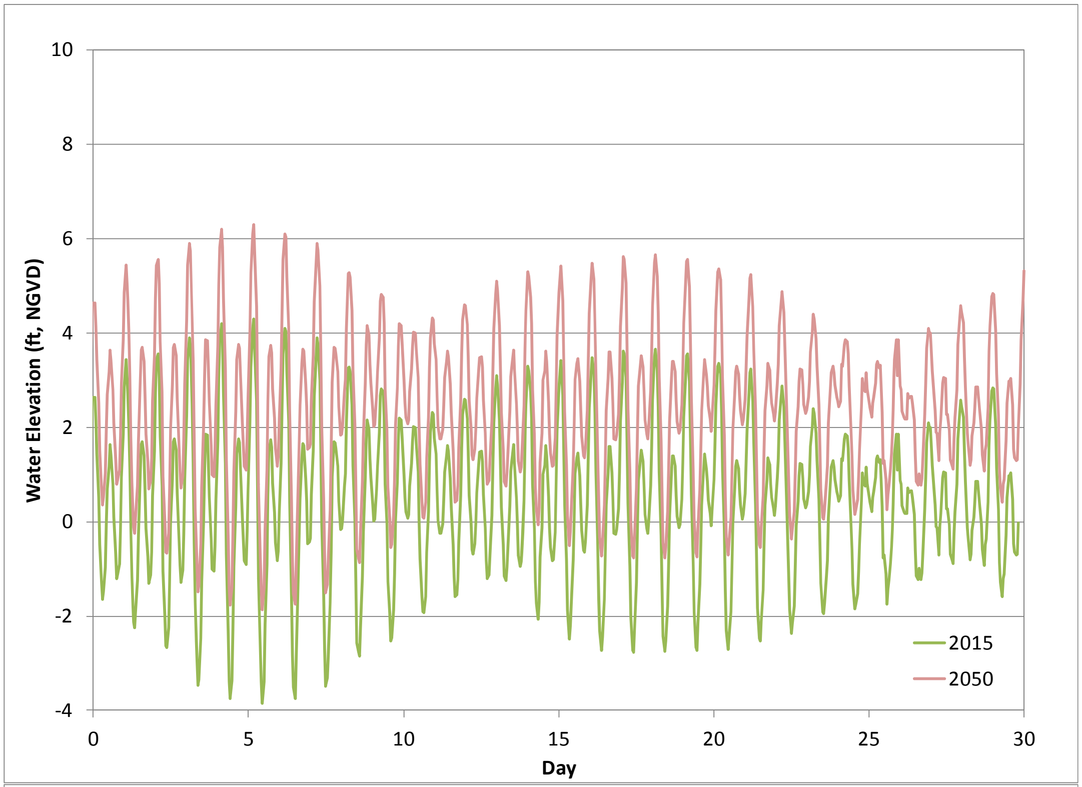
It was assumed that the TEA tidal series for Year 2050 and Year 2100 would have the same increases (i.e. 2-ft and 5.5-ft respectively for Year 2050 and Year 2100) from Year 2015 mean sea levels. These values were added to the tide elevations of the TEA tidal series of 2015, and the resulted tide elevations for Year 2050 and Year 2100 are shown in Figure 6.2. These tides were specified as the downstream boundary conditions for the tidal hydraulics analysis model scenarios for Year 2050 and Year 2100.

6.3 TIDAL INLET CONDITIONS

For the Saltwater Alternative and Hybrid Alternative, the inlet channel that conveys tidal exchange between the ocean and Lagoon would vary over time from a post dredged condition (A - Open) to a transitional condition (B – transitional) then to a pre-dredge condition (C - Closed) (see Section 3.2.6). Model simulations were conducted to estimate tidal responses and inundation frequencies in the four basins under these three inlet conditions.

6.4 INUNDATION FREQUENCY

The tidal responses of water levels over a 30-day period were used to generate the inundation frequencies in each of the Lagoon basins. The inundation frequency indicates the percent of time in which a specific elevation (or lower elevation) is inundated by water. This is the primary hydrologic metric used to estimate the type of salt water habitat that would be established. Inundation frequencies were produced for the three inlet conditions expected during a maintenance dredge cycle as discussed above. These three curves capture the range of inundation frequencies expected through a maintenance dredge cycle.



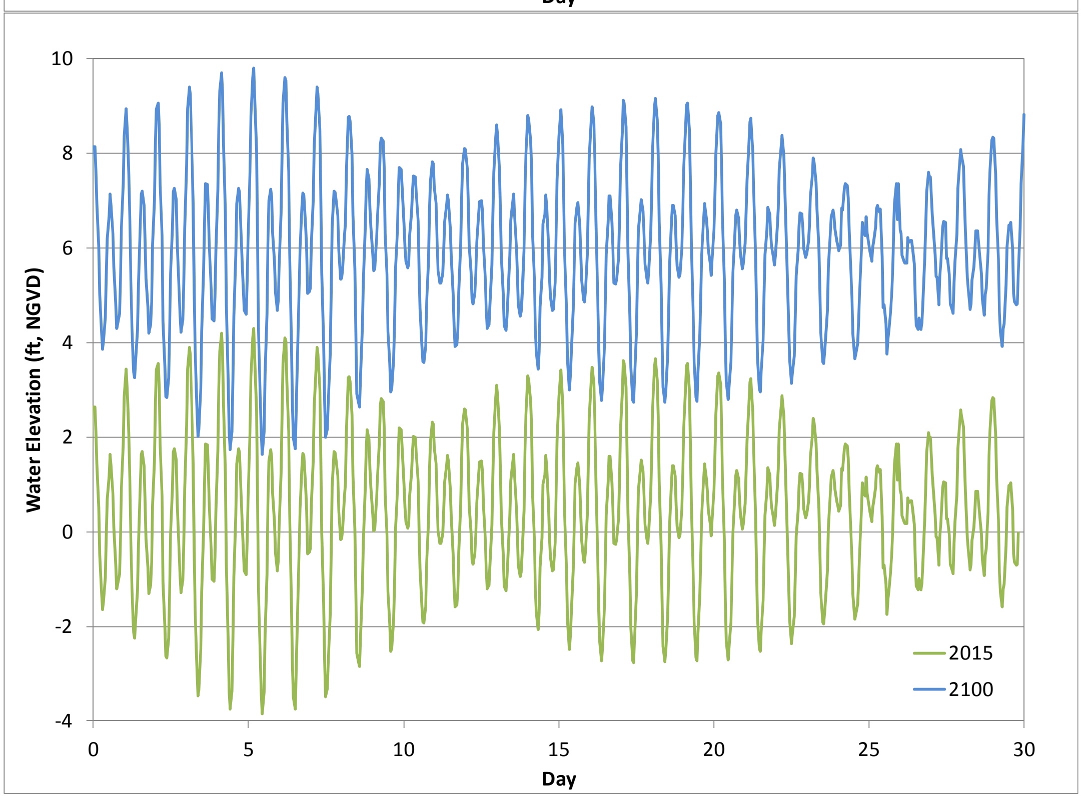


Figure 6.2 Year 2050 and Year 2100 TEA Tidal Series Compared To Year 2015 TEA Tidal Series

6.4.1 Saltwater Alternative

Inundation frequencies for the Saltwater Alternative are shown in Figure 6.3 to Figure 6.6 for Year 2015, Year 2050, and Year 2100, respectively. Each figure shows the inundation frequency in each basin compared with the inundation frequency of the tide. Deviations from the inundation of the tide correspond to the degree of tidal muting. As expected, the results show an increase in tidal muting as the inlet cross section decreases.

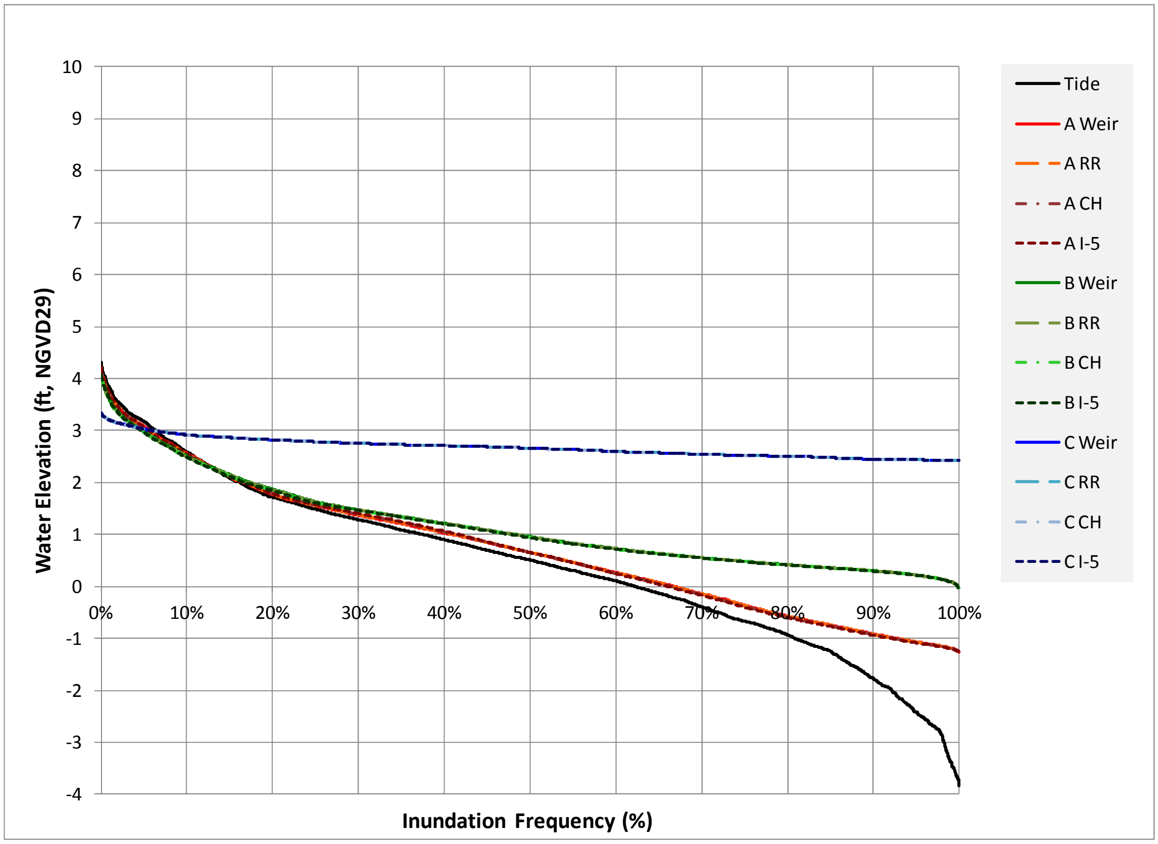


Figure 6.3 Inundation Frequency for Saltwater Alternative for Year 2015

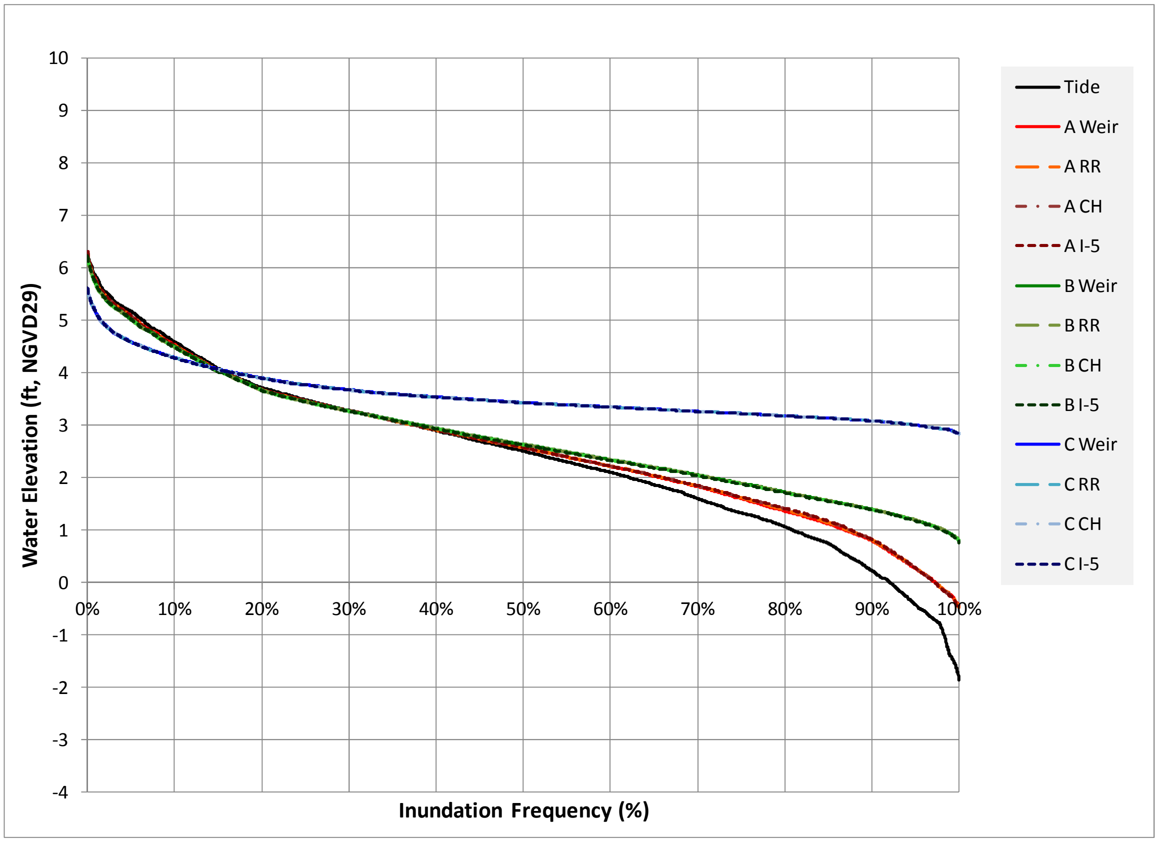


Figure 6.4 Inundation Frequency for Saltwater Alternative for Year 2050

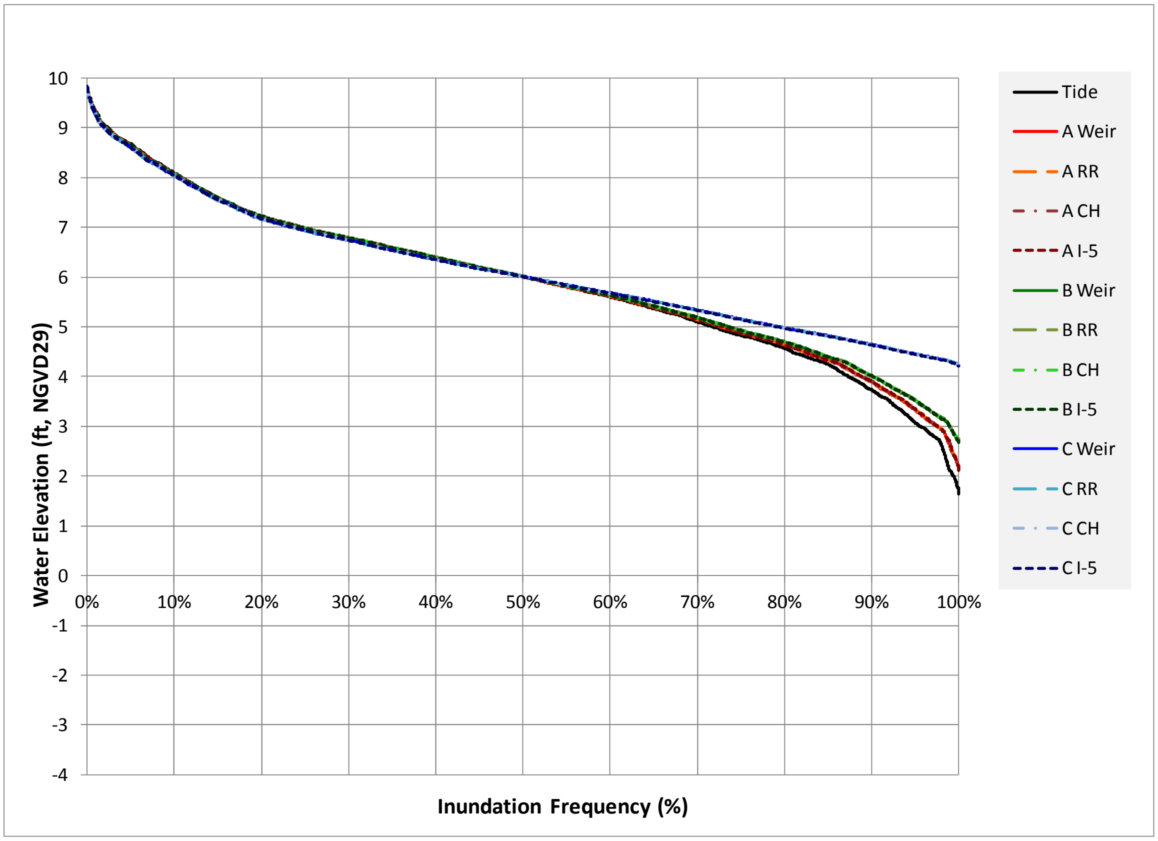


Figure 6.5 Inundation Frequency for Saltwater Alternative 2100

6.4.2 Hybrid A

Inundation frequencies for the Hybrid A are shown in Figure 6.6 to Figure 6.8 for Year 2015, Year 2050, and Year 2100, respectively. Each figure shows the inundation frequency in each basin compared with the inundation frequency of the tide. Deviations from the inundation of the tide correspond to the degree of tidal muting. As expected, the results show an increase in tidal muting as the inlet cross section decreases. For the I-5 Basin, inundation frequencies are presented only for Year 2100. The weir structure installed for the Hybrid Alternative at the I-5 Bridge would keep the I-5 Basin from tidal exchange under the 2015 and 2050 conditions.

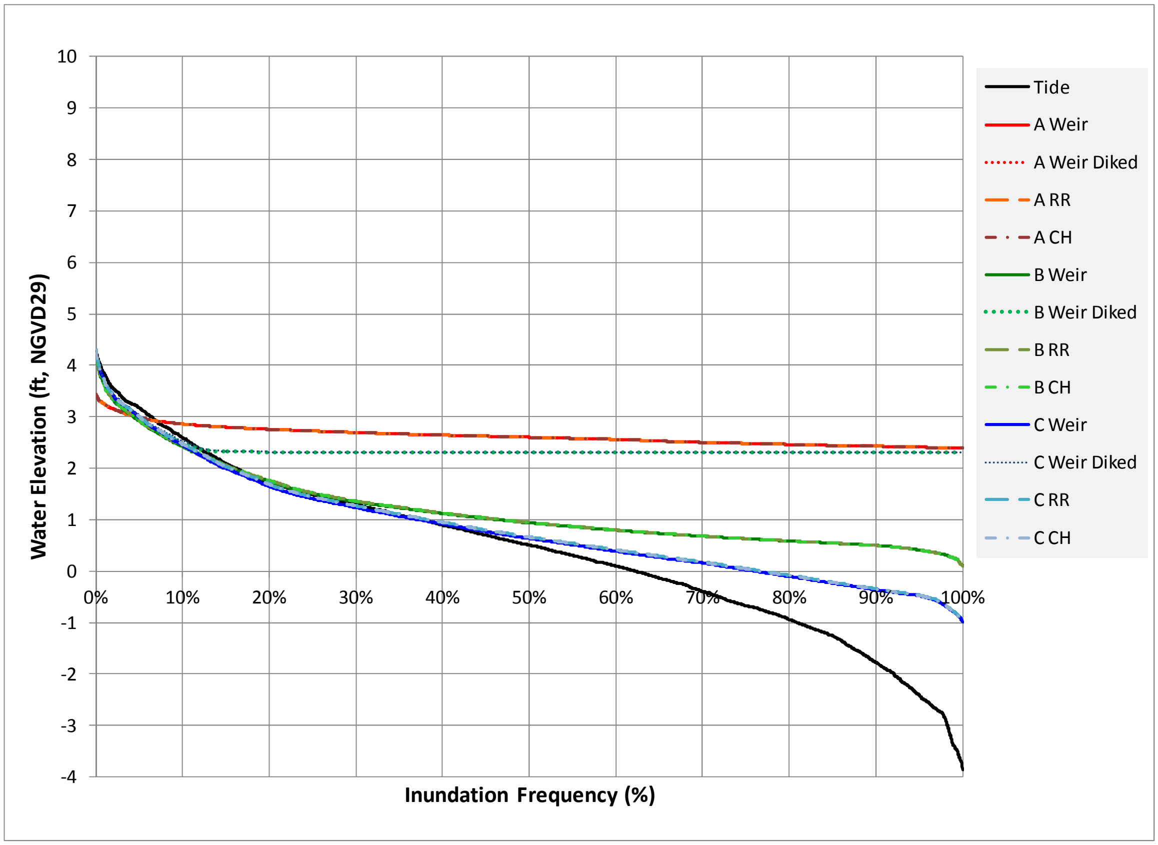


Figure 6.6 Inundation Frequency for Hybrid A for Year 2015

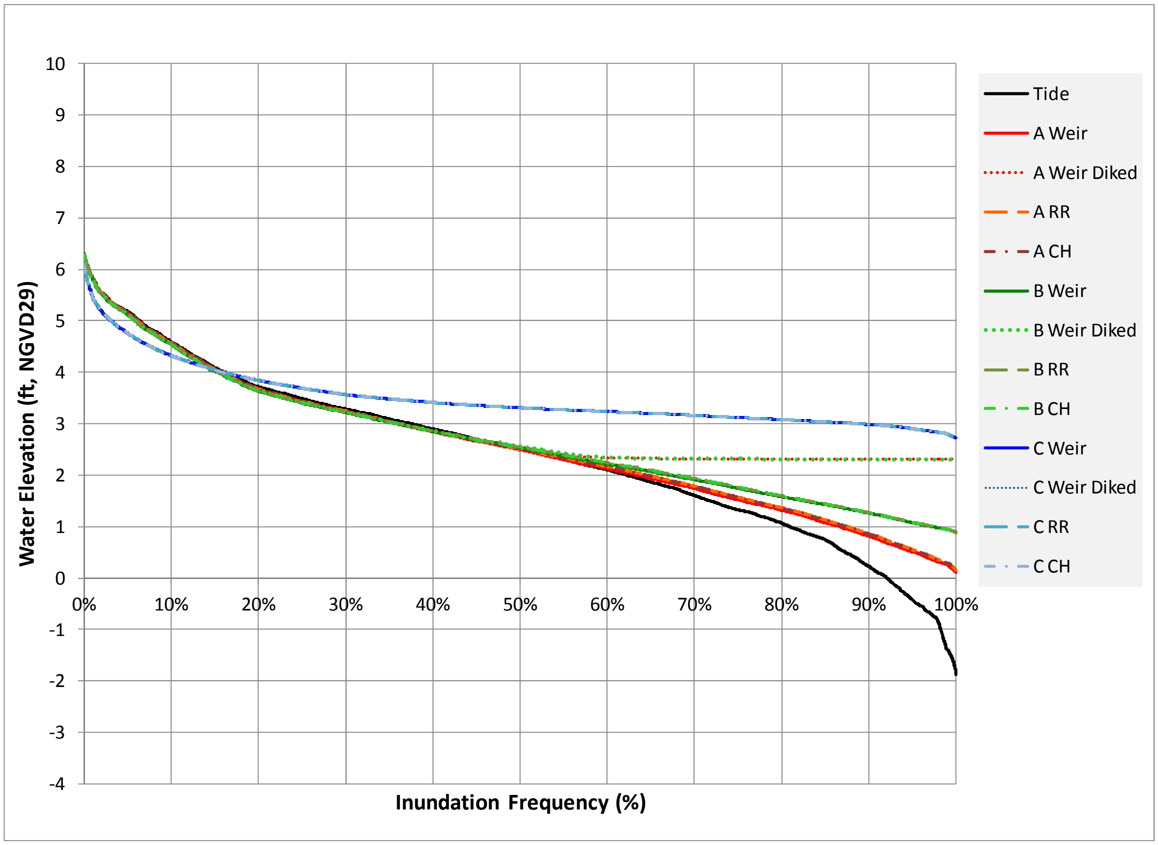


Figure 6.7 Inundation Frequency for Hybrid A for Year 2050

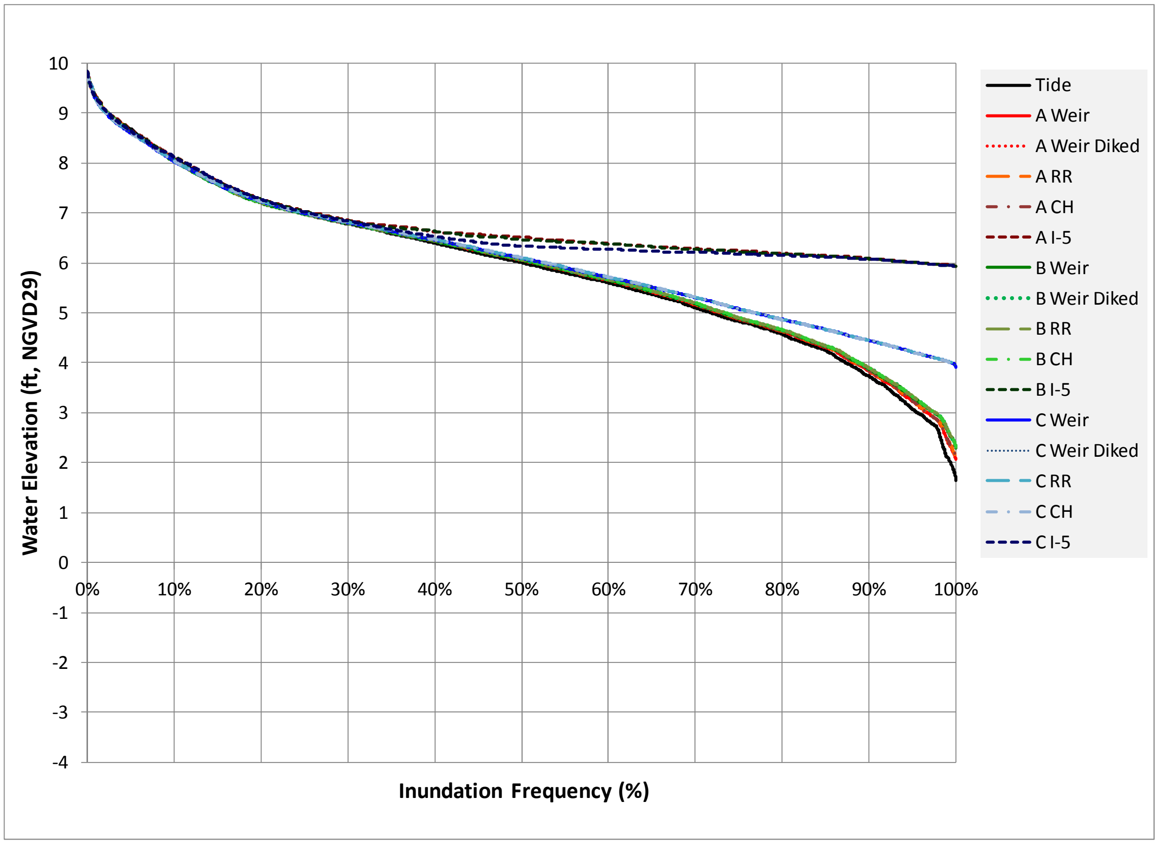


Figure 6.8 Inundation Frequency for Hybrid A for Year 2100

6.4.3 Hybrid B

Inundation frequencies for the Hybrid B are shown in Figure 6.9 to Figure 6.11 for Year 2015, Year 2050, and Year 2100, respectively. Each figure shows the inundation frequency in each basin compared with the inundation frequency of the tide. Deviations from the inundation of the tide correspond to the degree of tidal muting. Hybrid B shows an increase in tidal muting between the Weir Basin and I-5 Basin. For the I-5 Basin, inundation frequencies are presented only for Year 2100. The weir structure installed for the Hybrid Alternative at the I-5 Bridge would keep the I-5 Basin from tidal exchange under the 2015 and 2050 conditions.

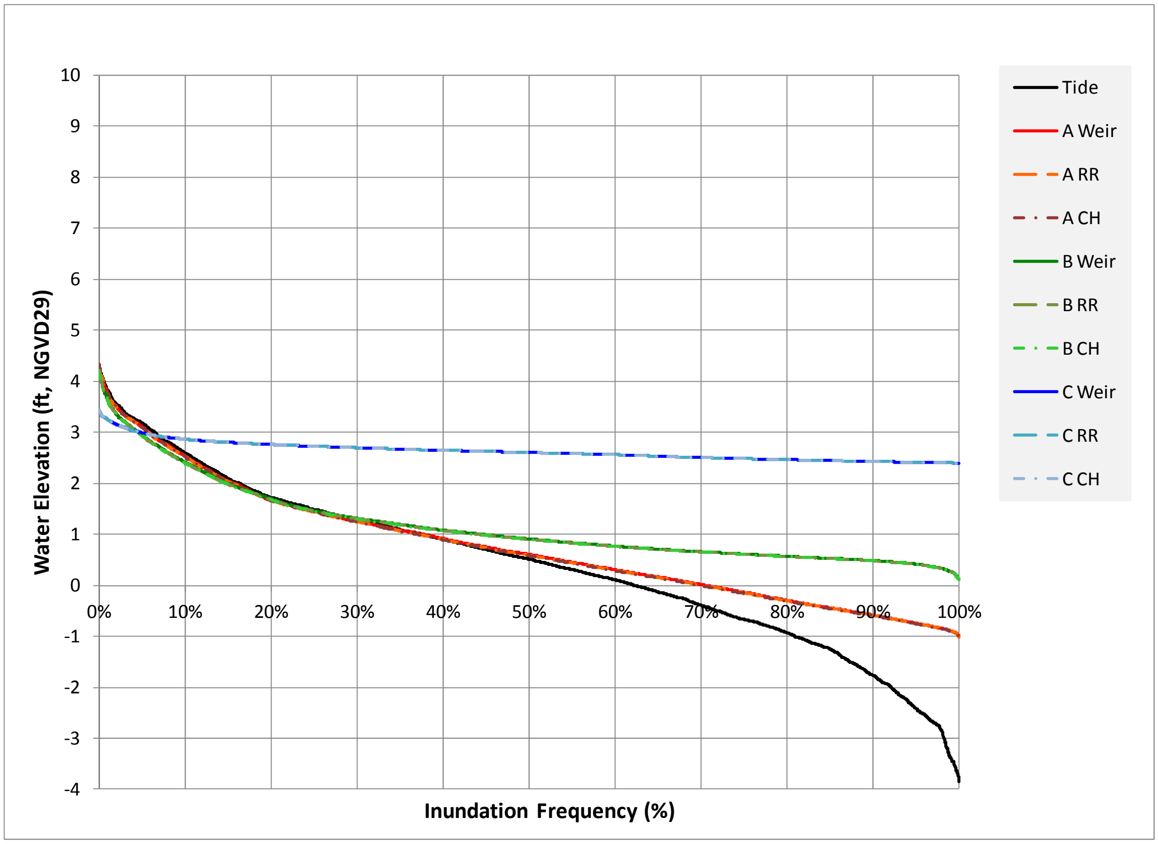


Figure 6.9 Inundation Frequency for Hybrid B for Year 2015

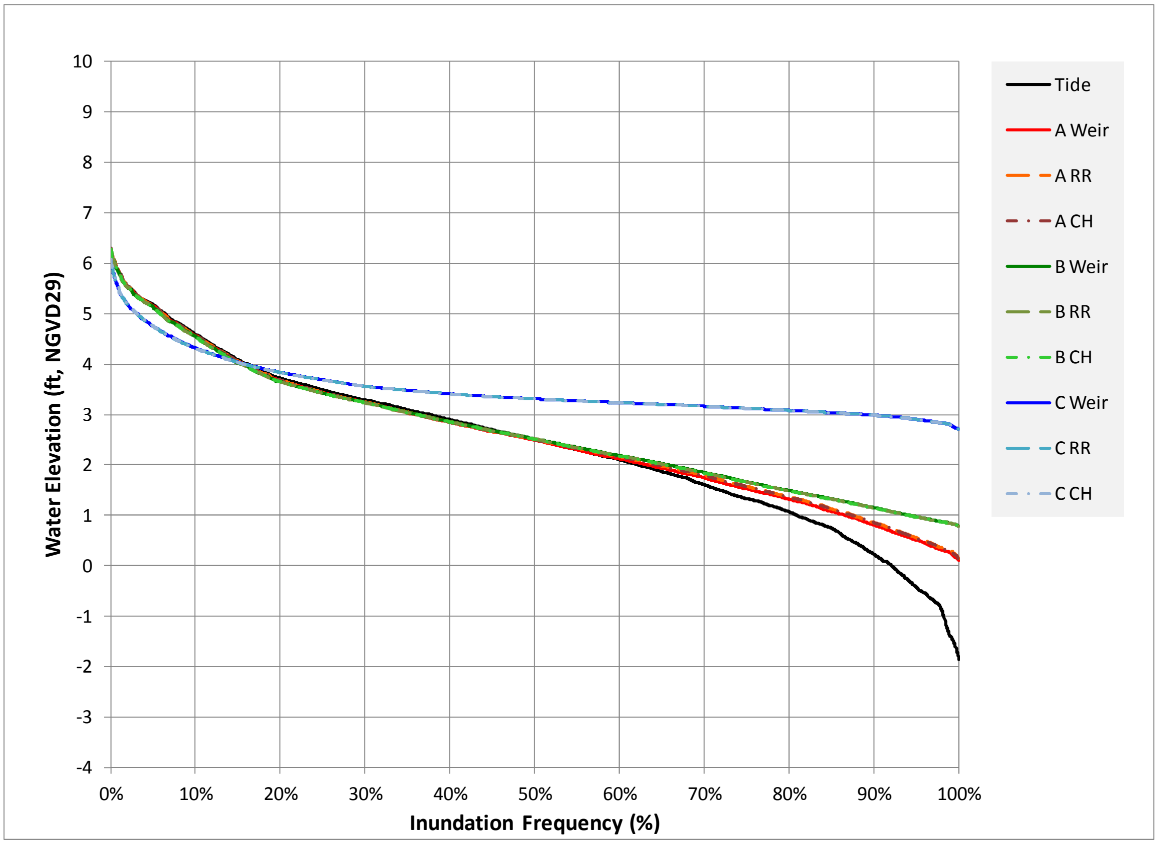


Figure 6.10 Inundation Frequency for Hybrid B for Year 2050

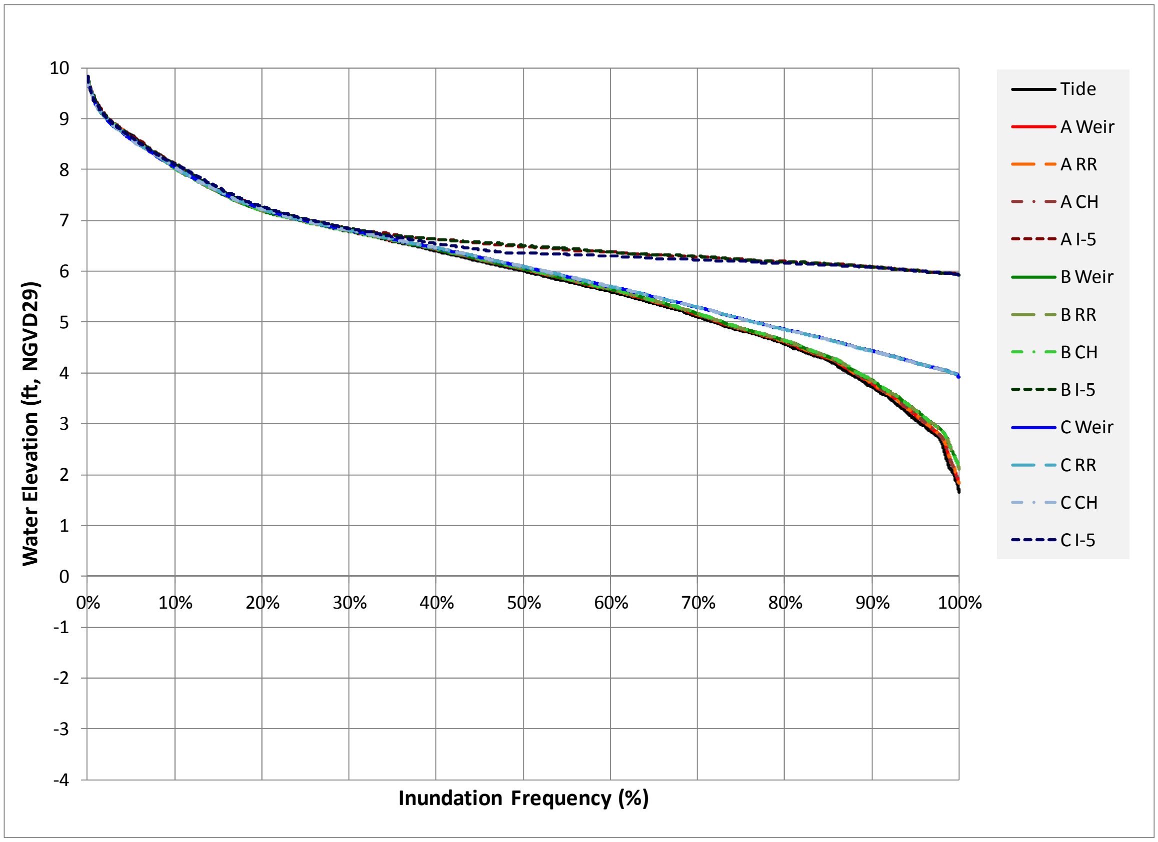


Figure 6.11 Inundation Frequency for Hybrid B for Year 2100

6.4.4 No-Project Condition

In Year 2100, the Lagoon is estimated to be filled with sediment and mean sea level is higher than the existing weir such that saltwater would enter the Lagoon. The tidal hydraulic analysis was conducted for the Year 2100 No-Project Condition. Inundation frequencies for the No-Project Condition were estimated and are shown in Figure 6.12 for Year 2100. The results serve as a comparison between the No-Project Condition and enhancement alternatives.

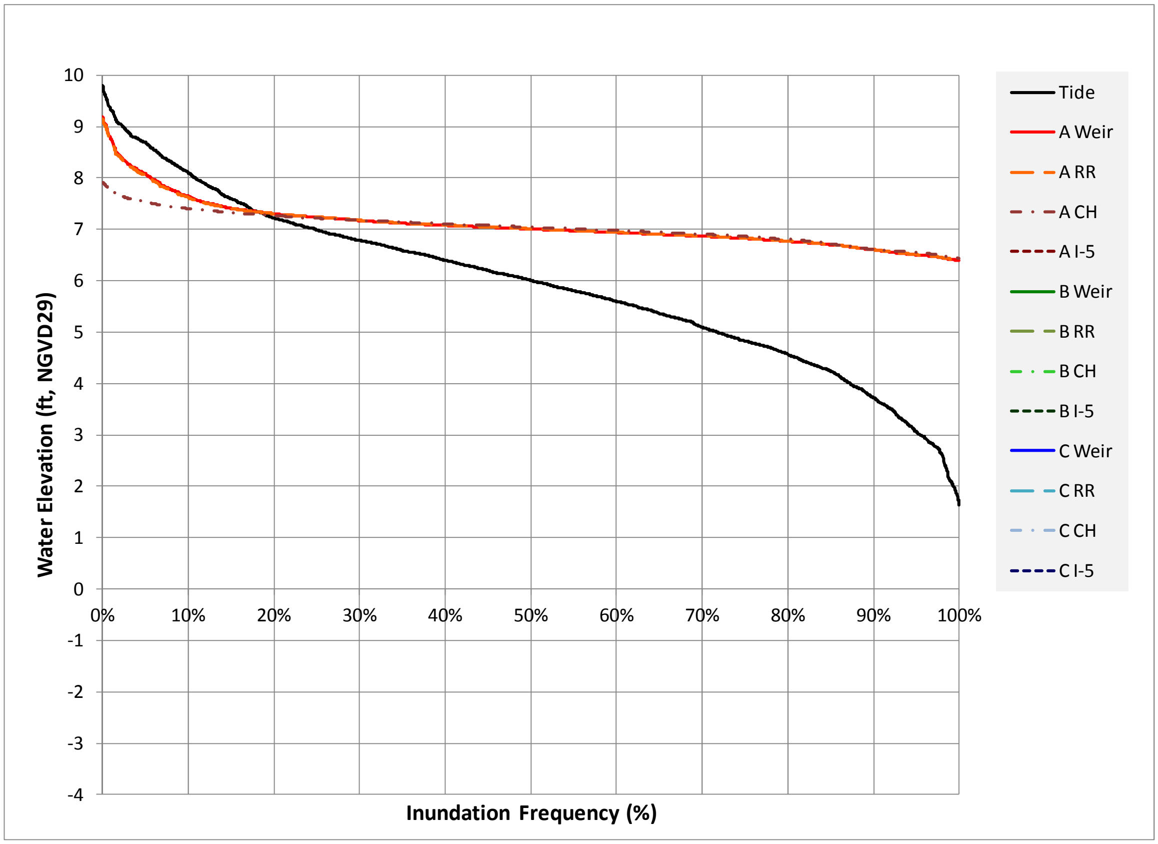


Figure 6.12 Inundation Frequency for No-Project Condition for Year 2100

6.5 HABITAT DISTRIBUTION

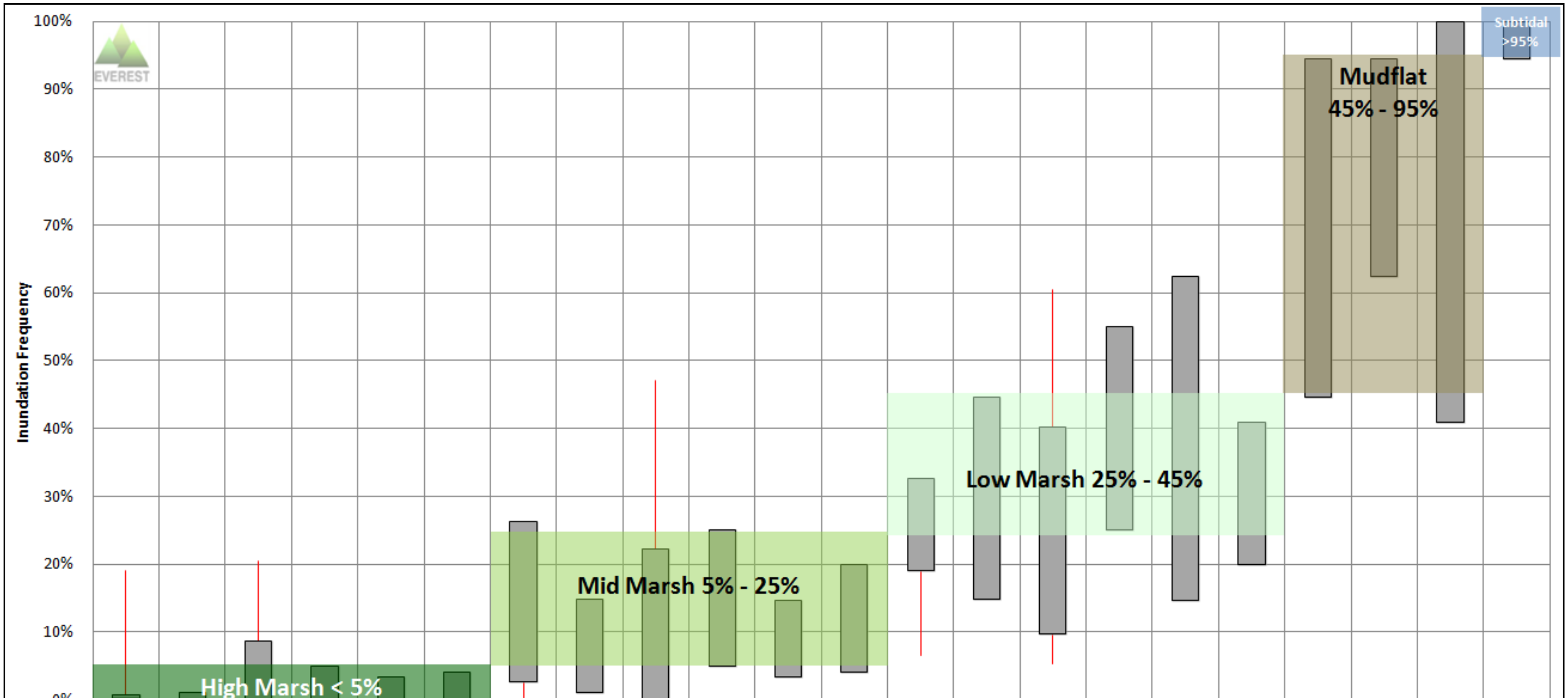
The saltwater wetlands habitat distributions were determined by the application of empirical relationships between habitat types and inundation frequency. The inundation frequency of the saltwater areas varies over time in response to the tide that enters and exits the Lagoon through the tidal inlet. The empirical relationship between the habitat type and inundation frequency is illustrated in Figure 6.13 and summarized in Table 6.1. This relationship was developed based on a number of data sources, including the prior work relating tidal zonation to habitat type based on elevation for full tidal range salt marshes in Southern California (Zedler 1977 and 1982) by relating habitat type to inundation frequency rather than elevation. The methodology of developing the habitat and inundation frequency relationship for this project is summarized in Appendix A. Based on the relationship between habitat type and inundation frequency, uplands habitat establishes in areas that are rarely inundated with water. Intertidal areas would develop into high salt marsh, middle salt marsh, low salt marsh, and mudflat. Areas that are inundated with water almost all the time are designated as open water and these are further categorized as vegetated or unvegetated open water habitats.

Table 6.1 Inundation Frequency by Habitat Type

HABITAT TYPE	MAXIMUM INUNDATION FREQUENCY (%)
Upland	0
High Marsh	5
Middle Marsh	25
Low Marsh	45
Intertidal Unvegetated	95
Open Water Vegetated	99
Open Water Unvegetated	100

The inundation frequency differences in each basin translate into differences in the habitat distribution for each basin for the Saltwater Alternative and saltwater portions of the Hybrid Alternative. Habitat distributions were estimated for the 2015 sea level and the transitional inlet conditions. While the three types of inundation frequency curves (namely, A – Open Inlet Condition, B – Transitional Inlet Condition, C – Closed Inlet Condition) capture the range of inundation frequencies expected through a maintenance dredge cycle, habitat distributions were estimated based on the transitional inlet condition since this condition is the most prevailing condition in the maintenance dredge cycle.

The habitat acreages in each basin are summarized in Table 6.2 to Table 6.4, and are illustrated in Figure 6.14, Figure 6.15, and Figure 6.16 for Saltwater Alternative, Hybrid A, and Hybrid B, respectively.



	Zedler High Marsh	Merkel High Marsh	Otay A High	Otay B High	SSDBSP High Marsh	SELRP High Marsh	Zedler Mid Marsh	Merkel Mid Marsh	Otay A Mid	Otay B Mid	SSDBSP Mid Marsh	SELRP Mid Marsh	Zedler Low Marsh	Merkel Low Marsh	Otay A Low	Otay B Low	SSDBSP Low Marsh	SELRP Low Marsh	Merkel Mudflat	SSDBSP Mudflat	SELRP Mudflat	Subtidal
Avg Max	0.7%	1.1%	8.7%	5.0%	3.4%	4.0%	26.3%	14.8%	22.2%	25.0%	14.6%	20.0%	32.7%	44.7%	40.1%	55.0%	62.5%	41.0%	94.4%	94.4%	100.0%	100.0%
Max	19.1%		20.5%				26.3%		47.0%				32.7%		60.4%							
Min	0.0%		0.0%				0.1%		0.0%				6.6%		5.4%							
Avg Min	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	1.1%	0.0%	5.0%	3.4%	4.0%	19.1%	14.8%	9.8%	25.0%	14.6%	20.0%	44.7%	62.5%	41.0%	94.4%

Figure 6.13 Habitat Inundation Frequencies and Habitat Distribution Relationship (San Diego County)

Table 6.2 Year 2015 Habitat Distribution for Saltwater Alternative

HABITAT	WEIR BASIN	RAILROAD BASIN	COAST HIGHWAY BASIN	I-5 BASIN	TOTAL
Upland/Non-Tidal	2.3	5.7	11.8	19.4	39.2
High Salt Marsh	1.0	1.7	18.8	21.2	42.8
Middle Salt Marsh	0.1	0.7	25.3	20.8	46.9
Low Salt Marsh	0.4	0.5	22.7	9.5	33.2
Mudflats	0.2	0.2	12.0	7.6	20.0
Open Water Vegetated	6.8	7.7	21.4	14.9	50.8
Open Water Unvegetated	-	1.1	-	2.9	4.0
Muted Open Water	-	-	-	-	-
Beach	0.8	-	-	-	0.8
Total	11.6	17.7	112.1	96.3	237.7

Units in acres

Table 6.3 Year 2015 Habitat Distribution for Hybrid A

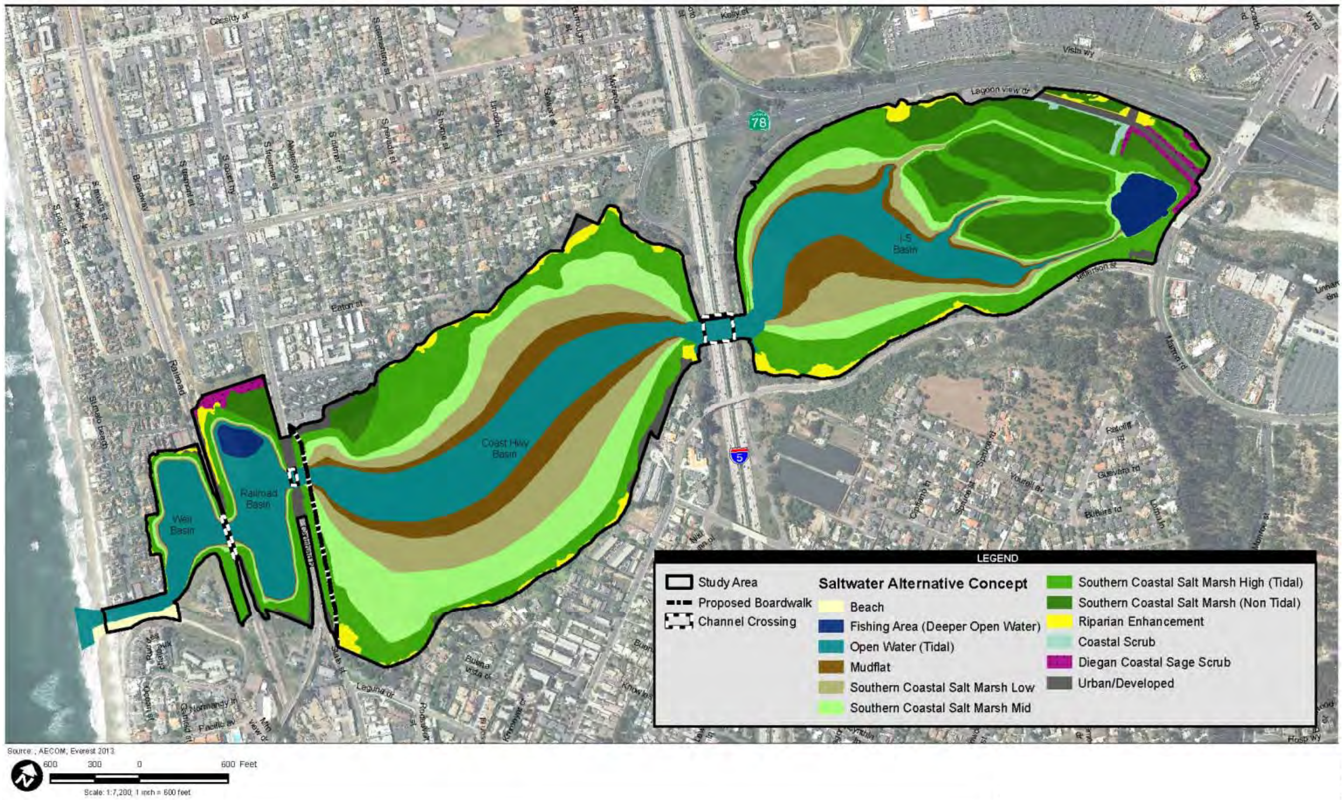
HABITAT	WEIR BASIN	RAILROAD BASIN	COAST HIGHWAY BASIN	I-5 BASIN	TOTAL
Upland/Non-Tidal	0.8	2.8	6.3	96.3	106.2
High Salt Marsh	2.2	3.5	20.8	-	26.5
Middle Salt Marsh	0.5	0.8	19.1	-	20.3
Low Salt Marsh	0.1	0.4	5.8	-	6.3
Mudflats	0.1	0.4	4.2	-	4.7
Open Water Vegetated	2.0	7.5	52.5	-	62.0
Open Water Unvegetated	-	1.1	2	-	3.1
Muted Open Water	5.1	-	-	-	5.1
Beach	0.8	-	-	-	0.8
Total	11.6	16.5	110.7	96.3	235.1

Units in acres

Table 6.4 Year 2015 Habitat Distribution for Hybrid B

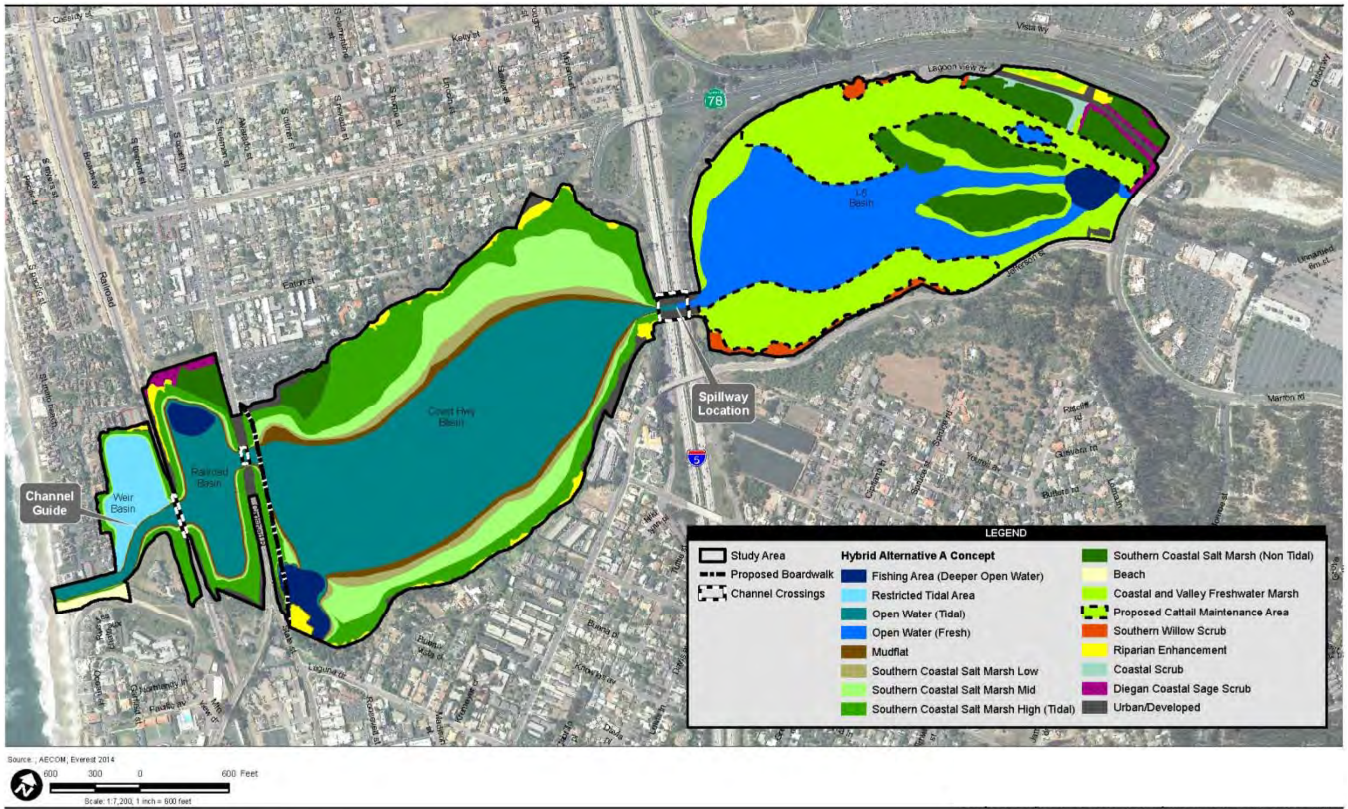
HABITAT	WEIR BASIN	RAILROAD BASIN	COAST HIGHWAY BASIN	I-5 BASIN	TOTAL
Upland/Non-Tidal	0.8	2.8	6.3	96.3	106.2
High Salt Marsh	2.2	3.5	20.8	-	26.5
Middle Salt Marsh	0.8	0.8	19.1	-	20.7
Low Salt Marsh	0.4	0.4	5.8	-	6.6
Intertidal Unvegetated	0.3	0.4	4.2	-	4.9
Open Water Vegetated	6.3	7.5	52.5	-	66.3
Open Water Unvegetated	-	1.1	2	-	3.1
Muted Open Water	-	-	-	-	-
Beach	0.8			-	0.8
Total	11.6	16.5	110.7	96.3	235.1

Units in acres



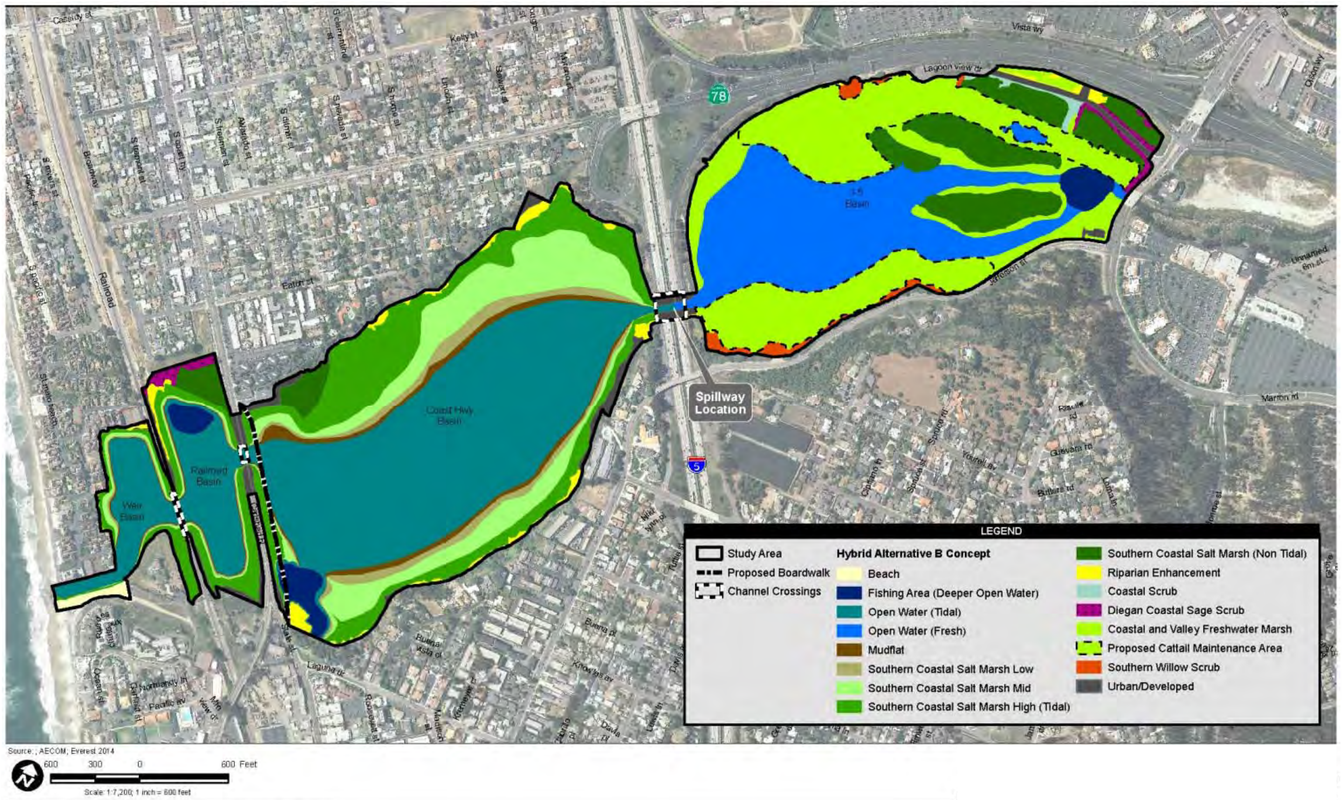
Prepared by AECOM

Figure 6.14 Habitat Distribution Map for Saltwater Alternative



Prepared by AECOM

Figure 6.15 Habitat Distribution Map for Hybrid A



Prepared by AECOM

Figure 6.16 Habitat Distribution Map for Hybrid B

7. CONCLUSIONS

The results of the fluvial and tidal hydraulics analyses were used to develop the following conclusions regarding flooding and erosion/scour associated with the Buena Vista Lagoon Enhancement Project.

7.1 FLOODING

A major factor in the evaluation of enhancement alternatives is the impact of those alternatives on flooding within and around Buena Vista Lagoon. Under Existing Conditions, it has been reported that Carlsbad Boulevard is subject to flooding during relatively large flood events. In addition, flooding is also a concern for the low lying residential community of San Malo that is located on the beach on the northern side of the lagoon. For these reasons, any increase in flooding associated with lagoon enhancement is not likely to be acceptable. The fluvial hydraulics analysis was conducted to assess flood conditions under Existing Conditions and the four enhancement alternatives to address these concerns.

Under Existing Conditions, the results revealed that overtopping of Carlsbad Boulevard would be expected under large storm events (e.g., 50-yr and 100-yr storms). This result is consistent with anecdotal reports of Carlsbad Boulevard flooding under severe storm events. The results also reveal that the highest flood levels occur in the I-5 Basin indicating that the I-5 Bridge provides a significant constriction to flood flow conveyance from Buena Vista Creek through the Lagoon to the ocean.

The results revealed that implementation of any of the four enhancement alternatives would improve flood conditions (i.e., lower flood levels) throughout the Lagoon in comparison to Existing Conditions. However, Carlsbad Boulevard and portions of the San Malo community would still be flooded during some storm events under the Freshwater Alternative, similar to Existing Conditions but to a slightly smaller degree. With the sea level rise conditions in 2100, the results indicate that flooding occurs in some areas in the San Malo community under the Freshwater and Saltwater Alternatives, nevertheless, the degree and extent of flooding are smaller than those of the No-project Condition.

Among the four enhancement alternatives, flood levels would generally be highest in all basins under the Freshwater Alternative due to the ocean outlet weir that restricts flow between the Lagoon and ocean. The results indicate that the flood levels under the Saltwater Alternative would be lower than those under the Freshwater Alternative. This is because under the Saltwater Alternative the Lagoon is open to the ocean, the channel connecting the Lagoon and ocean would be improved (i.e., wider and/or deeper), and the hydraulic connections between the four lagoon basins would be improved (e.g., cleared of vegetation, widened, and/or deepened). The results revealed that the flood levels in the I-5 Basin would be the highest under the Hybrid Alternative (Hybrid A and Hybrid B). This is because a weir would be constructed at the I-5 Bridge hydraulic connection to maintain freshwater in the I-5 Basin and this weir would be a constriction to flood flow resulting in higher flood levels in the I-5 Basin compared to the other enhancement alternatives. The flood levels in the other three basins under the Hybrid Alternative would be similar to and slightly less than those under the Saltwater Alternative.

7.2 EROSION/SCOUR

The impact of the enhancement alternatives on erosion within the Lagoon as well as scour under and near the hydraulic connections (e.g., bridges) is an important consideration in the evaluation of alternatives. Substantial increases in erosion could result in unacceptable changes to restored habitats and substantial increases in scour could threaten the integrity of bridges and roadways. Consequently, substantial increases in erosion and/or scour are not likely to be acceptable. In this study, the fluvial hydraulics analysis was conducted to assess erosion and scour conditions under existing and proposed (i.e., enhanced) conditions through comparison of water velocity predictions among alternatives and to sediment scour criteria (e.g., 1 ft/s).

Under Existing Conditions, the results indicated that the water velocities within the four basins during storm events of various magnitudes would not exceed the sediment scour criteria, except within the channel that runs through the Lagoon. Under all four enhancement alternatives, the results indicated that water velocities within the four basins during various storm events would not exceed the scour criteria. These results suggest that significant levels of erosion would not be expected to occur within the lagoon basins during storm events under Existing Conditions and that the enhancement alternatives would not likely increase the level of erosion.

Under Existing Conditions, the results indicated that the water velocities at the four hydraulic connections (I-5 Bridge, Carlsbad Boulevard Bridge, NCTD Railroad Bridge, and Weir) would exceed the sediment scour criteria in some cases. Of the three inland hydraulic connections (I-5 Bridge, Coastal Highway Bridge, and NCTD Railroad Bridge), the highest velocities would occur at the I-5 Bridge. These results suggest the potential for bridge scour at this location under Existing Conditions. At the ocean weir the results indicated even higher water velocities under Existing Conditions. Under the four enhancement alternatives, the results indicated that the water velocities at the four hydraulic connections (I-5 Bridge, Carlsbad Boulevard Connection, NCTD Bridge, and Weir) would exceed the sediment scour criteria in most cases. Of the three inland hydraulic connections (I-5 Bridge, Coastal Highway Bridge, and NCTD Railroad Bridge), the highest velocities would occur at the I-5 Bridge suggesting the potential for bridge scour at this location under all four enhancement alternatives. At the ocean weir the results indicated substantially higher water velocities with the largest increases associated with the Saltwater Alternative and Hybrid Alternative while the increases associated with the Freshwater Alternative would be similar but larger than Existing Conditions. These results indicate that slope protection would likely be needed at the three bridge locations to maintain the integrity of the bridge infrastructure and associated roadway/railway embankments.

7.3 TIDAL ANALYSIS

Tidal analyses were conducted for the four enhancement alternatives. Results of the tidal hydraulics simulations were used to estimate inundation frequencies and corresponding habitat distribution for each basin under the four enhancement alternatives. The resultant habitat distribution for the Saltwater and Hybrid Alternatives are summarized below. It can be seen that the non-tidal/upland area in the Hybrid Alternative is much larger because the I-5 weir would maintain freshwater in the I-5 Basin. For the same reason, there are more intertidal salt marshes in the Saltwater Alternative.

Table 7.1 Year 2015 Habitat Distribution Comparison

HABITAT	SALTWATER ALTERNATIVE	HYBRID A	HYBRID B
Upland/Non-Tidal	39.2	106.2	106.2
High Salt Marsh	42.8	26.5	26.5
Middle Salt Marsh	46.9	20.3	20.7
Low Salt Marsh	33.2	6.3	6.6
Mudflats	20.0	4.7	4.9
Open Water Vegetated	50.8	62.0	66.3
Open Water Unvegetated	4.0	3.1	3.1
Muted Open Water	-	5.1	-
Beach	0.8	0.8	0.8
Total	237.7	235.1	235.1

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APPENDIX A

Habitat Breaks & Inundation Frequency

Since tidal muting may occur within the restored tidal basins of the Buena Vista Lagoon Enhancement Project, elevation break points must then be based on inundation frequency. This is preferred over absolute elevations copied from other surveys or projects since they can vary by location and muting. A compendium of inundation frequencies is provided in the Figure 6.13 in the main document. The data sources can briefly be described as:

- *Zedler* – Maximum, minimum, 70% maximum, and 70% minimum habitat inundation frequencies based on measured elevations in the Tijuana Slough (Zedler, 1982), converted to inundation frequencies using the La Jolla tide station.

- *Merkel* – a habitat versus elevation curve was provided by Merkel and Associates (Everest, 2004). Elevations read from this curve were converted to inundation frequencies using the La Jolla tide station.

- *Otay A* – maximum, minimum, average maximum, and average minimum habitat elevations were measured in 2011 at the Otay River and in Table 3 of Josselyn (2012). These were converted to inundation frequencies using the San Diego tidal station.

- *Otay B* – recommended inundation frequencies for habitat types were reported in Table 6 of the Josselyn (2012) document.

- *South San Diego Bay Salt Ponds* – elevation ranges used in the restoration of the South San Diego Bay Salt Ponds were published by Everest (2011). These were based on previously published data, recent measurements, and other corrections. These elevations were uncorrected back to the ’83-’01 tidal epoch and then converted to inundation frequencies using the San Diego tidal station.

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