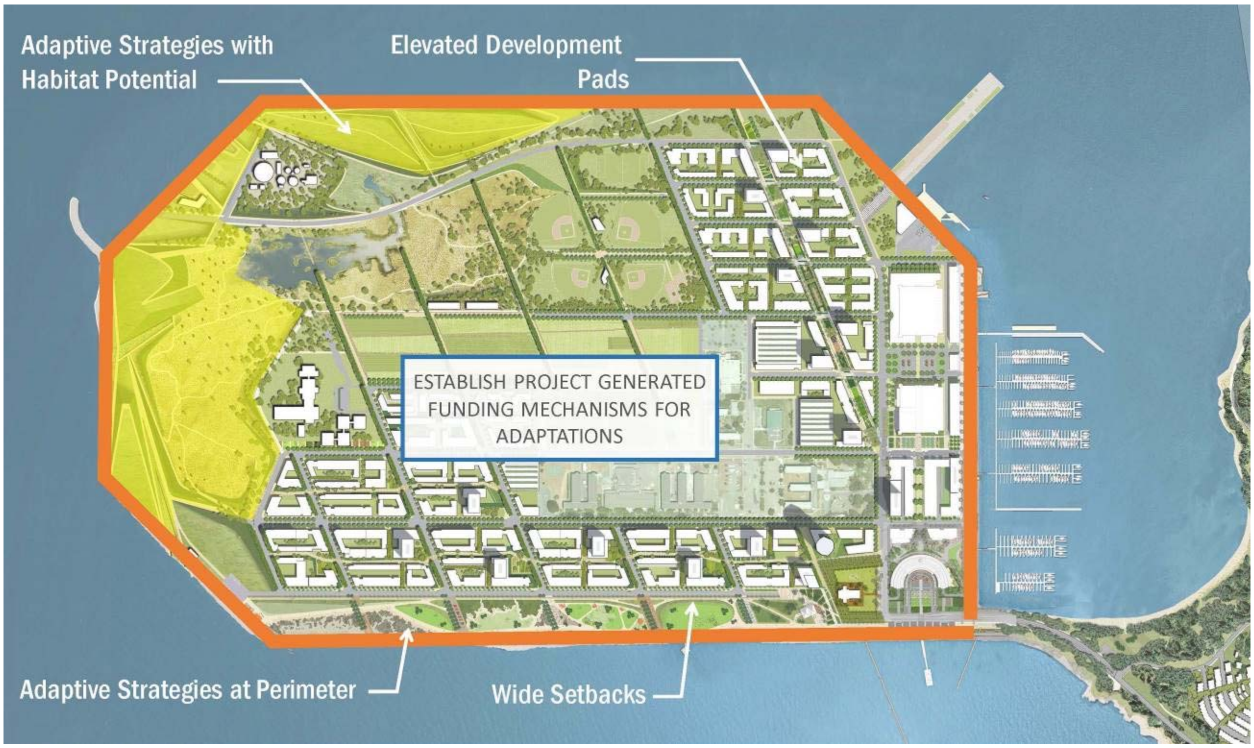
Treasure Island Development Project

Sea Level Rise Risk Assessment and Adaptation Strategy for Rising Sea Levels



Prepared for:

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August 1, 2016 (v3)
M&N Job No: 8548

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1. INTRODUCTION

1.1 BACKGROUND

This report provides a summary of the coastal flooding and sea level rise risk assessment, as well as an adaptation strategy for the Treasure Island Development Project.

The Treasure Island Development Authority (TIDA) and Treasure Island Community Development (TICD) are working together in a public-private partnership towards the redevelopment of Treasure Island (Project). The Project's environmental impact report was certified in 2011, and construction of the first phase is anticipated to start in 2016-2017. Development plans for Treasure Island include 8,000 new homes, up to 500 hotel rooms, a 400-slip marina, restaurants, retail and entertainment venues, and nearly 300 acres of parks and open space as shown on Figure 1-1.

Figure 1-1: Proposed Development Plan for Treasure Island

Projected to be one of the most environmentally-sustainable large development projects in U.S. history, the project was selected as one of 16 founding projects of the Clinton Climate Initiative's Climate Positive Development Program. Treasure Island's location in the Bay and typical low-lying terrain makes the proposed development a perfect example of the need to plan for sea level rise.

Treasure Island was constructed using sand mined from San Francisco Bay in 1936 for the Golden Gate International Exposition. Yerba Buena Island is a natural rock island and is significantly higher in elevation than Treasure Island. The Project encompasses both Treasure Island and Yerba Buena Island; however, because Yerba Buena Island's roadways and development parcels are significantly above present and future water levels, the focus of the sea level rise adaptation strategy is Treasure Island.

Moffatt & Nichol (M&N) has supported the Treasure Island development design over the years and has produced numerous documents summarizing sea level rise projections, coastal flooding, and tsunami estimates. The document list includes:

- M&N, *Coastal Flooding Analysis & Adapting to Sea Level Rise*, October, 2014
- M&N, *Treasure Island Ferry Terminal Coastal Engineering Assessment*, Sept. 14, 2009
- M&N, *Treasure Island Coastal Flooding Study*, Apr. 2009

This report, "Sea Level Rise Risk Assessment and Adaptation Strategy for Rising Sea Levels", references information from the above reports and provides additional details where necessary.

1.2 PURPOSE

This report is intended to provide a summary of coastal vulnerability to sea level rise, to satisfy BCDC's requirement for "a risk assessment based on the estimated 100-year flood elevation that takes into account the best estimates of future sea level rise in 2050 and 2100". This report also summarizes the adaptation strategy based on the risk assessment results.

1.3 CURRENT POLICIES

Potential solutions to incorporating sea level rise into the planning/design process for coastal developments may be defined by mandates or policy guidance on the part of those charged with the public interest, including FEMA (Federal Emergency Management Agency), the U.S. Army Corps of Engineers (USACE), Coastal Zone Management Agencies, or Regional entities that oversee the wellbeing of their respective coastlines and coastal communities.

At the federal level, the USACE and U.S. Environmental Protection Agency (EPA) have recognized that global warming and rising seas need to be considered within the design life of all federally funded projects. This process applies to federally funded projects only and is not triggered for projects such as this Treasure Island Project, for which the only USACE involvement is a permit. The National Flood Insurance Program administered by FEMA, states that all new projects should be elevated above the most recent Base Flood Elevation as provided in the Flood Insurance Rate Maps, or adequately flood-proofed. FEMA does not include sea level rise in its flood mapping criteria for flood insurance.

The California Natural Resources Agency requires all state-funded and state agency projects to incorporate the effects of sea level rise and climate change in project planning, and has recommended guidance to evaluate sea level rise. These include reports by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT 2013) and the California Natural Resources Agency (CNRA 2009).

Since TIDA is a state agency, the above requirements need to be complied with. For San Francisco Bay, the applicable Coastal Zone Management Agency is the San Francisco Bay Conservation and Development Commission (BCDC), which has developed specific guidance policies for addressing climate change that incorporate the findings of the CO-CAT 2013 document. Projects within BCDC's jurisdiction are subject to the policies described in detail in the *San Francisco Bay Plan (*amended 2011). A summary of the recommendations of the Bay Plan are as follows:

1. The Sea Level Rise Adaptation Strategy should incorporate an adaptive management approach;

2. The Sea Level Rise Adaptation Strategy should be consistent with the goals of SB 375 and the principles of the California Climate Adaptation Strategy;
3. The Sea Level Rise Adaptation Strategy should be updated regularly to reflect changing conditions and scientific information and include maps of shoreline areas that are vulnerable to flooding based on projections of future sea level rise and shoreline flooding;
4. Inundation maps should be prepared under the direction of a qualified engineer and regularly updated in consultation with government agencies with authority over flood protection; and
5. Particular attention should be given to identifying and encouraging the development of long-term regional flood protection strategies that may be beyond the fiscal resources of individual local agencies.

Specific requirements of this policy are described in BCDC's *New Sea Level Rise Policies Fact Sheet,* which are summarized below:

1. ***Risk Assessments**: Sea level rise risk assessments are required when planning shoreline areas or designing larger shoreline projects. If sea level rise and storms that are expected to occur during the life of the project would result in public safety risks, the project must be designed to cope with flood levels expected by mid-century. If it is likely that the project will remain in place longer than mid-century, the applicant must have a plan to address the flood risks expected at the end of the century.*
   - *Risk assessments are NOT required for repairs of existing facilities, interim projects, small projects that do not increase risks to public safety, and infill projects within existing urbanized areas.*
   - *Risk assessments are ONLY required within BCDC's jurisdiction.*
   - *Risk assessments for projects located only in the shoreline band, an area within 100 feet of the shoreline, need only address risks to public access.*
2. ***Sea Level Rise Projections**: Risk assessments must be based on the best estimates of future sea level rise. The California Climate Action Team's sea level rise projections, ranging from 10-17 inches at mid-century and 31-69 inches at the end of the century, currently provide the best available sea level rise projections for the West Coast. However, scientific uncertainty remains regarding the pace and amount of future sea level rise, and project applicants may use other sea level rise projections if they provide an explanation.*
3. ***Protecting Existing and Planned Development**: Fill may be placed in the Bay to protect existing and planned development from flooding as well as erosion. New projects on fill that are likely to be affected by future sea level rise and storm activity during the life of the project must:*
   - *Be set back far enough from the shoreline to avoid flooding;*
   - *Be elevated above expected flood levels;*
   - *Be designed to tolerate flooding; or*
   - *Employ other means of addressing flood risks.*
4. ***Designing Shoreline Protection**: Shoreline protection projects, such as levees and seawalls, must be designed to withstand the effects of projected sea level rise and to be*

integrated with adjacent shoreline protection. Whenever feasible, projects must integrate hard shoreline protection structures with natural features that enhance the Bay ecosystem, e.g., by including marsh or upland vegetation in the design.

5. ***Preserving Public Access**: Public access must be designed and maintained to avoid flood damage due to sea level rise and storms. Any public access provided as a condition of development must either remain viable in the event of future sea level rise or flooding, or equivalent access consistent with the project must be provided nearby."*

This report is intended to address the specific guidance stated in BCDC's Climate Change and Safety of Fills policies.

2. VULNERABILITY ASSESSMENT

2.1 ASSESSING VULNERABILITY TO COASTAL FLOODING

The island was constructed using sand mined from San Francisco Bay in ca. 1936 for the Golden Gate International Exposition. The sandy fill layer is susceptible to liquefaction, and the underlying compressible bay mud layer is subject to settlement over time, which makes it challenging to build tall levees along the perimeter. Several segments of shoreline areas are presently overtopped by waves and are within the 100-year floodplain, as mapped by FEMA. It was recognized that development within the flood prone parcels would require a detailed statistical analysis of tides, waves, and tsunamis, and construction of appropriate mitigations.

A detailed coastal flooding study was conducted for this project (M&N 2009), which showed that coastal flooding in the area is due to varying water levels resulting from a combination of astronomical tides, storm surge, waves on the island shoreline, and tsunamis. Unlike rivers, where guidance on minimum crest elevation of riverfront areas is provided by FEMA and/or the Army Corps of Engineers due to a high degree of confidence on water levels, coastal areas need to be analyzed on a site-specific basis because water levels in coastal areas are influenced by several factors, each of which varies statistically. FEMA's recommended procedure to establish the Base Flood Elevation is to conduct a Probabilistic Analysis of these factors, based on a combination of coincident events that results in a 1% annual chance of flooding. Additional factors that need to be considered include sea level rise, settlement, structure or project design life, and planned uses within the area to be protected.

2.1.1 EXTREME WATER LEVELS

The detailed coastal assessment (M&N 2009) considered all relevant tidal gage records in the area, and a comprehensive statistical analysis of astronomical tides, storm surges, and tsunamis was performed. Results for extreme water levels are summarized in Table 2-1.

Table 2-1: Summary of Extreme Water Levels for Treasure Island Vicinity

Return Period (years)	Peak Still Water Elevation (feet, NAVD88)		90% Confidence Interval based on Tides Only	
	Tides Only	Tides + Tsunamis	Lower Bound	Upper Bound
5-yr	8.2	8.2	8.1	8.3
10-yr	8.4	8.4	8.3	8.6
50-yr	8.9	8.9	8.7	9.2
100-yr *(Base Flood Elevation)*	9.1	**9.2***	8.9	9.4
500-yr	9.7	-	-	-

* Used as 100-yr Still Water Level

Vertical Datum

All elevations referenced in this report are in feet, unless specifically noted, and relative to the North American Vertical Datum (NAVD) of 1988.

Still Water Level, Total Water Level, and Base Flood Elevation

The water levels shown in the table above represent *Still Water Level* (SWL), which includes astronomical tide, storm surge, and tsunamis over the period of observation. It represents a "static" water level that persists for a prolonged period (several minutes to hours at a time).

The SWL is different from *Total Water Level* (TWL), which represents the superposition of wind waves, Pacific swell, boat wake, and wave runup at any given SWL elevation. The TWL represents a "dynamic" water level that may occur for only a few seconds at a time, albeit repeatedly over the period of a storm or boat passage. It is the highest elevation reached by the water, however short-lived it is. The distinction between SWL and TWL is important to note, particularly along coastal areas, because embankments exceeded by SWL elevation constitutes an inundation or large-scale flooding scenario, whereas embankments exceeded by TWL elevation constitutes an overtopping scenario that could lead to short-term flooding if the storm duration is prolonged. A discussion of waves and TWL is provided in the next section.

The *Base Flood Elevation* (BFE) is a regulatory standard for insurance purposes. The definition of the BFE, per FEMA, is *"The flood having a one percent chance of being equaled or exceeded in any given year."* For inland areas of Treasure Island that are not affected by wave-related flooding, the BFE typically corresponds to the 100-year return period still water level (+9.2'). Along the perimeter embankment, the BFE varies based on wave exposure and it corresponds to the total water level.

FEMA is in the process of establishing the BFE for the City and County of San Francisco, and draft maps for public review have been issued. The methodology used for the present study, which was completed prior to the FEMA maps being published, is consistent with FEMA guidance. In general, the TWL along the perimeter as computed for this site-specific study (M&N 2009) is higher than what FEMA shows in their preliminary maps. The higher computed TWL elevations, in conjunction with the desire to have a smaller amount of overtopping than allowed by FEMA for non-levee embankments, resulted in higher perimeter crest elevations than what would be acceptable by FEMA. On the other hand, the SWL as estimated by FEMA (+9.7') is higher than that computed for this site-specific study, which was +9.2'. Other widely recognized studies for the same area have estimated values of:

- +9.25' (Port of San Francisco, 2012)
- +9.6' (San Francisco Public Utilities Commission, 2014)
- +9.2' (U.S. Army Corps of Engineers 1984)

Given that the differences between all the relevant studies is minor (less than 6 inches), the comprehensive site-specific analysis conducted for this study was used for design purposes.

2.1.2 WIND WAVES AND WAVE RUNUP

As described above, areas along the Treasure Island shoreline also experience the effect of waves from wind storms in the local area and distant swells that roll in through the Golden Gate. The detailed coastal assessment (M&N 2009) included an evaluation of waves to assess the vulnerability of shoreline areas and to develop recommendations for crest elevations. The combination of wave height, wave period, and still water level is called wave runup, which is the phenomenon that the shoreline would experience (rather than just wave height). It is therefore wave runup that is used to develop shoreline crest elevations. Estimating extreme wave runup involves detailed probabilistic analyses using Monte Carlo or Joint-Probability techniques to combine wind waves, swell waves, tides, storm surges, and tsunamis, which was performed as described in the detailed coastal assessment (M&N 2009). A summary of the extreme wave runup around the perimeter of the Treasure Island shoreline is shown in Table 2-2.

Table 2-2: Summary of Extreme Wave Runup for Treasure Island Shoreline

Return Period (years)	Maximum Runup Elevation (ft, NAVD88)				
	Southwest	Northwest	North	Northeast	East
5	11.1	12.2	13.5	10.5	9.2
10	11.6	12.8	14.2	11.0	9.5
50	12.5	14.0	15.7	12.1	9.9
100	12.9	14.6	16.3	12.5	10.0

The runup values shown above, along with a freeboard that is based on allowable overtopping, are typically used to design shoreline crest elevations. Sea level rise projections, based on expected project life, are then added to the resulting crest elevations to minimize frequent raising of shoreline embankments. A discussion of sea level rise, as well as recommended perimeter crest elevations, is provided in the next section.

2.2 ASSESSING VULNERABILITY TO SEA LEVEL RISE

Sea level rise is not an episodic phenomenon – in fact it has a high probability (virtually certain) of occurrence – the variable is the rate at which it will occur. In developing the estimates of future flood elevations for the project, it was necessary to select a set of sea level rise projections based on the literature, and then add it to the probabilistic analysis described above.

Thousands of peer-reviewed publications on the topic of climate change and associated sea level rise have been published in the past 20 years. However, the majority of guidance papers produced by federal, state, and other governmental agencies rely on the following literature:

- Assessments based on General Circulation Models (GCM) that use emission scenarios such as those by the Intergovernmental Panel on Climate Change (IPCC 2001, 2007, 2013);
- Assessments based on Semi-empirical models (Rahmstorf, 2007, Vermeer & Rahmstorf, 2009);
- Illustrative Assessments (National Research Council (NRC 1987, USACE 2009);
- Assessments based on a combination of GCMs and Semi-empirical models, such as those by the NRC (2012) and the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT, 2013)

A detailed synthesis of the above documents was provided in the *Coastal Flooding Analysis & Adapting to Sea Level Rise* report (M&N, October, 2014). A summary of the various sea level rise projections is shown on Figure 2-1.

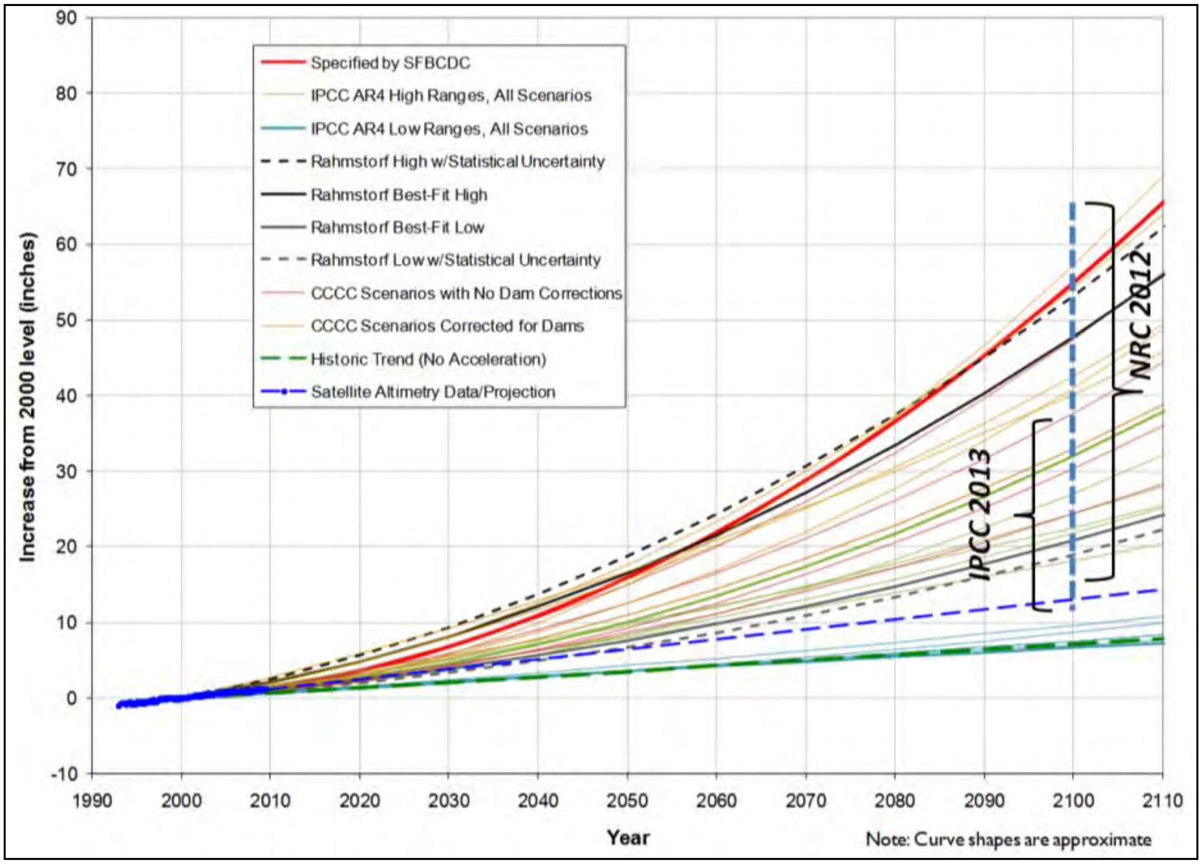


Figure 2-1. Summary of Various Sea Level Rise Projections

2.2.1 PROJECT SPECIFIC SEA LEVEL RISE PROJECTIONS

For the Treasure Island project, two criteria were used in the sea level rise analysis to evaluate the likelihood and the range of projections.

- First, it was important to distinguish between scientific projections (such as those based on modeling of emissions and/or semi-empirical models) and illustrative cases such as those in the NRC 1987.
- Second, the science of climate change and sea level rise is evolving and improving, even if it does not lead to a narrower spread of projections over time. For example, ice sheet dynamics is a very active research field, and measurements of the polar ice caps are showing rapid melt in some areas. Therefore, more recent projections should be given more consideration than those made earlier.

The CO-CAT 2013 and the NRC 2012 reports are specific to California, are the most recent publications, and utilize the body of literature generally accepted by the scientific community; they were therefore recognized by the Treasure Island project to be the *best available science* for this project. Both use the same underlying emission scenarios and therefore recommend the same sea level rise projections. Table 2-3, based on these reports, summarizes the sea level rise projections for the San Francisco Bay area, including the low and high range values.

Table 2-3: Sea Level Rise Projections for San Francisco, California (NRC 2012)

Time Period	Low	Projected	High
2000-2050	4.5”	11.0”	23.8”
2000-2070*	8.4”	18.5”	38.5”
2000-2100	16.5”	36.0”	66.0”

Interpolated based on City & County of San Francisco’s Sea Level Rise Guidance document (City & County of SF Sea Level Rise Committee 2014).

2.2.2 Sea Level Rise Risk Assessment

The CO-CAT guidance recommends that sea level rise values for planning be selected based on risk tolerance and adaptive capacity, and provides a good discussion on risks and consequences related to coastal flooding and sea level rise, and identifies a practical decision-making process. Consequently, a risk-based approach was used to estimate the specific amount of sea level rise allowance that would need to be added to various elements of the project (for example, proposed development grades vs. storm drain design vs. perimeter crest elevations).

Risk is usually evaluated by comparing the *Likelihood* of an impact such as specific amounts of sea level rise by a certain time, to the *Consequence* of these impacts (CO-CAT 2013, IPCC 2007, NRC 2012). This can be expressed as:

Risk = Likelihood × Consequence

Consequences of sea level rise for a particular project depend on both the *Vulnerability* of the asset to sea level rise (a measure of the extent, scale and magnitude of the impact), and the *Adaptive Capacity* of the asset (a measure of the ability of a system to cope with consequences of climate change). For example, an asset which is highly vulnerable to sea level rise and also has a low adaptive capacity will have a high consequence of failing. An asset that has high adaptive capacity and/or low potential impacts will experience fewer consequences. This is graphically presented in Figure 2-2, which demonstrates how the consequences of a decision are determined by the amount of impact and by adaptive capacity (CO-CAT 2013). There are higher consequences when there are greater impacts and lower adaptive capacities.

	Low Adaptive Capacity	Medium Adaptive Capacity	High Adaptive Capacity
High Impact	HIGH CONSEQUENCES	HIGH CONSEQUENCES	MEDIUM CONSEQUENCES
Medium Impact	HIGH CONSEQUENCES	MEDIUM CONSEQUENCES	LOW CONSEQUENCES
Low Impact	MEDIUM CONSEQUENCES	LOW CONSEQUENCES	LOW CONSEQUENCES

Figure 2-2. Evaluating Consequences of Sea Level Rise (CO-CAT 2013)

To evaluate risk to an asset, both Likelihood and Consequence need to be characterized. An asset could be a commercial, residential, or recreational property, an infrastructure facility, public health and safety, and/or the environment. The likelihood factor in the above expression can be described by the scientific studies that have estimated projections of sea level rise, both globally as well as for San Francisco Bay. This is summarized in Figure 2-3, which demonstrates how the amount of risk is determined by looking at consequences and likelihood. There is lower risk when a higher amount of sea level rise is used.

For projects where too much sea-level rise would cause project impacts such as flooding,

	if use lower estimates of sea-level rise	if use medium estimates of sea-level rise	if use higher estimates of sea-level rise
	Higher Likelihood Impacts	Medium Likelihood Impacts	Lower Likelihood Impacts
High Consequence	HIGH RISK	HIGH RISK	MEDIUM RISK
Medium Consequence	HIGH RISK	MEDIUM RISK	LOW RISK
Low Consequence	MEDIUM RISK	LOW RISK	LOW RISK

Figure 2-3. Evaluating Risks Due to Sea Level Rise (CO-CAT 2013)

Based on the approach suggested in the Co-CAT guidance, a typical Risk Assessment therefore consists of the following steps:

1. Assess Vulnerability (coastal flooding under present and future conditions);
2. Determine Adaptive Capacity and Risk Tolerance to Sea Level Rise (compare flooding to proposed grades);
3. Estimate Value of Asset Over its Expected Life, both tangible as well as intangible (assess economic value of project);
4. Develop an Adaptation Strategy for future Sea Level Rise

The vulnerability assessment (step 1 above) was completed as described in the coastal flooding study (M&N 2009). To determine risk tolerance (and steps 3 and 4 above), discussions related to the planning horizon for the development were initiated with project planners. Given that a typical financing mechanism (loans and/or bonds) takes about 30 years to service the debt; a 70-year duration would allow a minimum of two such debt mechanisms after the planning/construction phase of about 10 years. This was also perceived to be about the length of time at which significant infrastructure improvements are made to communities.

The decision was therefore made to design the project such that very low risk of sea level rise related impacts would occur over the 70-year duration. Over this period, even with the most aggressive projection of sea level rise, the increase in sea level reaches 36-inches between 2075 and 2080 (see Figure 2-4). In fact for many of the projections shown in the literature (see Figure 2-1), the 36-inch increase is not reached until after 2100.

The design strategy and elevations of specific project features are described in the next section.

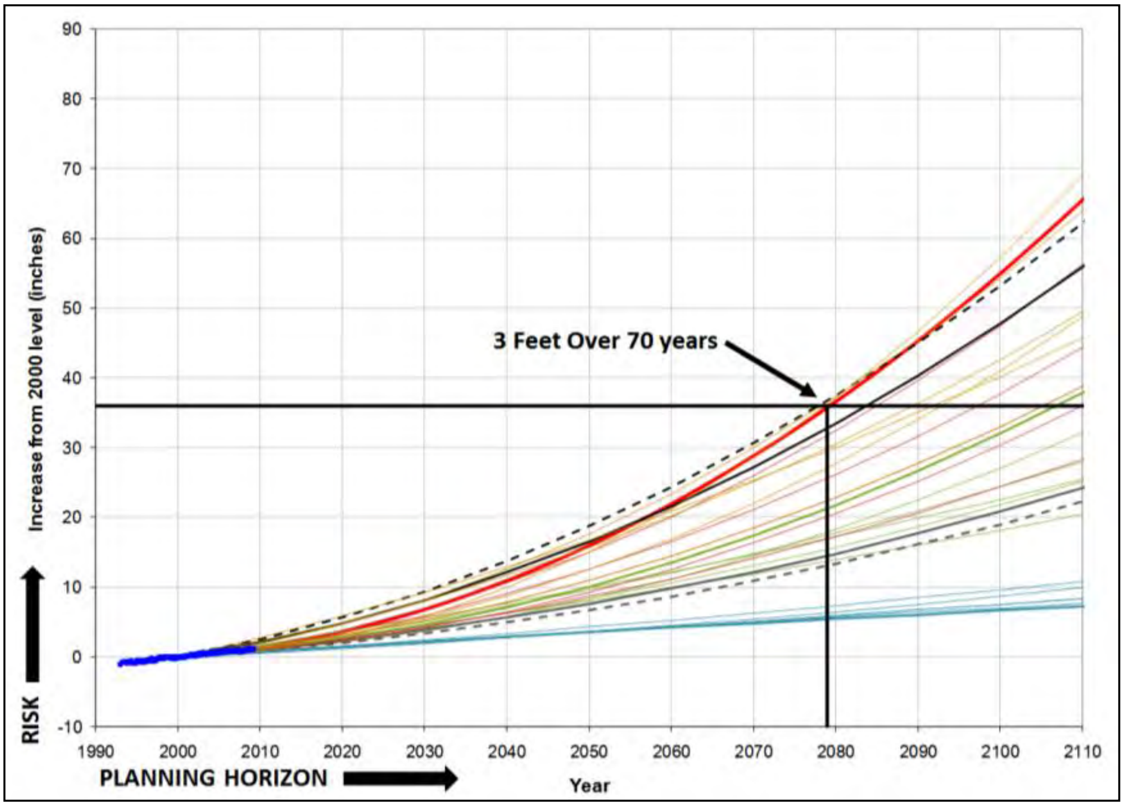


Figure 2-4. Risk Tolerance for the Treasure Island Project

3. PROJECT DESIGN FEATURES

3.1 OVERALL APPROACH

Based on the vulnerability analysis, quantitative estimates of sea level rise for San Francisco Bay, and numerous discussions with TIDA, TIDC, and other City agencies, a strategy for protection against sea level rise was adopted for the project customized to the adaptive capacity of different elements.

Since building structures are generally "immovable" (i.e. high consequences), whereas a shoreline protection system and/or storm drain system can be adapted to keep up with changing sea levels (i.e. low consequences), different planning horizons were adopted for the different elements. In general, the sea level rise strategy was built around the following key elements, which are summarized in Figure 3-1. Additional details are provided following the figure.

1. Raise grades for the new development to accommodate sea level rise over a 70-year horizon.
2. Improve the perimeter protection and interior drainage – at least up to mid-century levels and if possible more – to prevent obstruction of view corridors and ponding, while still providing protection against coastal flooding. Include sufficient development setbacks to allow future improvements along the perimeter to address sea level rise.
3. Since the Ferry Terminal has a design life of 40-years, design the terminal features such that no adaptations would be needed over the project life.
4. Develop an Adaptation Strategy for improvements in the future, when sea levels exceed the allowances built during initial construction. These will include adaptations to the shoreline crests, drainage system, and the ferry pier.
5. Identify a stream of funding to construct these improvements as part of the Adaptation Strategy.

Figure 3-1. Design Philosophy for Addressing Sea Level Rise

3.1.1 DEVELOPMENT AREAS

Since building pads and finished floors are not adaptable, raise all buildings and entrances to subterranean parking and streets to include a 36-inch sea level rise allowance plus a freeboard of 6 inches (total of 42-inches above the BFE). This allowance would be used for finished floor elevations of all buildings, which would ensure that even if no shoreline protection improvements are undertaken, or in the event of a slope failure along the shoreline, buildings and transportation infrastructure would not be flooded for water levels 42 inches higher than current BFE. This exceeds the elevations in the 2080 time frame according to the most aggressive sea level rise, and well beyond 2100 according to the NRC 2012 projections.

3.1.2 SHORELINE PROTECTION SYSTEM

It is not practical to build a high wall around the project for a design condition that may not happen for several decades, because it would pose a visual obstruction and severely limit public access. At the same time, it is not practical to build to present sea level conditions and keep raising it as sea levels rise. Therefore, at initial construction the perimeter elevation will be raised to prevent coastal flooding associated with the 1% annual chance storm event (BFE, analogous to the TWL) for present day conditions, as well as an additional allowance for 16-inches of sea level rise.

Future sea level rise related improvements (elevation increases) would occur along the shoreline to keep up with rising sea levels. The perimeter system would be designed with a development setback wide enough that would allow future increases, including the high range estimate of 66-inch per NRC 2012, with either the same or a different structural configuration. This will ensure that the project will not be mapped in a flood zone either now or in the future.

3.1.3 STORM DRAIN SYSTEM

The storm drain system will be constructed such that it can gravity-drain, until such time that sea level rise reaches 16-inches, beyond which adaptation measures will be implemented consisting of installing storm drain pumps.

3.1.4 FERRY TERMINAL

Since the Ferry Terminal has a design life of 40-years, design the terminal features (pier, float, gangway, and breakwaters) such that no adaptations would be needed over the project life.

3.1.5 ADAPTATION STRATEGY

When sea level rise approaches or exceeds the level of protection that the shoreline perimeter is designed for, adaptation will be needed. Specifics of the adaption strategy are described in Section 4 of this report.

3.2 SUMMARY OF PROJECT DESIGN FEATURES

Based on the location of the major phases of the Project (see Figure 3-2) and the above described design philosophy, the following specific features were adopted:

A. Given the comparatively high elevations of land on the island (most of island higher than 100-yr water level), a decision was made to accommodate 36-inches of sea level rise over the 70-yr period by raising development features that have low adaptive capacity (building pads and major streets) rather than rely on flood control levees soon after construction to address future water levels. This would ensure that these assets are protected well into the future (2070 to beyond 2100 depending on observed sea level rise rates) regardless of the condition of the shoreline.

B. For the perimeter for Phase 1 of construction (southern and western portions of island), where the urban Cityside Park is proposed, a 36-inch allowance for sea level rise at time of initial construction was found to be practical, and will therefore be implemented at the outset.

C. For the perimeter for Phases 2, 3, and 4 of construction (northern and eastern potions of island), where open space features such as parks and trails are envisioned along the shoreline, a different approach was used. These open space features have a high adaptive capacity and higher resilience than an urban setting; therefore, in those areas, a two-phased construction of shoreline protection will be implemented to address SLR:
   - Build with an initial allowance for 16-inches of sea level rise (highest mid-century estimate);
   - Raise in the future to accommodate 36-inches of sea level rise (highest end of century sea level rise).

D. Design the storm drain system with adequate capacity and sufficient freeboard above the top of pipes such that the system would operate under gravity at last until such time that a sea level rise of 16-inches has occurred. After that, relatively simple adaptation measures such as adding storm drain pumps to the system would be implemented.

E. Develop an adaptation strategy that includes a project specific Adaptive Management Plan and a Financing Plan for future sea level rise adaptations, when water levels exceed the allowances described above. The adaptation strategy including the relevant plans is described in the following section.

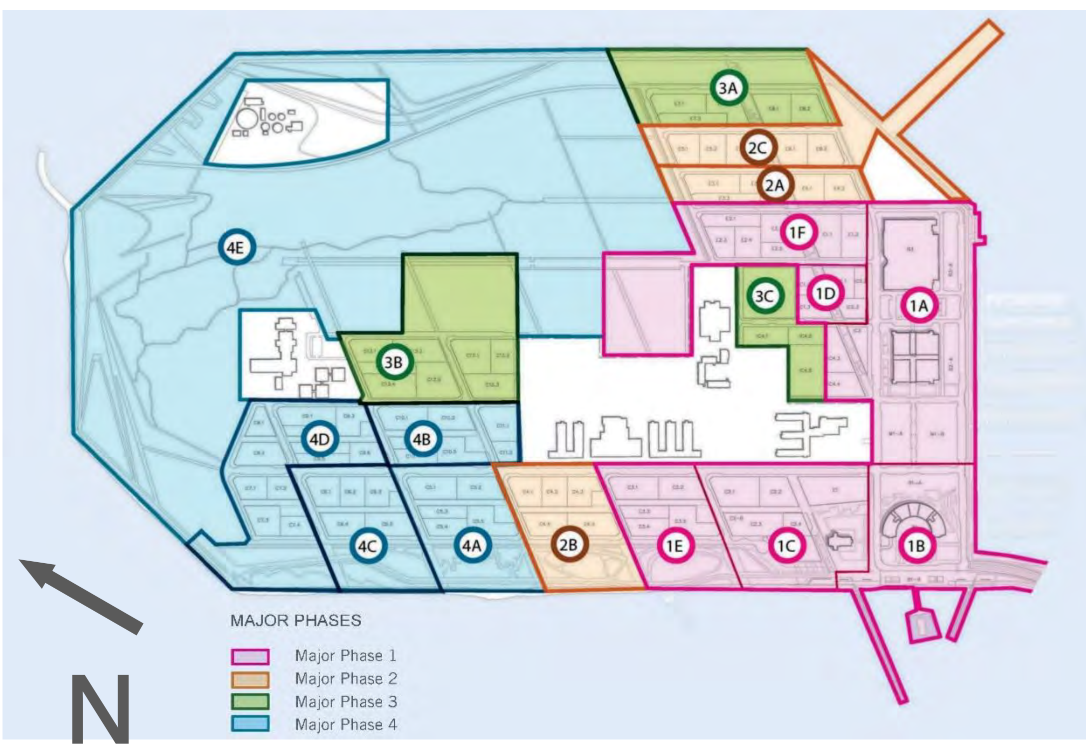


Figure 3-2: Planned Phasing for the Development Project

The Risk Assessment resulted in an identification of the deficiencies in, or vulnerability of, the existing (pre-project) perimeter system. Table 3-1 summarizes existing shoreline elevations and recommended crest elevations for various allowances of sea level rise. The proposed shoreline crest elevations are also graphically depicted in Figure 3-3.

Inundation maps that show likely flooding of the site if the proposed project were not to be constructed, as well as maps that show the reduction in flooding due to the proposed improvements are included in Appendix A.

Table 3-1. Existing and Required Perimeter Elevations for Various Amounts of SLR

Location	Station Location	Existing Elevation	Required Crest Elevation (NAVD)			
			No SLR	16" SLR	24" SLR	36" SLR
Southwest	3+00	12	9.6	10.9	11.6	**12.6**
	17+00	11	12.8	14.1	14.7	**15.5**
West	31+00	13	13.7	15.0	15.5	**16.3**
Northwest	45+00	13	14.1	**15.3**	15.8	16.6
	51+00	14	14.4	**15.6**	16.1	16.9
	55+00	14	14.6	**15.8**	16.2	17.0
North	61+00	14	13.9	**15.1**	15.7	16.5
	67+00	12	13.9	**15.1**	15.7	16.5
Northeast	78+00	11	13.9	**15.1**	15.6	16.3
	84+00	11	12.7	**14.0**	14.6	15.4
East	96+00	11	10.4	**11.7**	12.4	13.4
	104+00	11	10.1	**11.4**	12.1	13.1
	114+00	12	10.0	**11.4**	12.0	13.0
Southeast	128+00	11	9.8	**11.2**	11.8	12.8
	132+00	12	9.6	**10.9**	11.6	12.6
South	144+00	12	9.2	10.5	11.2	**12.2**
	150+00	11	9.2	10.5	11.2	**12.2**

* No freeboard - but overtopping check included for pedestrian access along shoreline

Notes:

i. Estimates shown in the table assume a 2H:1V slope below elevation +12' NAVD and a 3H:1V slope above that.

ii. **Bold** numbers represent elevations that are proposed at time of initial construction.

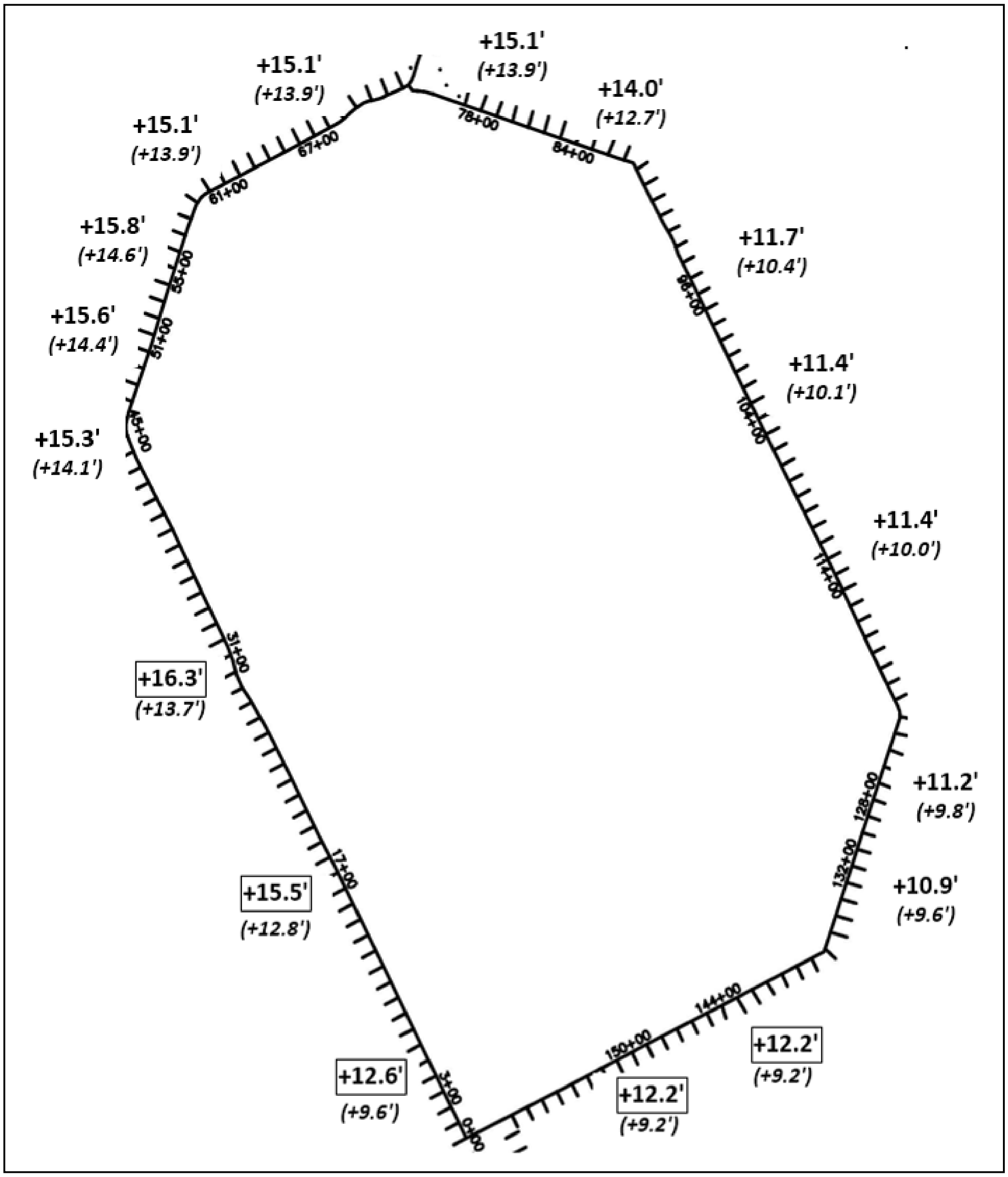


Figure 3-3. Proposed Perimeter Crest Elevations

Notes:

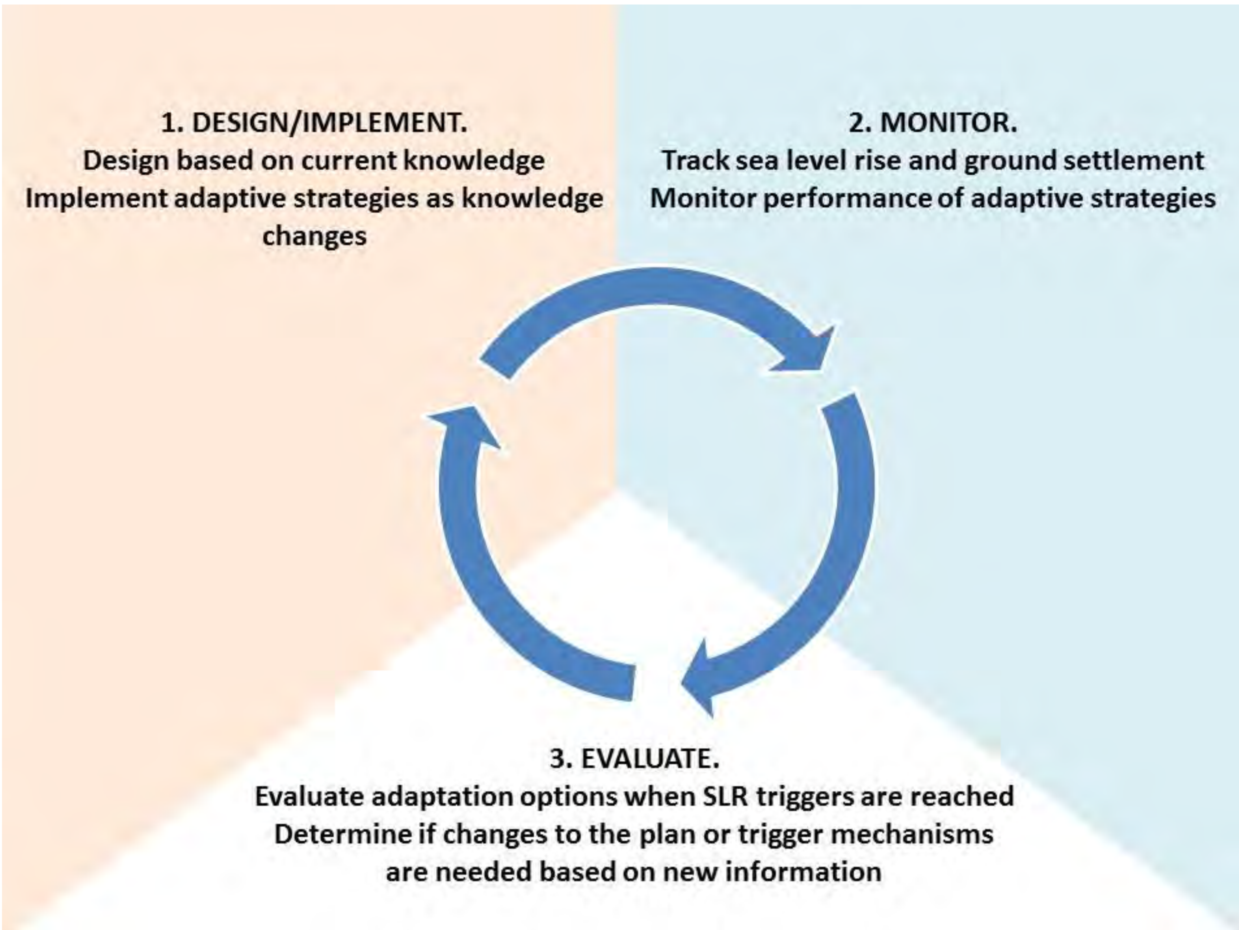
i. Numbers in (parentheses) represent required elevations if no sea level rise were to be included.

ii. **Bold** numbers represent proposed elevations, which include 16-inches of sea level rise allowance.

iii. **Bold** number for Phase 1 of the project along the southern and western portion of the island includes 36-inches of sea level rise allowance

4. ADAPTIVE MANAGEMENT PLAN

The purpose of this Adaptive Management Plan is to provide a framework for monitoring and adaptively managing the development of Treasure Island for rising sea levels. Management and monitoring of sea level rise will be implemented both during the project development phase and over the long term following project build out. Adaptive management provides a framework for managing projects and processes given levels of uncertainty based on monitoring, and adjustment of management decisions based on the results of that monitoring. The figure below conceptually illustrates how this framework was applied to managing and adapting to future sea level rise for the Treasure Island project.



Elements covered by this Adaptive Management Plan include the following, each of which is further described below:

1. Assignment of Responsibilities;
2. Maintenance of Public Access;
3. Monitoring Program;
4. Trigger Mechanisms;
5. Implementation Strategies;
6. Funding Mechanism

4.1 ASSIGNMENT OF RESPONSIBILITIES

- The project applicant (TICD, TIDA, and its designees) will be responsible for implementing all elements of this plan during the period of project build out.
- TIDA will manage all elements of the adaptation strategy for Treasure Island, including facilitating the long-term provision of public access, monitoring the effects of sea level rise, managing trigger mechanisms for adaptation, implementing adaptation measures, and managing the funding mechanism.
- When certain triggers are reached, TIDA will implement management actions to ensure continued protection of assets in the face of rising sea levels, utilizing the funds from the funding mechanism (see next section).
- TIDA will be responsible for obtaining environmental clearances and regulatory approval for implementation of adaptation strategies.
- TIDA will continue to update and implement this Plan based on monitoring results and new information.

4.2 MAINTENANCE OF PUBLIC ACCESS

- The 55-acre area of Treasure Island located within BCDC's 100-foot shoreline band jurisdiction will be designated as required public access as part of the BCDC permit. The required public access and the remaining portions of the larger open space areas will be managed by TIDA as a trustee on behalf of the people of California, subject to the public trust for commerce, navigation and fisheries ("public trust" or "trust").
- When rising sea levels encroach on this 55-acre area, implementation strategies described in this document will be triggered and regulatory approvals required to implement those strategies will be obtained.
- Areas currently subject to the public trust will remain so, regardless of the adaptation strategies that are implemented. As part of future BCDC permit amendments for adaptation strategy implementation, the location and size of public access could be adjusted per the Commission's policies in effect at that time.

4.3 MONITORING PROGRAM

The tasks described below have already been initiated (during the project planning and design phases) and will continue over the period of construction, prior to project build out.

- TIDA will monitor sea levels using scientific guidance and updates from a variety of federal agencies (including NOAA, USGS, and others), regional agencies (such as the USACE, BCDC and others), and state and federal guidance documents (such as CO-CAT and NRC reports).
- TIDA will utilize licensed surveyors and benchmarks on the island to monitor ongoing settlement by conducting periodic topographic surveys (cross sections) at Treasure Island. Monitoring of settlement and sea levels (previous item) will be used to determine if trigger thresholds have been reached.
- TIDA will periodically monitor the physical effects of SLR on shoreline improvements through condition assessments to determine if sea level rise is affecting the functionality of shoreline structures.

- TIDA will prepare monitoring reports on a 5-year cycle, which will be used to update this plan as needed based on the findings.

4.4 TRIGGER MECHANISMS

Phase 1 Area (built initially with 36-inch SLR Allowance)

- When a sea level rise of 30-inches has occurred (compared to 2000 levels), planning would be initiated by TIDA to improve the shoreline protection system to act as a flood barrier (such as a levee or floodwall). Permits and approvals from relevant regulatory agencies will be initiated and appropriate environmental documentation will be prepared based on the adaptation strategy selected for a particular area. These improvements would be constructed before a sea level rise of 36-inches (compared to 2000 levels) has occurred. The improvements would provide for future sea level rise as projected at that time (e.g. 66 inches or larger). The time duration between the 30-inch trigger and a 36-inch sea level rise, even for the highest rate of sea level change, is about 8 years, which is expected to be an adequate amount of time to obtain required approvals and permits, and construct the improvements.
- If any of the proposed sea level rise adaptations result in the flooding of an area where Navy environmental cleanup activities were performed (see Figure 4-1), the Regional Water Quality Control Board shall be consulted and an evaluation shall be performed at that time to assess if additional risk management is needed and if potential cleanup is necessary.

Phases 2, 3, and 4 (built initially with 16-inch SLR Allowance)

- For these phases, when a sea level rise of 12 inches has occurred (compared to 2000 sea levels), planning would be initiated by TIDA to implement adaptations for shoreline areas (see Implementation Strategies below). Permits and approvals from relevant regulatory agencies will be initiated and appropriate environmental documentation will be prepared based on the adaptation strategy selected for a particular area. These improvements would be completed before a sea level rise of 16 inches (compared to 2000 levels) has occurred. They would mitigate more frequent wave overtopping and storm drain backups, and would include allowances for future sea level rise as projected at that time. At a minimum, the improvements would accommodate a sea level rise of 36-inches (compared to 2000 levels). The time duration between the 12-inch trigger and a 16-inch sea level rise, even for the highest rate of sea level change, is about 11 years which is expected to be an adequate amount of time to obtain required approvals and permits.
- If sea level rise approaches 12 inches (compared to 2000 sea levels) during the project build-out period itself, construction plans for those future phases will include a minimum sea level rise allowance of about 36 inches (compared to 2000 levels). Applicable consultations will be completed for any necessary modifications to permits and environmental approvals prior to construction.
- When a sea level rise of 30-inches (compared to 2000 levels) has occurred, planning would be initiated by TIDA to improve the shoreline protection system to act as a flood barrier (such as a levee or floodwall). Permits and approvals from relevant regulatory agencies will be initiated and appropriate environmental documentation will be prepared based on the adaptation strategy selected for a particular area. These improvements would be constructed before a sea level rise of 36-inches (compared to

2000 levels) has occurred. The improvements would provide for future sea level rise as projected at that time (e.g. 66 inches or larger).

- If any of the proposed sea level rise adaptations result in the flooding of an area where Navy environmental cleanup activities were performed (see Figure 4-1), the Regional Water Quality Control Board shall be consulted and an evaluation shall be performed at that time to assess if additional risk management is needed and if potential cleanup is necessary.

4.5 IMPLEMENTATION STRATEGIES

The elevation and structural characteristics of Treasure Island's perimeter will inform future shoreline adaptation strategies. The proposed development setback distances will allow for a variety of future modifications along the shoreline to accommodate a broad range of future sea level rise scenarios. All strategies would factor in the importance of the provision of public access and public safety. Shoreline modifications would likely include a combination of the following implementation strategies depending on desired open space uses and wave runup characteristics at different locations around the island. Initial construction and representative examples of future adaptations, where envisioned, are presented in Figure 4-2, Figure 4-3, Figure 4-4 and Figure 4-5.

- Raising the shoreline embankment in place to function as a storm surge or flood barrier, including a levee;
- Constructing a series of embankments of increasing heights away from the water, such that there is habitat value between embankments as the space fills with periodic wave overtopping and subsequently drains between high tides;
- Constructing sea walls – particularly at the proposed ferry quay and along the marina promenade, where they would also function as a public amenity;
- Laying back the shoreline and creating beaches or marshes that would limit wave runup and overtopping, and create accessible public amenities or habitat areas..

4.6 FINANCING PLAN

The Disposition and Development Agreement for the project between TIDA and TICD, as well as the Development Agreement between the City and County of San Francisco and TICD, include a Financing Plan with a mechanism for funding the adaptive management strategies and improvements described in Section 4. The Financing Plan directs that Special Taxes* collected via the establishment of Community Facilities Districts (CFD) on Treasure Island and Yerba Buena Island can be used to pay for future Sea Level Rise Improvements. More specifically, if the appropriate regulating authorities require the construction or installation of improvements to ensure that the shoreline, public facilities, and public access will be protected should sea level rise at the perimeter of the islands, TIDA, the City and TICD agree to finance the improvements with such project-generated CFD Bonds.

*Special Taxes are supplemental property taxes collected in the same manner as general property taxes.

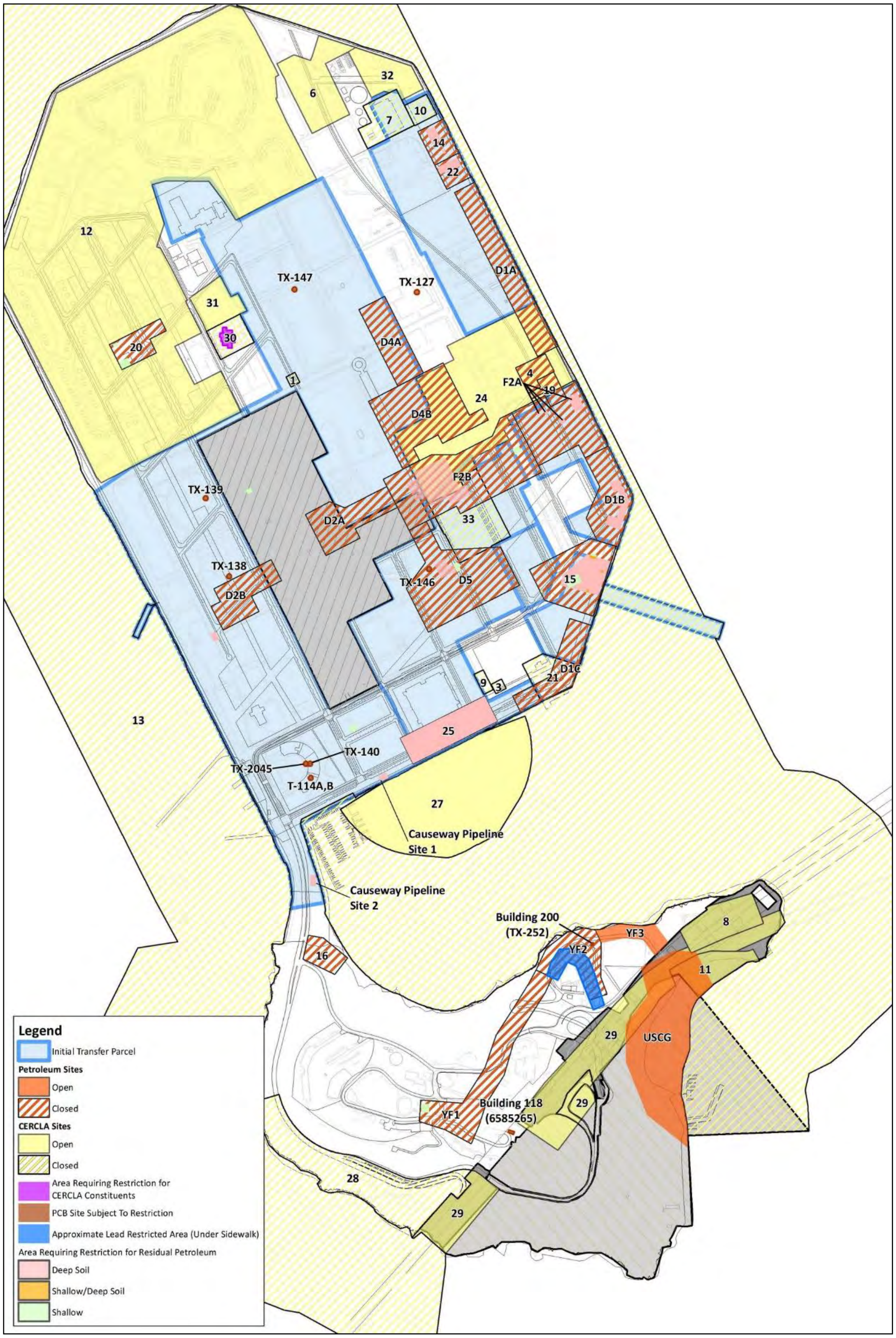


Figure 4-1: CERCLA and Petroleum Sites on Treasure Island
(Source: Terraphase Engineering)

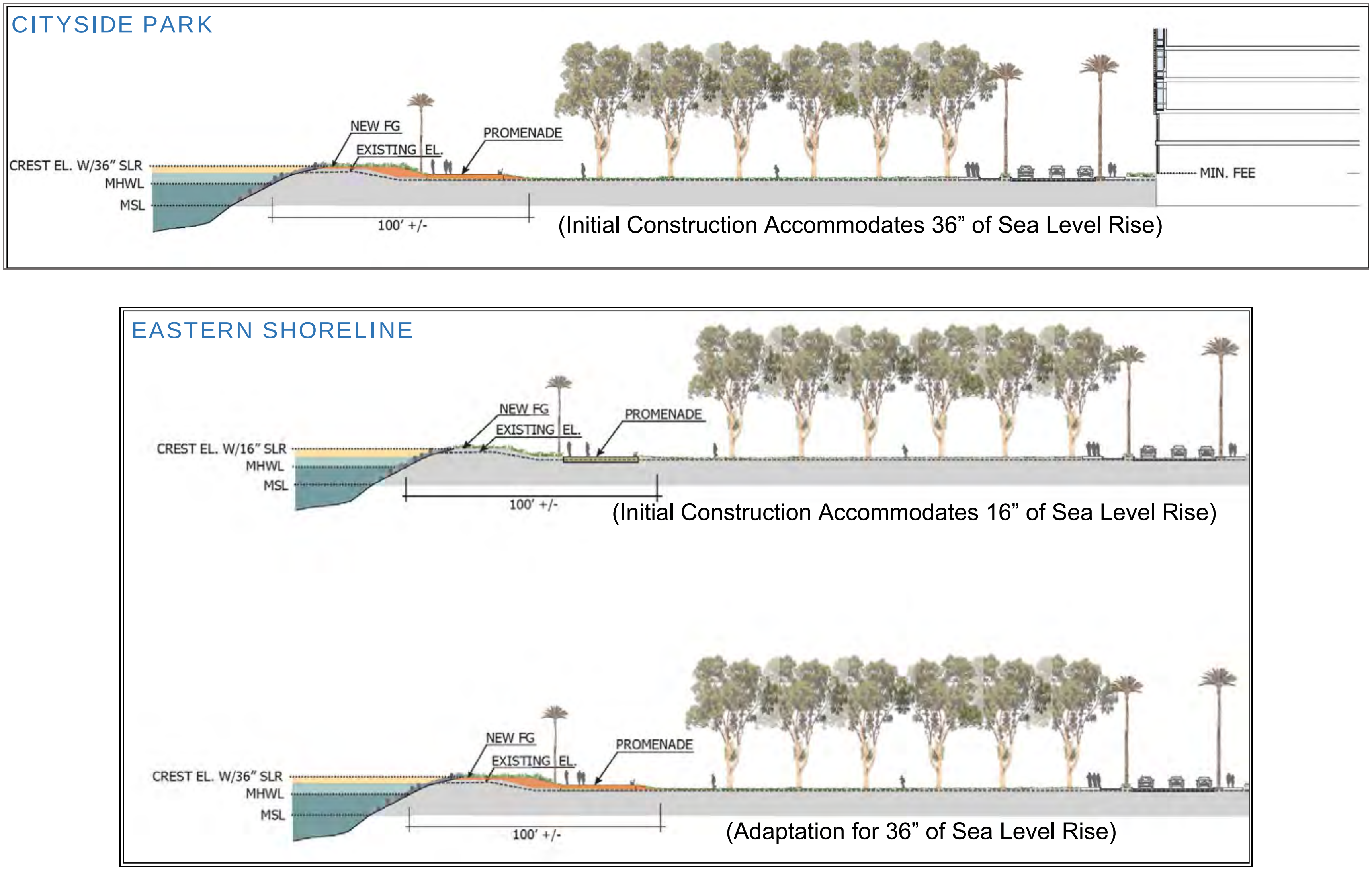


Figure 4-2: Cityside and Eastern Shoreline

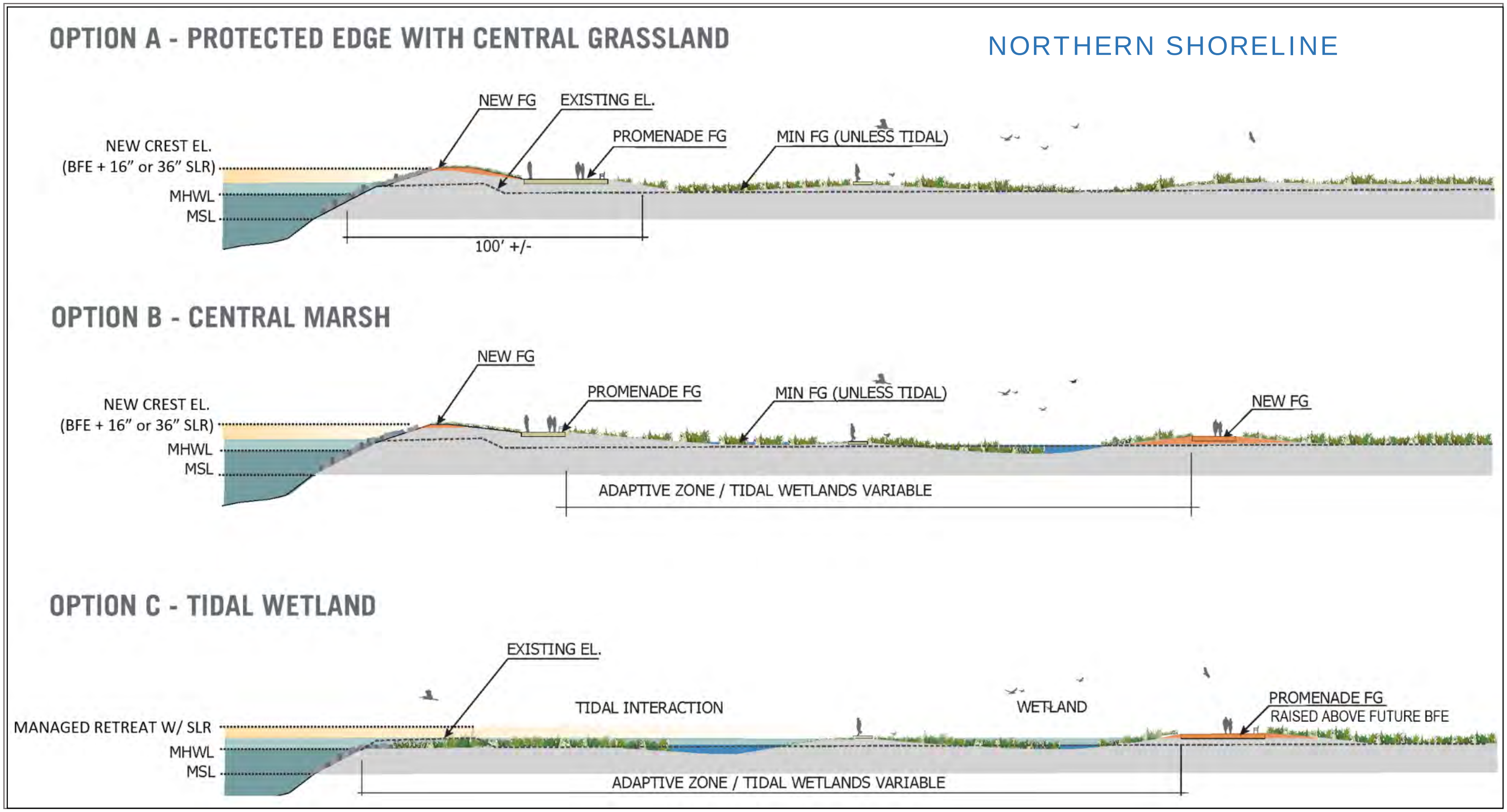


Figure 4-3: Northern Shoreline

(Initial Construction Accommodates 16" of Sea Level Rise)

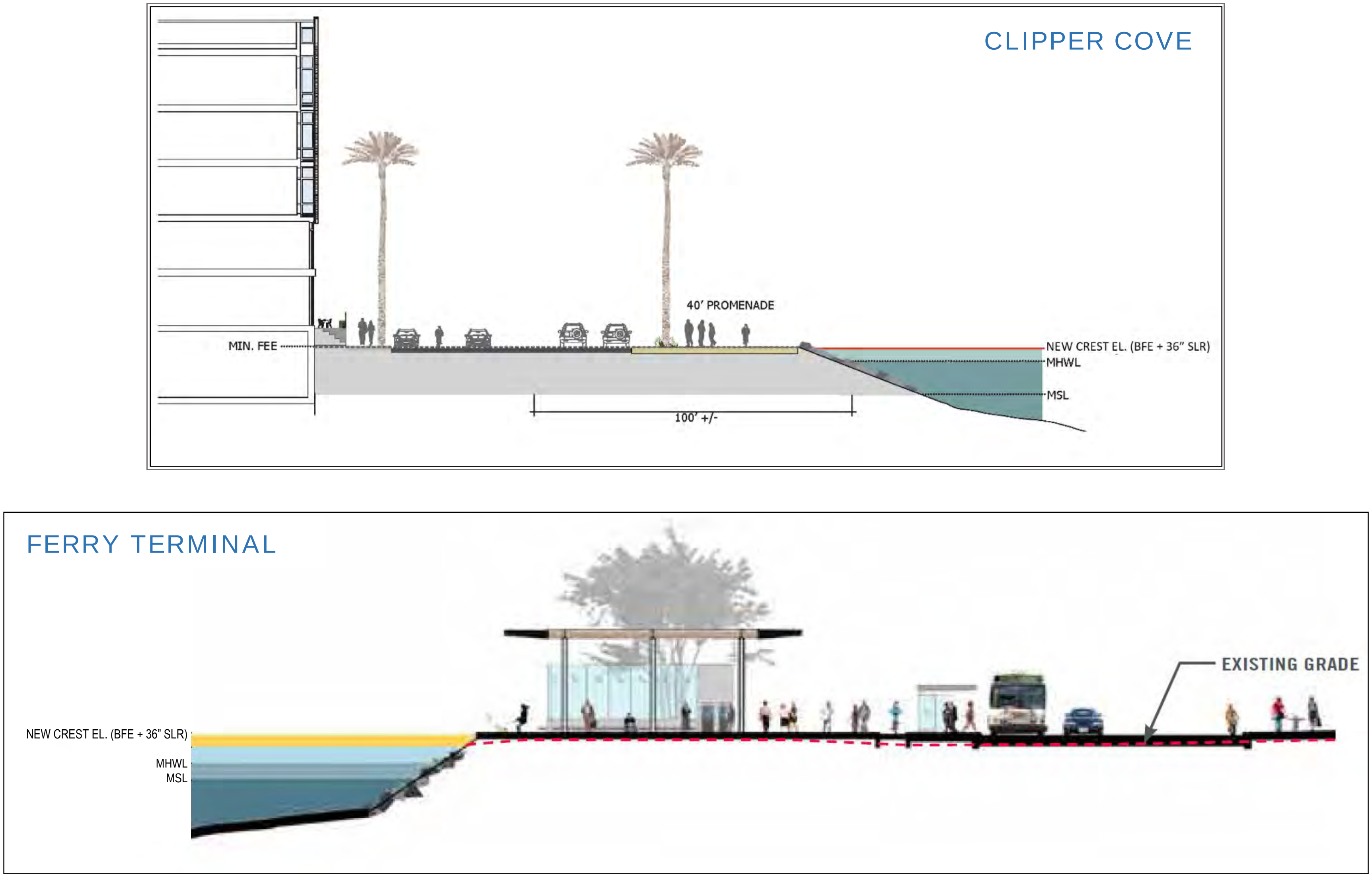


Figure 4-4: Clipper Cove and Ferry Terminal Shoreline

(Initial Construction Accommodates 36" of Sea Level Rise)

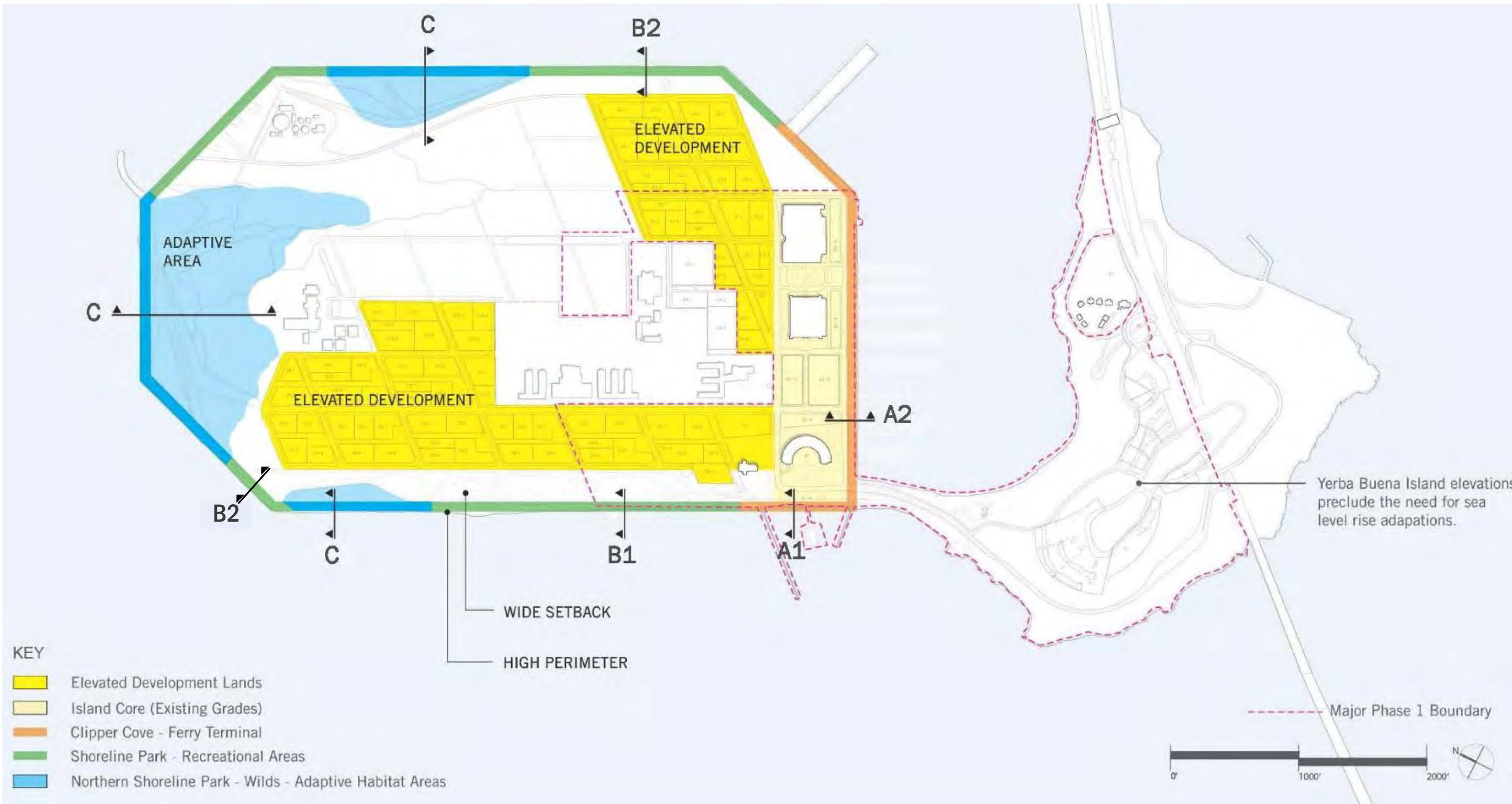


Figure 4-5: Sea Level Rise Strategy

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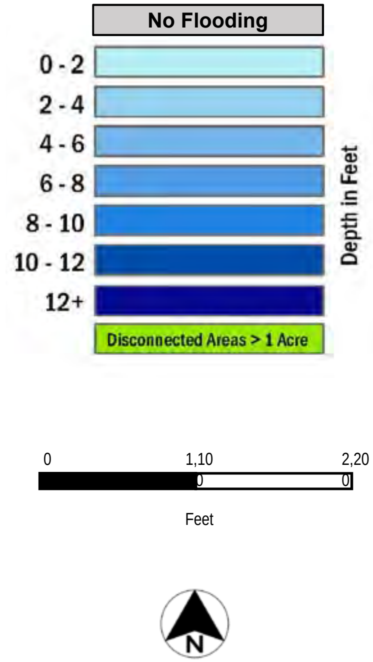
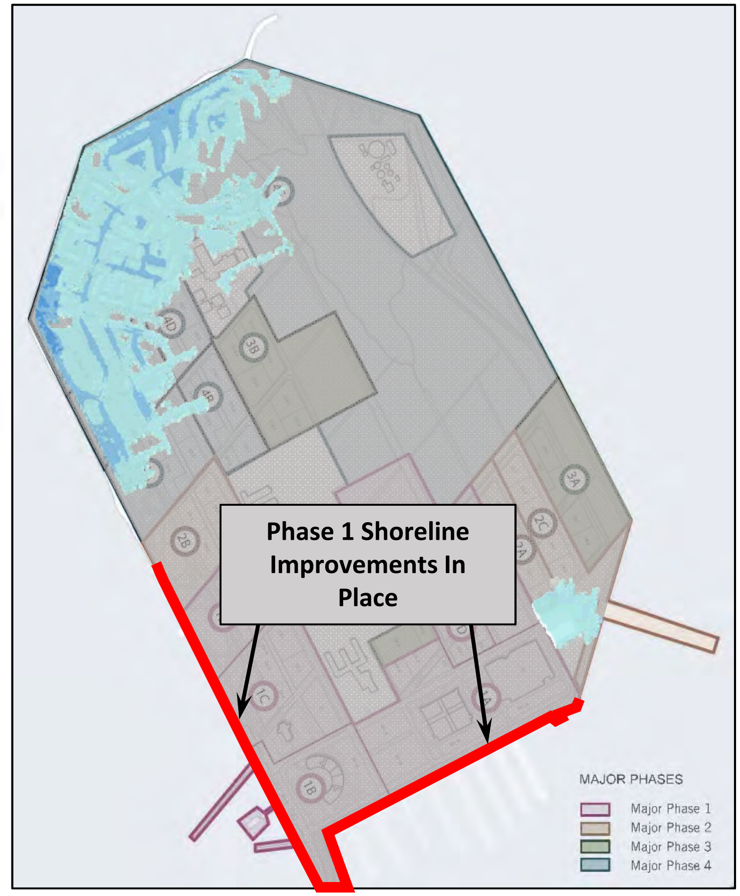
APPENDIX A

Inundation Maps for Without Project and With Project Conditions



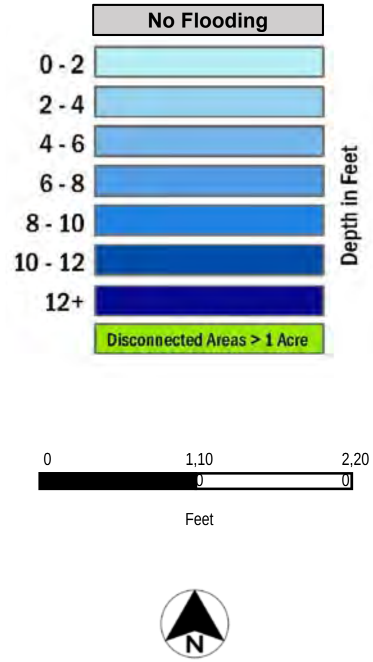


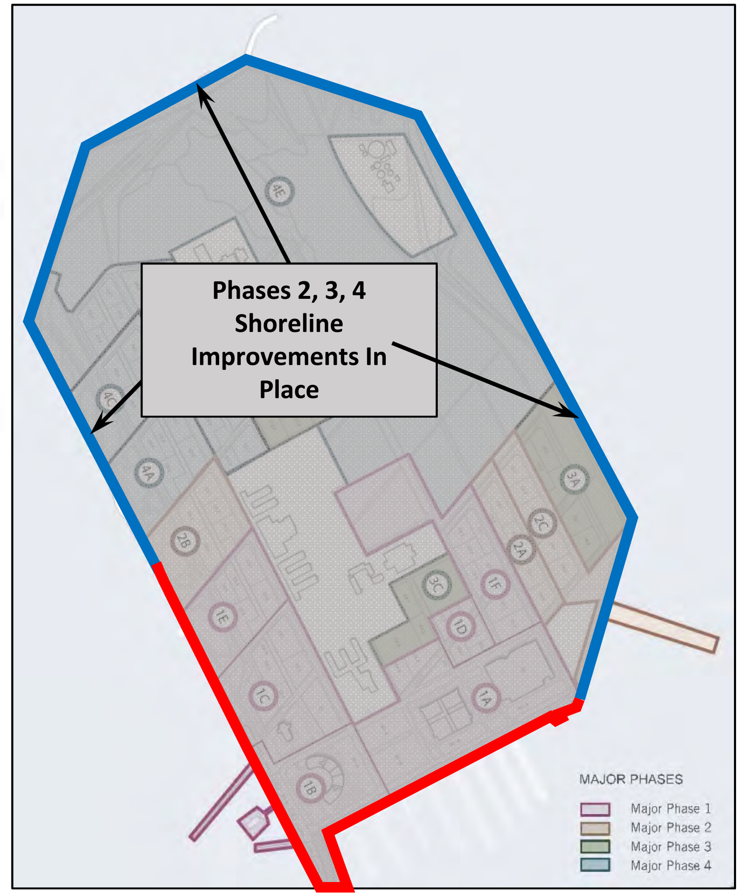
Pre-Project (Existing) Conditions

Post-Project Conditions (End of Phase 1)

TREASURE ISLAND SEA LEVEL RISE INUNDATION MAPS DATE: 01-JULY-2016 Job No: 8548	moffatt & nichol 2185 N. California Blvd. Ste 500 Walnut Creek, CA 94596 925-944-5411	EXHIBIT 1: 100-YEAR BFE ELEVATION = +9.2 FEET NAVD88 SHEET 1 OF 6

Without Project Conditions





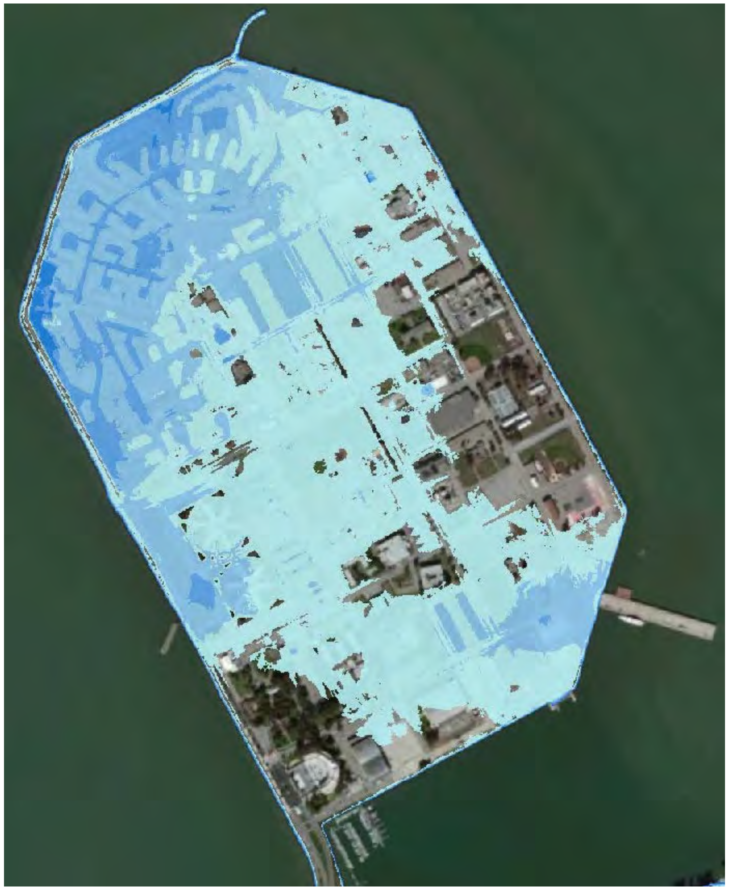
Post-Project Conditions (All Phases)

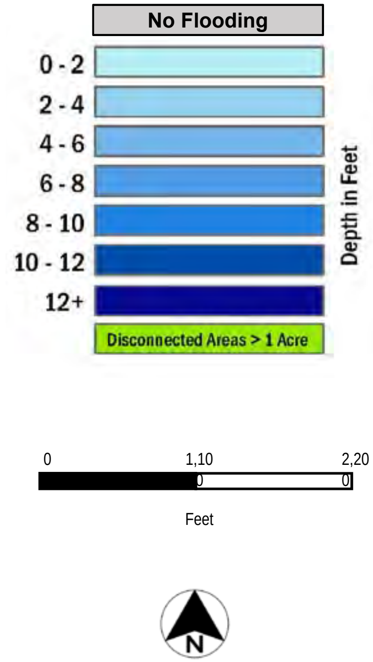
TREASURE ISLAND
SEA LEVEL RISE INUNDATION MAPS
DATE: 01-JULY-2016
Job No: 8548

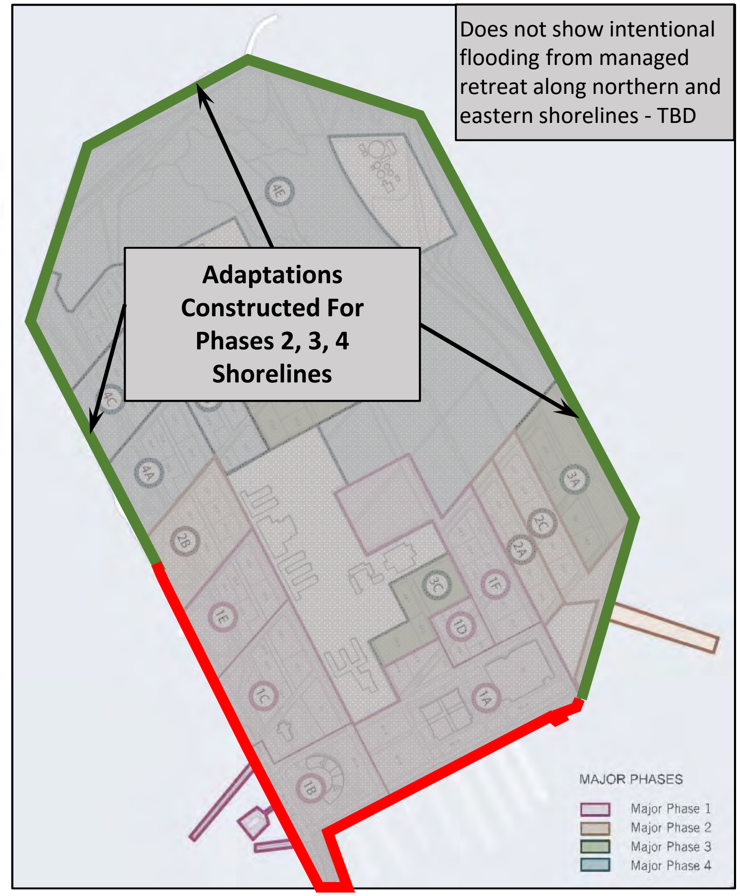
moffatt & nichol
2185 N. California Blvd. Ste 500
Walnut Creek, CA 94596
925-944-5411

EXHIBIT 2: 100-YEAR BFE +12" SLR
ELEVATION = +10.2 FEET NAVD88

SHEET 2 OF 6



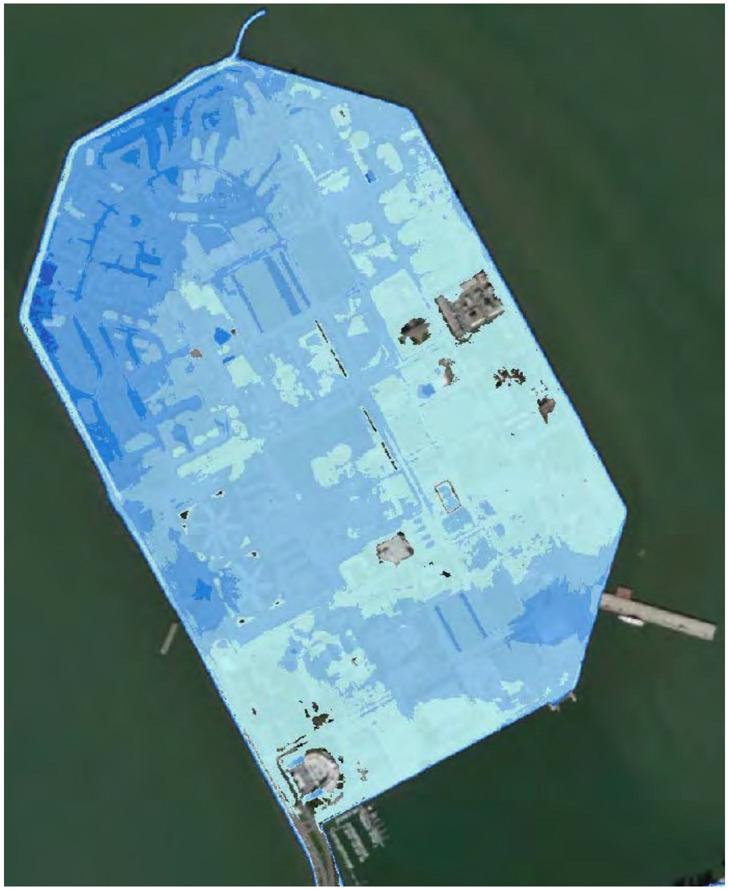




Without Project Conditions

Post-Project Conditions

TREASURE ISLAND SEA LEVEL RISE INUNDATION MAPS DATE: 01-JULY-2016 Job No: 8548	moffatt & nichol 2185 N. California Blvd. Ste 500 Walnut Creek, CA 94596 925-944-5411	EXHIBIT 3: 100-YEAR BFE +30" SLR ELEVATION = +11.7 FEET NAVD88 SHEET 3 OF 6



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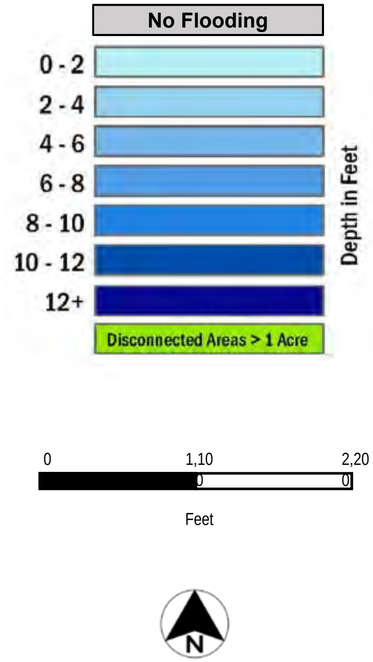

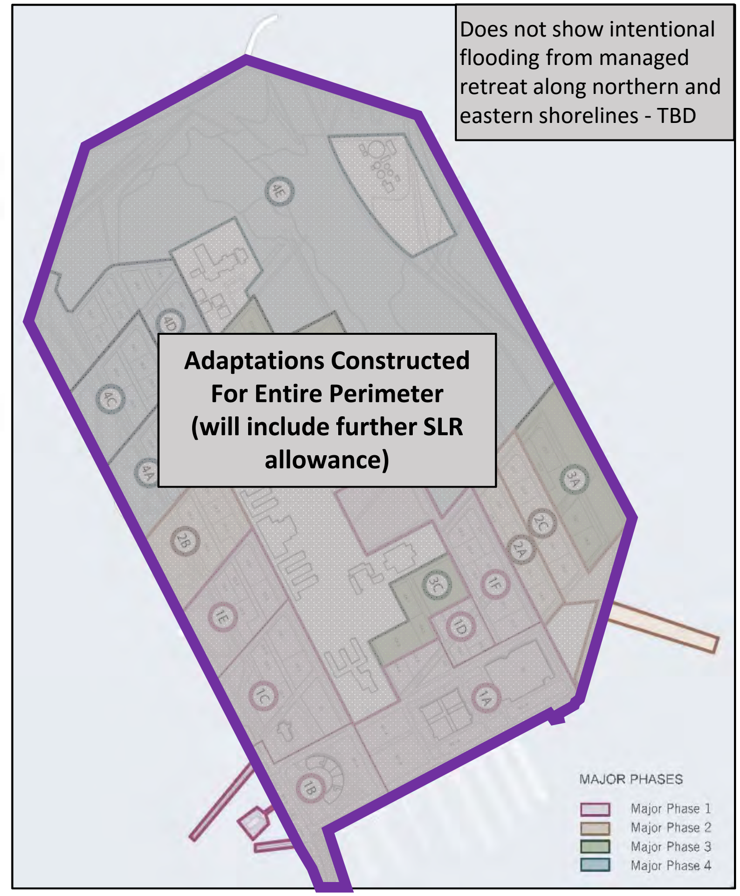

Post-Project (Proposed) Conditions

TREASURE ISLAND
SEA LEVEL RISE INUNDATION MAPS
DATE: 01-JULY-2016
Job No: 8548

moffatt & nichol
2185 N. California Blvd. Ste 500
Walnut Creek, CA 94596
925-944-5411

EXHIBIT 4: 100-YEAR BFE +48” SLR
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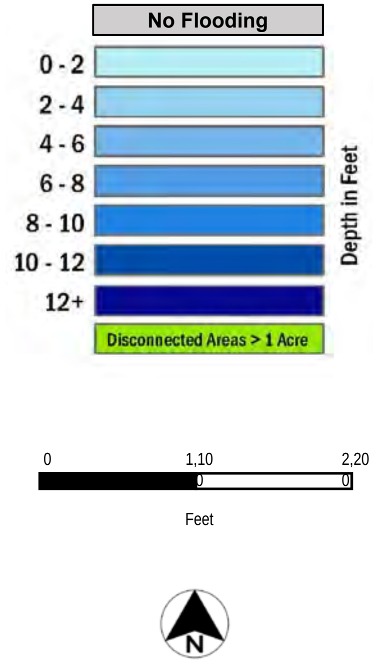
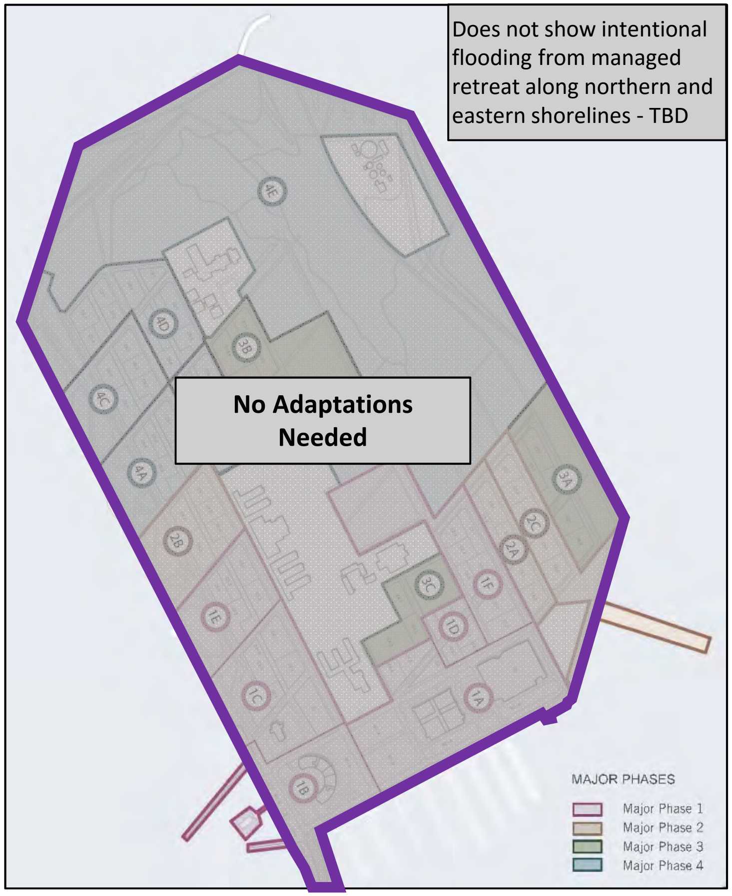
SHEET 4 OF 6

Without Project Conditions





Post-Project (Proposed) Conditions

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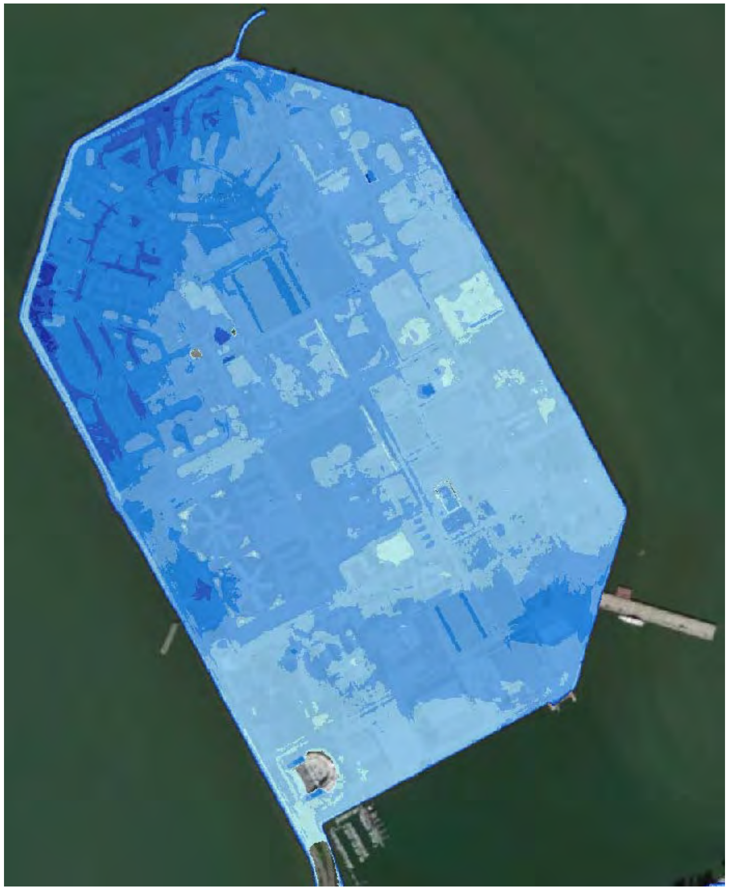

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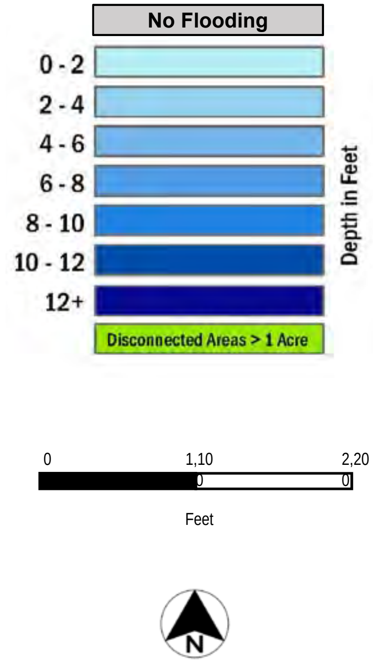

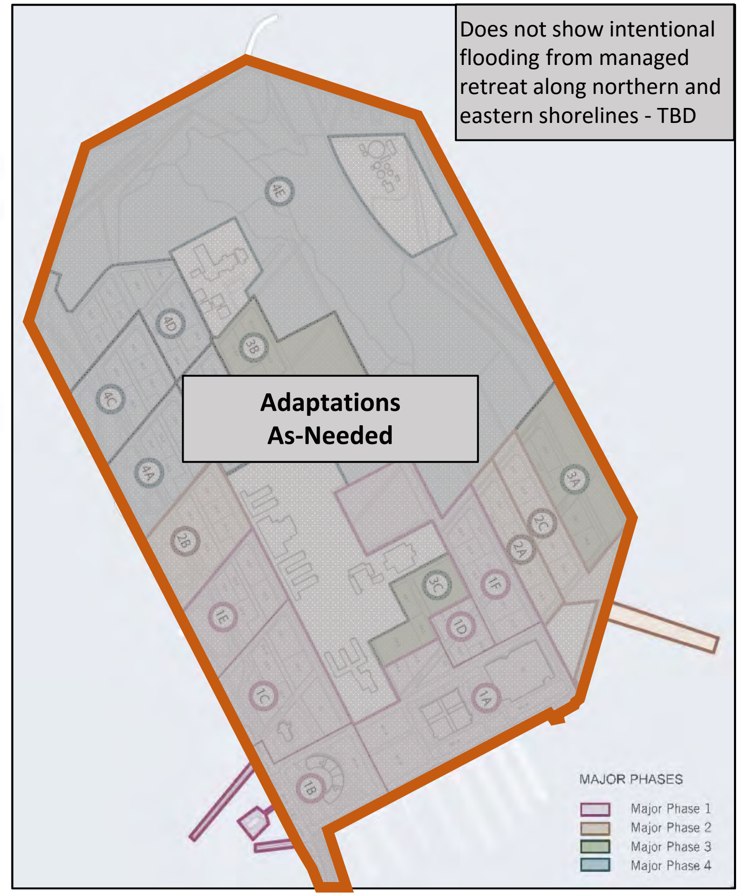

Post-Project (Proposed) Conditions

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