AB 691 Sea-Level Rise Assessment

For

The Crescent City Harbor District

June 10, 2019

Submitted to:

Crescent City Harbor District

101 Citizens Dock Road

Crescent City, California 95531

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ACRONYMS AND ABBREVIATIONS

CCHD	Crescent City Harbor District
GHG	Greenhouse Gas
GT	Great Diurnal Tidal Range
ICPP	United Nations Intergovernmental Panel on Climate Change
LHMP	Local Hazard Mitigation Plan
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
NOAA	National Oceanic and Atmospheric Administration
RCP	Representative Concentration Pathway
SLR	Sea-Level Rise

DISCLAIMER: The following Sea-Level Rise Assessment was prepared for the Crescent City Harbor District. All statements are the sole responsibility of PND Engineers, Inc., and do not necessarily reflect the views or policies of the Harbor District. This assessment is for planning purposes only. Site-specific evaluations may be needed to confirm or verify information presented herein.

1. Assessment of impacts of sea-level rise

The Crescent City Harbor District (CCHD) is situated on a low-lying portion of the Pacific coast in northern California. Like much of California, the Harbor District and surrounding areas are vulnerable to extreme coastal events combined with rising seas. Extreme events such as storm surges and tsunamis can and have caused widespread adverse impacts to coastal resources and infrastructure without the addition of higher sea levels. Understanding the effects of sea-level rise (SLR) on the region's coastline when combined with extreme coastal events is critical in allowing the Harbor District to identify its most at-risk resources and aid in developing strategies to adapt these resources to changes.

In 1931 the Crescent City Harbor District was form in accordance with Statutes of 704. It originally consisted of the tide and submerged lands measuring 400 acres (Figure 1). The CCHD owns and controls land and tideland properties waterward of the 1948 Ordinary High-Water Mark bounded by Crescent City to the west, Crescent Beach to the east, a U.S. Highway 101 corridor to the north, and Lighthouse Way Breakwater to the south. The Harbor District's property is bounded by a series of breakwaters, except to the north where the boundary becomes less linear. These granted lands, as amended in 1963, were approved of "for the establishment, improvement, and conduct of a harbor, for the construction, maintenance and operation of wharves, docks, piers, slips, quays and other utilities, structures, facilities, and appliances necessary or convenient for commerce, navigation and fisheries, and for public recreation purposes" (Statutes of California, 1963). The Harbor District now consists of approximately 4,052 acres of land and water area. As part of its fiduciary duty, the CCHD is required to take reasonable steps to keep control of and preserve the trust lands. As the effects of climate change and SLR have the potential to cause a wide range of impacts to trust lands, the District provides the assessment herein to describe how it will address potential effects on critical facilities and resources, per Assembly Bill No. 691.

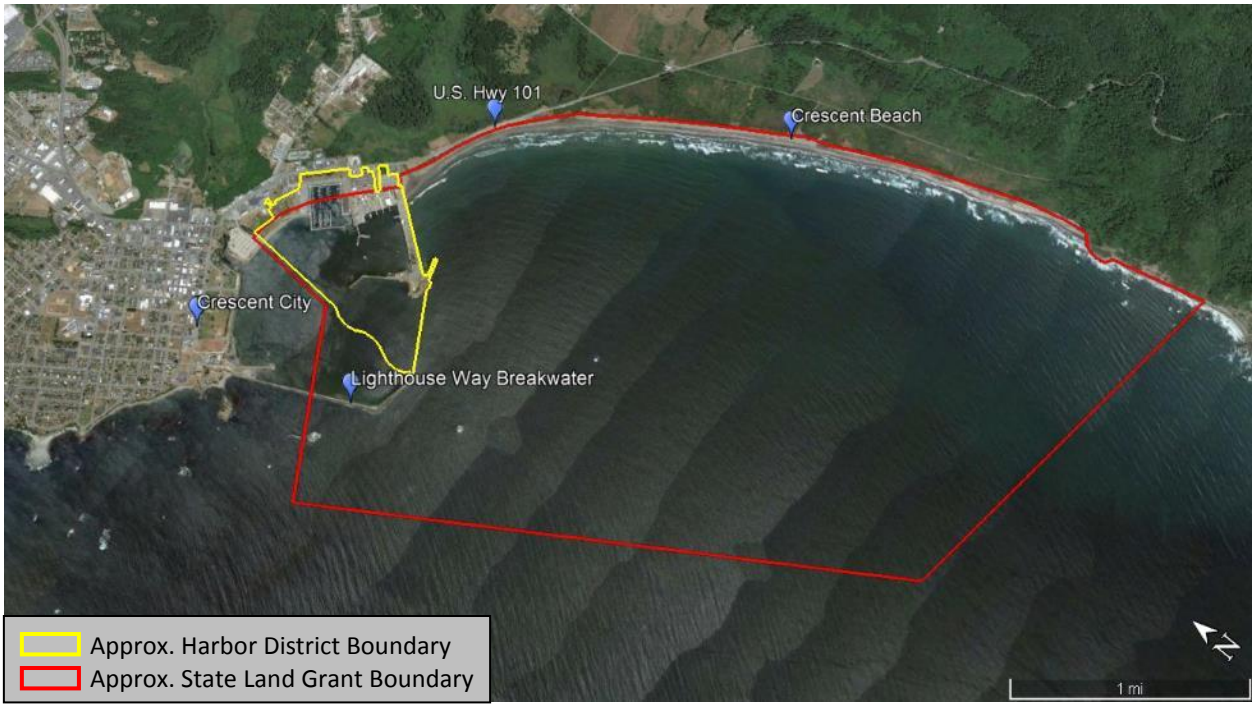


Figure 1: Crescent City Harbor District Sovereign Tide and Submerged Land Boundaries

a. Inventory vulnerable natural and built resources and facilities

A large majority of built infrastructure in the CCHD is located within the harbor boundary. The CCHD harbor is considered critical as it is the only "harbor of refuge" between Humboldt Bay, California, and Coos Bay, Oregon. This shallow-draft harbor supports the U.S. Coast Guard Station Crescent City and patrol boat USCGC Dorado, commercial and sport fishing operations, recreational boating, and maritime and non-fishing related businesses. The harbor is protected against coastal hazards like wave impacts, erosion, and flooding by four breakwaters and one groin (Figure 2). Seventeen additional built resources and facilities are present within the breakwater area. To the east of the harbor are two additional natural resources, South Beach and Crescent Beach. South Beach is partially sheltered from coastal hazards by the Anchor Way Breakwater and Whaler Island Groin to the northwest, plus a small rip-rap armored seawall that protects the Crescent Beach Motel and parking lot. Between the two beaches there are eight public access points that are bound by U.S. Highway 101 to the north. A complete inventory of vulnerable natural and built resources that are directly within the boundaries of the CCHD is provided in Table 1. Additionally, the most apparent coastal hazard risks to each recourse is provided.

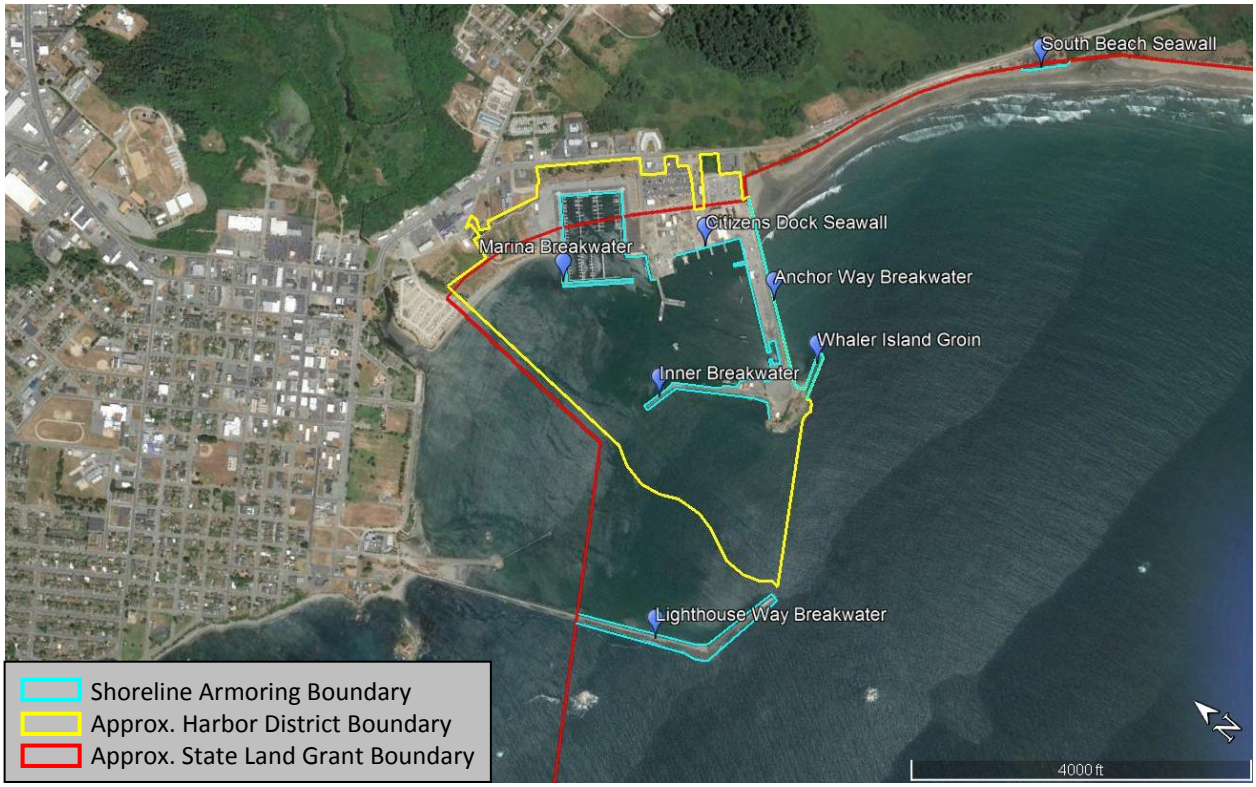


Figure 2: Crescent City Harbor District Critical Protection Facility Boundaries

Table 1: Inventory of Vulnerable Resources in the CCHD and Their Coastal Hazard Risks

No.	Critical Facility (count or description)	Resource	Coastal Hazard Risks
1	Administrative Dock and Pump-Out Station	Built	Tsunami, inundation, flooding, saltwater intrusion, sea-level rise, impaired function
2	Anchor Way Boat Ramps	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
3	Anchor Way Breakwater	Built and Natural	Tsunami, damage from extreme waves, sea-level rise, impaired function
4	Beaches (3 total)	Natural	Loss of Resources and/or Public Access, Transformation, sea-level rise
5	CCHD Boat Ramps	Built	Tsunami, inundation, flooding, , sea-level rise impaired function
6	Citizen's Dock	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
7	Dredge Ponds	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
8	Inner Boat Basin Docks	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
9	Inner Breakwater	Built	Tsunami, damage from extreme waves, sea-level rise, impaired function
10	Lighthouse Way Breakwater[1]	Built	Tsunami, damage from extreme waves, sea-level rise, impaired function
11	Maintenance/Storage Buildings (5 total)	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
12	Marina Breakwater	Built	Tsunami, damage from extreme waves, sea-level rise, impaired function
13	Office/Retail Buildings (13 total)	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
14	Restroom Buildings (5 total)	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
15	Roads and Parking Areas	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
16	Seafood Processing Plants (2 total)	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
17	Shipyard Building	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
18	Solar Array[1]	Built	Tsunami, damage from extreme waves, sea-level rise, impaired function
19	South Beach Seawall	Built	Tsunami, damage from extreme waves, sea-level rise, impaired function
20	Synchrolift, Travelift, and Dock	Built	Tsunami, inundation, flooding, sea-level rise, impaired function
21	Utilities (Power, Sewer, Water)	Built	Tsunami, inundation, flooding, saltwater intrusion, sea-level rise, impaired function
22	Whaler Island Groin	Built	Tsunami, damage from extreme waves, sea-level rise

[1]*Asset not owned by the CCHD.*

b. Consider impacts and recommendations described in the current State Sea-Level Rise Policy Guidance

The physical impacts of SLR include inundation, flooding, increasing shoreline erosion, larger tidal prisms, wave heights and force, saltwater intrusion, and changes in sedimentation and littoral drift patterns. In order to manage these impacts and those from extreme events, there are a number of adaption strategies possible. These strategies can include the reactive approach of "do nothing," as it is referred to in the California Coastal Commission SLR Guidance (2018), or proactive approaches such as protection, accommodation, and retreat of resources. A definition and example of each proactive approach is provided below:

> **Protection:** Defend a resource as is, in its current location. Example: Hard or soft shoreline armoring, increasing stiffness of dock piles, and constructing flood gates.
>
> **Accommodation:** Modify existing resources to decrease hazard risks and thus increase their resiliency. Example: Elevating structures, retrofitting to increase strength, repositioning boats and ships within a harbor, and dune revegetation for a natural resource such as a beach.
>
> **Retreat:** Relocating or removing existing resources out of hazard areas and limiting new development in that area. Example: Permanently relocating a building to higher ground and removing all small boats from a harbor.

Within the CCHD land grant boundary there are two main types of environments. One is a highly armored and engineered environment with little adaptability in terms of retreat. In other words, the harbor's infrastructure includes extremely critical assets that work in conjunction together and have an expected lifespan well beyond 2050. Such long-lived assets were not made to be relocated, as maritime industries and infrastructure rely exclusively on shoreline access. The second environment types within the CCHD are naturally occurring wide and flat beaches with a highway, parking, and access points that lend themselves more readily to all three adaption approaches.

c. Consider impacts of storms and extreme events

Climate change is predicted to alter storms' characteristics by increasing their intensity, frequency, spatial extent, duration, and timing (IPCC, 2014 and National Academies Press, 2016). According to the 2018 Del Norte Local Hazard Mitigation Plan (LHMP), several hazards have been identified to be of highest concern to Crescent City, including tsunamis and earthquakes, followed by severe weather and flooding.[1]

i. Tsunamis

Crescent City has long been known as one of the nation's most susceptible cities to tsunamis. Tsunamis can be produced by earthquakes, landslides, and submarine volcanic explosions. The configuration of the region's coastline and the shape of the ocean floor lend themselves to the formation of these destructive waves on the local section of coastline. In the last eighty years, thirty-nine tsunamis have been detected within Del Norte County; four of which caused more than $37 million in damage. The worst-case scenario for the County would be a tsunami

[1] While the 2018 LHMP does consider SLR to have a low potential of risk in Crescent City, it is also stated that SLR may "impact economically important assets in coastal areas." SLR will have a higher potential for risk should it increase by four feet (LHMP, 2018).

triggered by a seismic event along the Cascadia subduction zone. Historical records suggest that such a tsunami could produce a wave with heights between fifteen and sixty feet. A wave with such height is estimated to yield 186,059 tons of debris and cause $1.42 billion in damage, without accounting for secondary impacts (LHMP, 2018). Aside from the tremendous hydraulic force of a tsunami wave, secondary impacts can be devastating. Examples of secondary impacts include floating debris endangering lives and undermining roads, buildings, bulkheads, etc.; trapped flood waters contaminating drinking water; sewer systems and culverts becoming clogged; and power generation facilities being inundated. Additionally, there is generally little warning time for evacuation, leaving more people vulnerable to all of these threats. For the CCHD, the infrastructure of highest concerns would be U.S. Highway 101, breakwaters and piers, and drainage and utility systems (LHMP, 2018). To compound the threat further, higher than average sea levels will create a higher launching point for tsunami waves moving inland. Therefore, the depth and extent of inundation will be greater as the mean sea level surface increases.

ii. Earthquakes

Del Norte County is susceptible to regular earthquake activity, as evidenced by a magnitude 5.5 or greater event every 3.6 years, on average, or the five seismic events between 2000 and 2018. As more than 87% of the homes in Crescent City were built before modern seismic codes were in force, many structures may need seismic retrofits in order to withstand even a moderate earthquake. Within the CCHD, the soft soils are considered to be of a type that are most affected by ground shaking, and therefore are most susceptible to liquefaction. Structures on these soils may experience significant structural damage. However, specific geotechnical data to confirm the extent of liquefaction is not available for the District and SLR is anticipated to have only a minor impact on this effect. Therefore, it is not considered further. The loss of road systems and harbor facilities after an earthquake would cause significant impacts to the local economy and may significantly disrupt response and recovery efforts. According to the 2018 LHMP, “citizens are expected to be self-sufficient up to two weeks after a major earthquake without government response agencies, utilities, private-sector services, and infrastructure components.” The reason for these seemingly very large amounts of survival supplies simply has to do with access. Responders are not anticipating that they will be able to arrive and care for all County citizens immediately after a devastating earthquake. Residents will be essentially isolated for a period of time. For the CCHD, the secondary impacts to an earthquake include ground subsidence, fires, gas leaks, contamination of water supplies, and power outages.

iii. Severe weather and coastal flooding

Severe weather is defined by the 2018 LHMP as “any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life.” This could include prolonged periods of rain, blizzards, thunderstorms, or damaging winds. Flooding is a common secondary hazard to severe weather in the CCHD. The last seven severe storms (six of which occurred during winter) had a damage assessment of $799,000. One such storm in 2018 produced substantial debris and impairment to the Anchor Way Breakwater, as depicted in Image 1. It is estimated that a significant number of structures in the CCHD were built

before floodplain development regulations were in place; therefore, these structures may be particularly vulnerable to coastal flood hazards. A 1-percent-annual-chance flood event could produce nearly 80,000 tons of debris (LHMP, 2018). If piers and docks cannot reasonably be designed to withstand extreme conditions like coastal flooding, the structures must be modified to protect against projected coast flooding or accept the consequences of damage and/or failure. As climate change increases the number of severe storms, CCHD facility owners and operators may experience more frequent disruptions in the utilities and services they depend on. More resources may need to be directed to response and recovery efforts more often. Additionally, changes in the design of coastal flood protection facilities may be needed as additional SLR stresses are placed on these systems.

Image 1: Anchor Way Breakwater Debris from a 2018 Storm

d. Consider changing shorelines

According to the 2017 FEMA Flood Insurance Study for Del Norte County, coastal flooding near Crescent City Harbor District is often associated with the simultaneous occurrence of king tides, large waves, and storm surge, especially during the winter. These combined effects produce coastal flooding that causes additional inundation and associated damage due to the simultaneous nature of these events. As these storm events increase in their previously mentioned characteristics, beaches will be significantly impacted. Beaches are essentially continuous for miles outside the harbor and are highly vulnerable to high-tide flooding without the additional pressures of SLR. When combined with rising sea levels, shorelines will experience a higher initiation point for waves moving inland. Therefore, the depth and extent of flooding will be greater as the mean sea level surface increases. The vast majority of these beaches are not supported by shoreline armoring. CCHD's shoreline is expected to recede due to coastal erosion and flooding. All of South and Crescent Beach are projected to be vulnerable to the combined effects of SLR, with much of the beach expanses condensed by rising tides by 2050. Figure 3 depicts areas that are currently exposed to high tide, coastal flooding without the addition of SLR projections or other coastal processes.

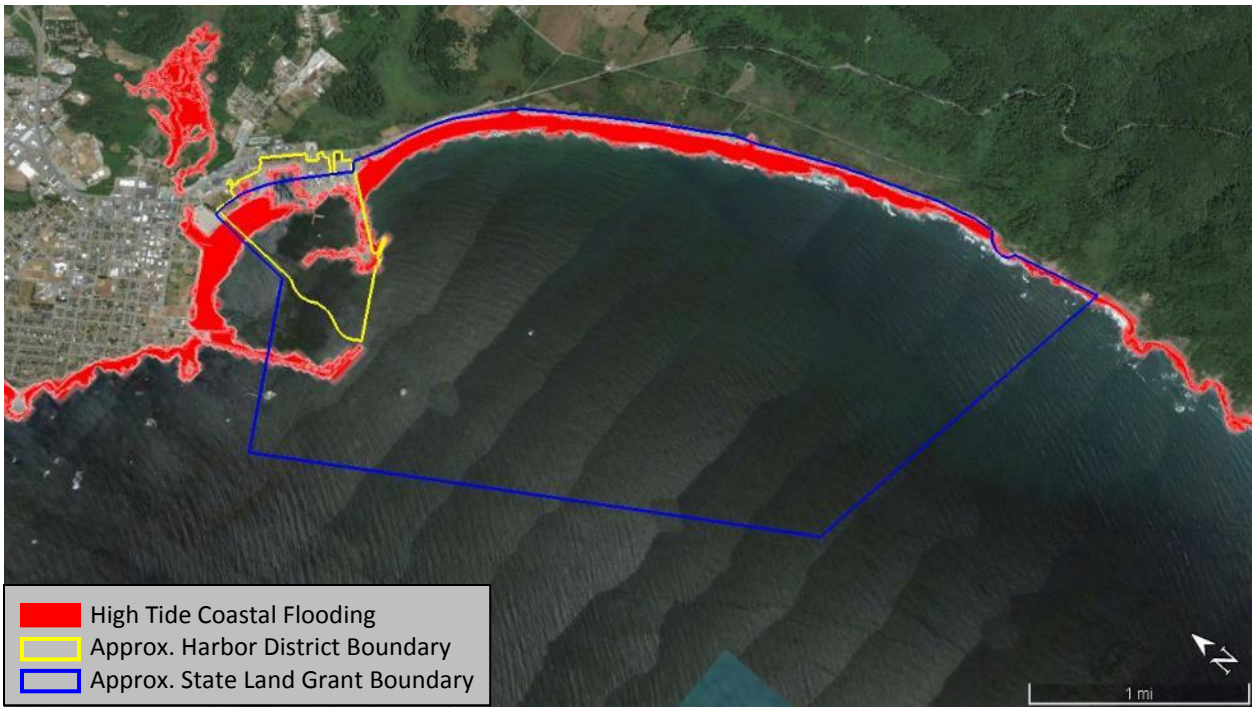


Figure 3: High Tide Coastal Flooding Zones

e. Consider trends in relative local sea level

Local sea levels are known to display regional variability. The shoreline along CCHD is rising faster than the current rate of SLR in an occurrence known as tectonic uplift. The land is bowing upward due to the subduction of the Gorda Plate beneath northern California. Quantitatively, the sea level relative to the CCHD's coastline is currently subsiding an average of 0.78 (Figure 4) to 0.8 mm per year (NOAA Tides and Currents, 2018 and Ocean Protection Council, 2018, respectively). However, this overall trend can adjust during periods of oceanographic phenomena such as El Niño Southern Oscillations, causing prolonged increases in water levels of one to two feet, or king tides, which average an increase of two to four feet across California (California Coastal Commission SLR Guidance, 2018). Additionally, local tectonic uplift trends are not likely to be indefinite and SLR may begin to occur at an accelerated rate (NRC 2012). While the CCHD's uplift is winning the race today, it may outpaced by SLR in the future, or the uplift rate my shift entirely due to a singular seismic event or long-term trend changes. Given this uncertainty, the effects of tectonic uplift trends are ignored in this study.

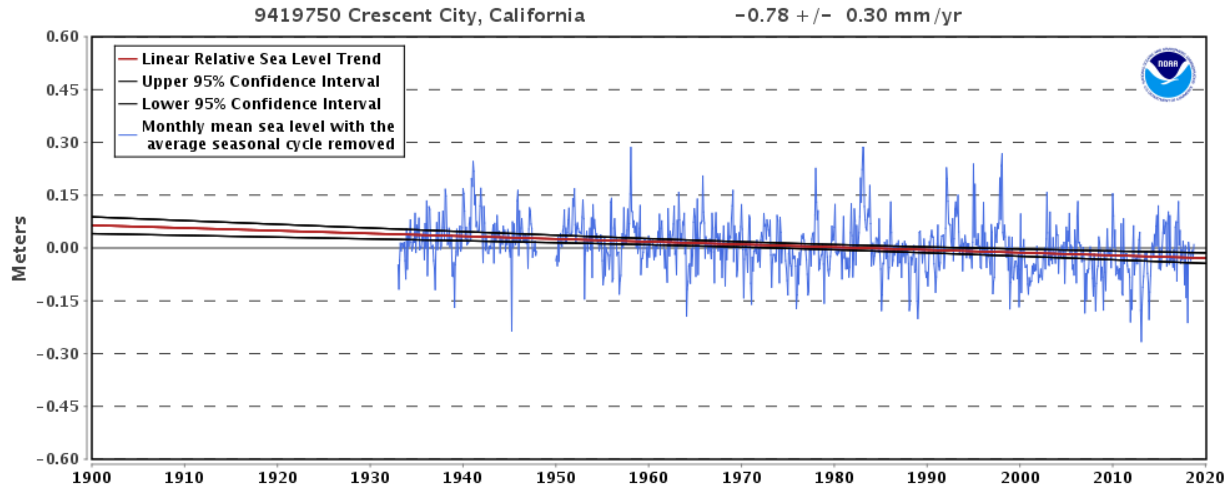


Figure 4: Sea-Level Rise Trend of Crescent City Harbor District

f. Consider impacts to public trust resources and values, including but not limited to public access, commerce, recreation, coastal habitats, and navigability

i. Public access

Public access is one of the elements that is most at risk from SLR. According to the California Coastal Commission SLR Guidance (2018), accessways could be greatly affected by rising seas. Projected rises in sea level may significantly alter South Beach and Crescent Beach. A rise of two feet in sea level will encroach greatly, and a rise of six feet will entirely inundate the current beach expanses, based on the NOAA Sea Level Rise and Coastal Flooding Impacts Viewer with a high level of confidence.[1] Outside the land grant area, but still a critical link to the CCHD, is a portion of U.S. Highway 101 and eight beach access points. These elements exist along low-lying areas and pass through the 1-percent-annual-chance flood hazard area in present day. In certain events, portions of the highway and beach access points may be blocked or damaged by flooding conditions, preventing or limiting access to many areas within the CCHD. As sea levels continue to rise, such flooding conditions may become increasingly more common.

ii. Commerce

The CCHD harbor is a critical component of the City's commerce and is highly vulnerable to future increases in sea levels greater than three feet[1] if adaptation strategies are not considered. Marinas, low-lying roads, wastewater treatment facilities, energy facilities, fuel storage facilities, and stormwater and utility infrastructure are at risk of impaired function due to flooding and saltwater intrusion. According to the 2018 LHMP, the Harbor's finite land and water areas will experience higher-use levels due to currently planned future development. Projects planned for the area include public facility improvements, restaurants,

[1] The NOAA Sea Level Rise and Coastal Flooding Impacts Viewer determines the tide level based on the great diurnal (GT) tidal range, per the methods of Gill and Schultz (2001). The great diurnal tidal datum is the height difference between the mean higher high water (MHHW) and the mean lower low water (MLLW) tidal datums over a 19-year tidal epoch spanning from 1983 to 2001.

hotels, retail shops, trail improvements, and the Tsunami Experience Center, complete with a sixty-two-foot vertical evacuation structure (Economic Development Plan, 2018). Such planned improvements should not ignore SLR. While the harbor is protected in the short-term from day-to-day coastal hazards, this may not continue well into the 21st Century without community adaption measures taking place.

iii. Recreation

According to the California Coastal Commission SLR Guidance (2018), "beaches, accessways, recreational amenities, and even surfing resources may be dramatically impacted by rising seas." Beaches within the CCHD are used for a variety of recreational activities typical in a northern California setting, such as beachcombing and walking. South Beach is also a popular location for surfing. Tourism injects a significant amount of money into the local economy annually, mostly from visitors to neighboring Redwood National and State Parks (Economic Development Plans, 2018), and climate change impacts will have a major adverse impact on recreation. As previously stated, SLR could lead to a loss of public access and recreational opportunities due to permanent inundation, episodic flooding, and erosion of beaches and trails. In areas in and around the CCHD, where beaches are limited in their ability to migrate inland due to development (such as U.S. Highway 101), beaches will become narrower or may disappear completely through inundation even at low tide.

iv. Coastal habitat

The vulnerability of the coastal habitat to SLR is the same as its exposure. Unsurprisingly, the natural environment is exposed to all elements during storms and extreme events. Flood events can damage riparian habitat, storm surges can erode beaches and redistribute sediment loads, and rises in sea levels can push these impacts further inland. SLR will reduce the amount of present-day coastal habitat. Nearshore inundation can cause landward migration of beaches over the long term, assuming there is no inshore development hindering this movement. Such nearshore development is abundant in the CCHD. With U.S. Highway 101, the South Beach Seawall, and several parking lots, CCHD beaches will not be able to migrate inland and may vanish altogether (NRC 2012). Loss of beach areas will have significant consequences for marine ecosystems and adjacent inland systems like wetlands. Coastal habitat and low-lying areas near industrial facilities are even more vulnerable to pollutant input. Pollutants in coastal waters can jeopardize the health of all wildlife, even those of economic importance such as salmon, shrimp, tuna, cod, and Dungeness crab. SLR will lead to declines in coastal water quality via inundation of CCHD facilities. This could occur via multiple routes, including the release of untreated wastewater or saltwater intrusion.

v. Navigability

While navigability was not assessed in the 2018 LHMP, it is anticipated that CCHD navigability will be greatly impacted by SLR due to its extensive harbor facilities. Flooding may cause more frequent disruptions in the utilities and storm drainage systems, thereby diverting an increasing amount of resources. Coastal flood debris could even block harbor entrances. Navigability will also be catastrophically impacted if the protective breakwaters fail or are overtopped too frequently. Armoring failure or overtopping could occur via SLR, storm surges,

tsunamis, or a combination of such events. This could lead to a situation where boats are severely damaged or are unable to enter or leave the harbor.

vi. Social equity, environmental justice, and the needs of vulnerable communities

The 2018 Ocean Protection Council's Document recommends that adaptation planning and strategies "prioritize social equity, environmental justice and the needs of vulnerable communities." Future consideration of such strategies can provide a more comprehensive and focused planning effort.

Crescent City was founded in 1853 around logging and fishing industries. With the decline of these industries, the resident population has decreased accordingly. Since 2010 the population has dropped by approximately 16%. The 1964 tsunami caused widespread adverse effects to the former thriving downtown commercial shopping district, and the area is said to have "never recovered" (LHMP, 2018). Accordingly, newer commercial development in the City has centered itself around U.S. Highway 101 as the region shifts to a more tourism-focused economy. Figure 5 depicts present day areas of the CCHD with vulnerabilities to SLR-related hazard preparedness and response based on population densities (Surging Sea Risk Zone Map, 2018). The entirety of the CCHD shoreline is located within the zone of highest vulnerability for people and businesses from a social and economic perspective. These are the areas considered to be least likely to possess the capacity and resources to prepare and respond to hazards like flooding. A designation of "High Vulnerability" indicates the Crescent City Harbor District's coastal area is within the 20% most vulnerable areas of California. As SLR encroaches on this community, the areas of highest vulnerabilities will only increase. Future consideration of these vulnerabilities is of utmost importance. Engaging communities that will face unequal distribution of SLR-related impacts, such as the fishing industry, will ensure that adaptation strategies accurately reflect their risk, needs, and priorities.

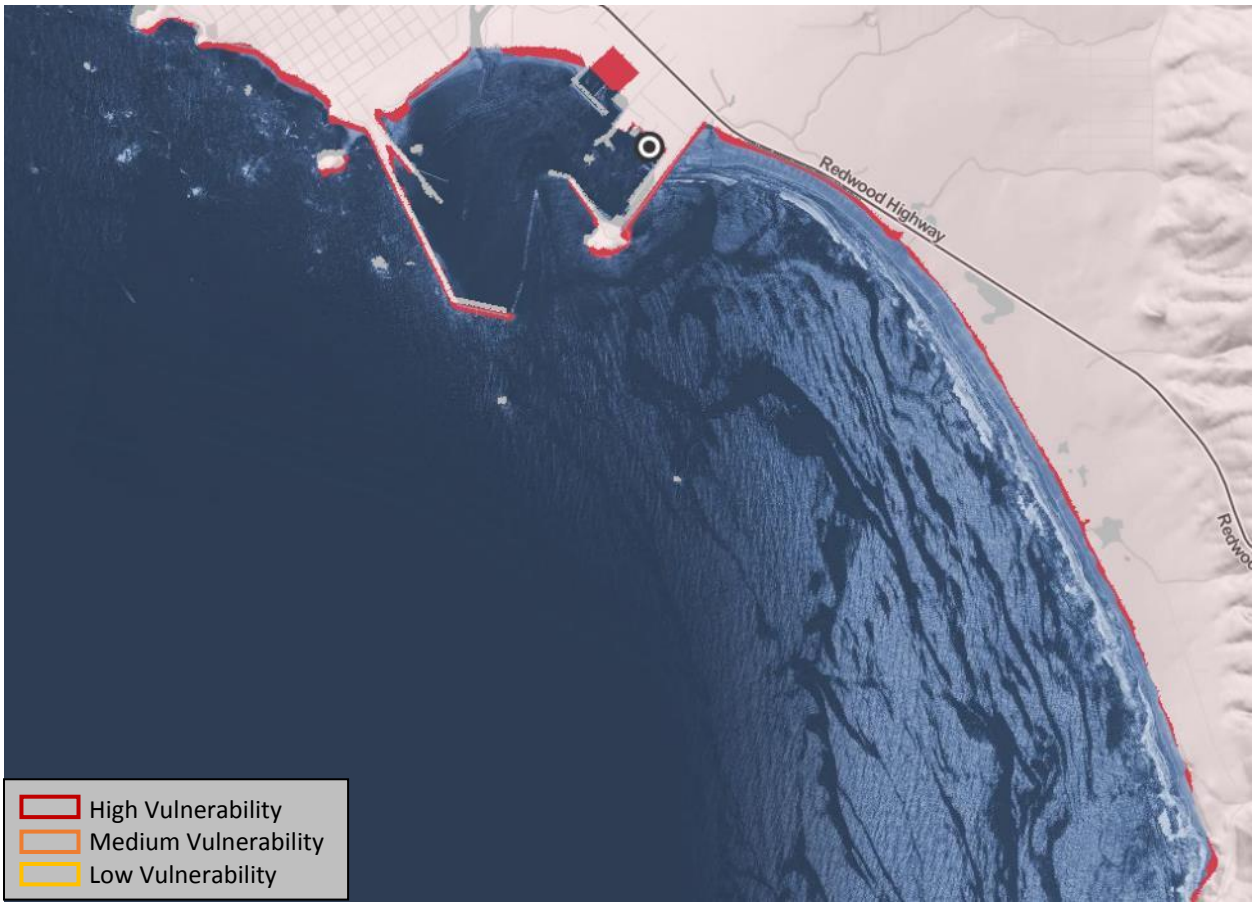


Figure 5: Social Vulnerability[1]

g. Prioritize vulnerabilities to be addressed

The CCHD will address SLR-related vulnerabilities in a manner that aligns with its mission statement and core values. Per the mission statement, "The Crescent City Harbor District provides sustainable marine and shore-based commercial, economic, educational, and recreational opportunities for the benefit of the community." Additionally, the core values of the CCHD are as follows:

1) Be an economic driver for the community.
2) Be fiscally responsible with public assets.
3) Be a leader in the community.
4) Be a partner for the benefit of the community.

In accordance with these principles, the CCHD is addressing their SLR vulnerabilities by considering the two main environments encompassed within the land grant area and the vulnerabilities specific to these environments. The two main types of environments within the CCHD are:

1) An armored and engineered harbor
2) Naturally occurring beaches

[1] The Surging Sea Risk Zone Map defines social vulnerability "as the ability of communities to prepare and respond to hazards like flooding."

To date, the CCHD has addressed a number of adaptation strategies and prioritized them in the 2018 LHMP. The proposed actions listed in Table 2 pertain to the inventoried natural and built resources and facilities in the CCHD that are exposed and vulnerable to SLR. These priority strategies will be addressed by the District as funding and resources allow.

Table 2: Adaptation Strategies for Critical Facilities within the CCHD

Adaptation Strategy	Priority	Timeline	Status
Develop Sea-Level Rise Mitigation Plans and Structure Elevation program.	High	Short-term	Pending
Repair areas of seawall where armor-stone has slipped into harbor compromising the integrity of the wall.	High	Short-term	Pending
Replace and elevate steel seawall that supports Citizens Dock, the CCHD Office, the Public Hoist and the Seafood freezers.	High	Long-term	Pending
Replace damaged fender piles and support piles on CCHD piers: Citizens Dock; Alber Seafood Dock; Wild Planet Dock; Pacific Seafood Dock; Travelift Dock; Fashion Blacksmith dock; Public Hoist Dock.	High	Short-term	In Process
Evaluate littoral drift and beach nourishment options to maintain South Beach.	Medium	Medium-term	Pending
Develop and implement a program to capture perishable data after significant events to support future mitigations efforts including the implementation and maintenance of the hazard mitigation plan.	Medium	Short-term	Unknown
Develop debris management plan.	Medium	Short-term	Unknown
Where appropriate, support retro-fitting, purchase or relocation of structures located in high hazard areas, prioritizing those structures that have experienced repetitive losses and/or are located in high or medium ranked hazard.	Medium	Short-term	Unknown
Structural Retrofitting of Existing Buildings.	Medium	Long-term	Unknown
Nonstructural retrofitting of Existing Buildings and Facilities.	Medium	Short-term	Unknown
Green Infrastructure, Solar and Wind Power Alternatives: Develop alternative sources of energy to get CCHD functioning quickly after a disaster without having to wait for county-wide power grid to become operational after a natural disaster.	Medium	Long-term	In Process
Replace and elevate Travelift Dock.	Medium	Medium-term	Pending
Repair, retrofit Concrete Seawall and Supports from Old Launch ramp to Crab Shack.	Medium	Long-term	Pending
Repair, retrofit elevate Sea wall structure from Crab Shack to USCG facility.	Medium	Long-term	Pending
Repair, retrofit elevate seawall along Ocean side of Anchor Way.	Medium	Long-term	Pending
Repair, elevate Whaler Island Groin Seawall.	Medium	Long-term	Pending
In case of power utility disruption, purchase generators for critical facilities and infrastructure that lack adequate back-up power including Harbor Maintenance Shop, Harbor Office, Harbor owned/operated Redwood RV Park.	Medium	Short-term	Unknown

2. Maps of 2030, 2050, and 2100 impacts

Probabilistic SLR projections provided in Table 3 are based on the methodologies of Kopp et al., 2014 and Sweet et al., 2017 for the H++ scenario. This assessment has selected the Medium-High Risk Aversion[1] SLR projections, per the recommendations of the 2018 Ocean Protection Councils Risk Decision Framework and 2017 Harbor Improvement Report.[2] However, a range of projections are provided to demonstrate a spectrum of potential scenarios. While the likelihood that SLR will meet or exceed the Medium-High Risk Aversion Projection is low (0.5% probability), this precautionary approach is suitable for the less adaptive, more vulnerable, manmade CCHD resources that will experience medium to high consequences as a result of underestimating SLR.

Table 3: Projected Sea-Level Rise for Crescent City Harbor District

Time Horizon (1991- 2009 baseline)	Emissions Scenario[1]	2018 Update Probabilistic SLR Projections (Feet)		
		Likely Range	1-In-200 Chance	H++ Scenario
		67% probability SLR is less than…	0.5% probability SLR meets or exceeds…	
		Low Risk Aversion	*Medium-High Risk Aversion[2]*	*Extreme Risk Aversion*
2030	High (RCP 8.5)	0.3	0.5	1.2[3]
2050	High (RCP 8.5)	0.7	1.5	3.1[3]
2100	Low (RCP 2.6)	1.5	4.8	9.3
2100	High (RCP 8.5)	2.5	5.9	9.3

[1] A Representative Concentration Pathway (RCP) is a greenhouse gas (GHG) concentration trajectory (IPCC, 2014). IPCC has established four RCPs that are consistent with possible future GHG emission scenarios. This report examines the two extreme scenarios of a low emissions trajectory (RCP 2.6) and a high emissions trajectory (RCP 8.5). RCP 2.6 assumes that GHG concentrations will peak between 2010 and 2020 then substantially decline. This trajectory aims to keep global warming within 2°C of pre-industrial temperatures. RCP 8.5 assumes that there will be no global efforts to constrain emissions and GHG concentrations will increase throughout the 21st century.

[2] Medium-High Risk Aversion SLR Projections are outlined in blue as these will be considered throughout the report.

[3] H++ scenario for North Spit, California which is the nearest projection (geographically) to the Crescent City Harbor District.

Figures 6–8 depict the RCP 8.5 Medium-High Risk Aversion SLR projections for 2030 (0.5 feet), 2050 (1.5 feet), and 2100 (5.9 feet). These figures were created from data on the NOAA Sea Level Rise and Coastal Flooding Impacts Viewer website. Due to limitations of the viewer, projections were rounded up to the nearest foot, and therefore are as follows: 2030 (1 foot), 2050 (2 feet), and 2100 (6 feet). Additionally, these projections do not account for coastal processes such as storm surge or erosion. All water levels are based on the GT datum, per the methods of Gill and Schultz (2001). As there are many unknowns when mapping future conditions, it is important not to focus on the exact extent of inundation, but rather to examine the level of confidence at that location.

[1] According to the State of California Sea-Level Rise Guidance (2018), "risk aversion is the strong inclination to avoid taking risks in the face of uncertainty."

[2] When considering significant infrastructure facilities or assets, the State of California Sea-Level Rise Guidance (2018) advises that additional consideration be given to the more extreme SLR projections and the Harbor Improvement Report (2018) recommends a consideration of a two foot rise in sea levels by 2050.

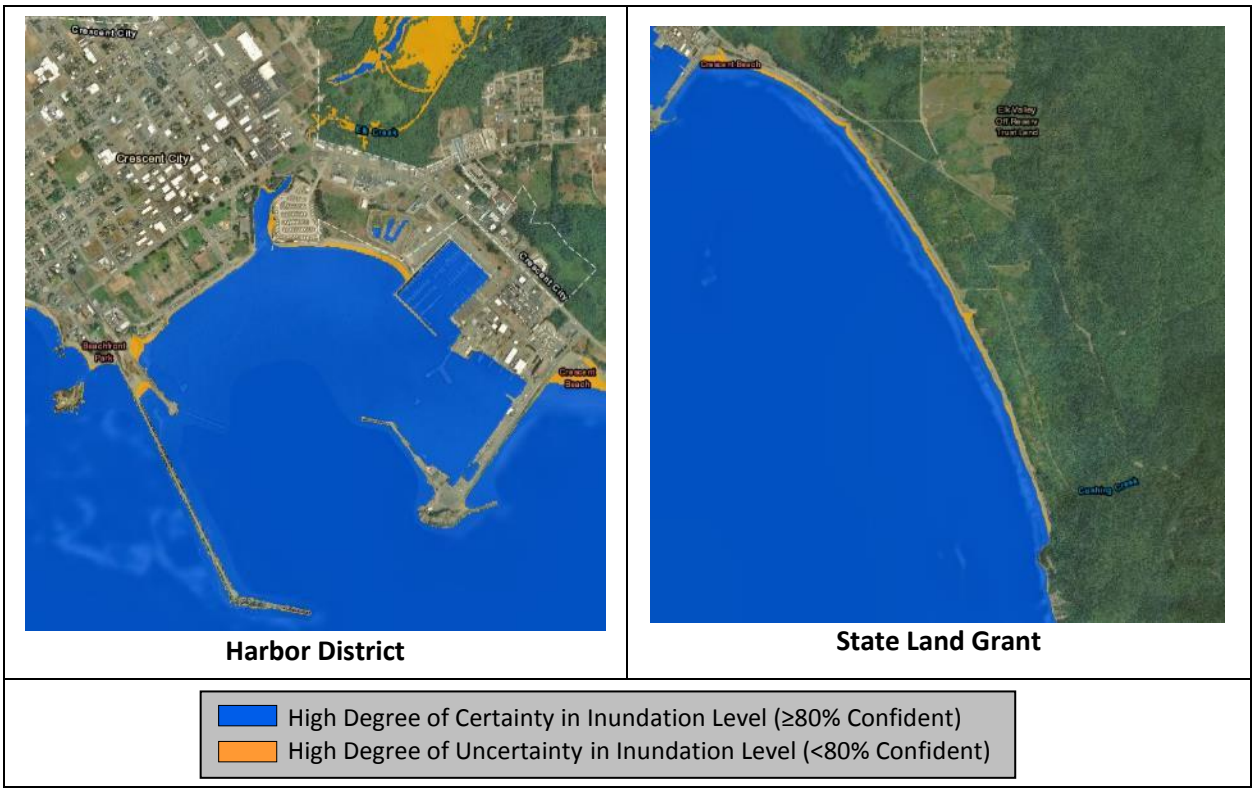


Figure 6: Sea-Level Rise of 1 Foot (Projection Year ~2030)

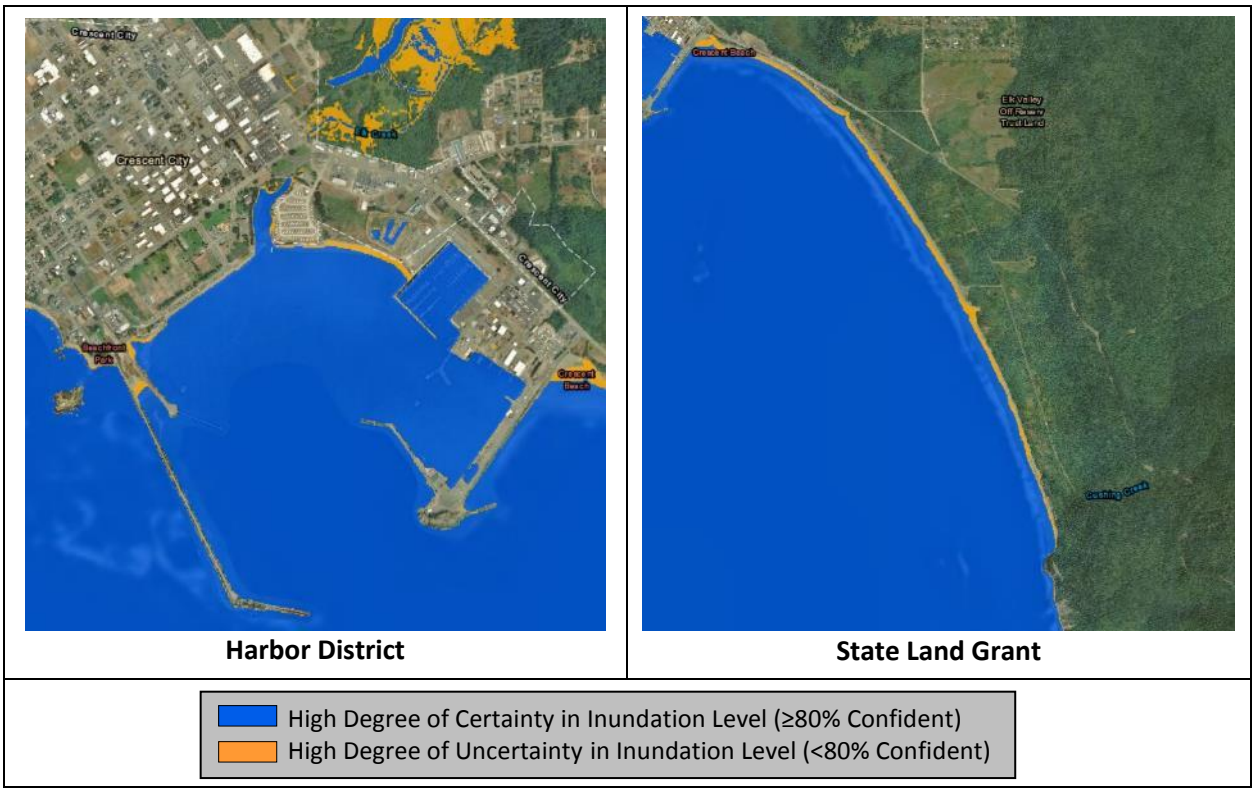


Figure 7: Sea-Level Rise of 2 Feet (Projection Year ~2050)

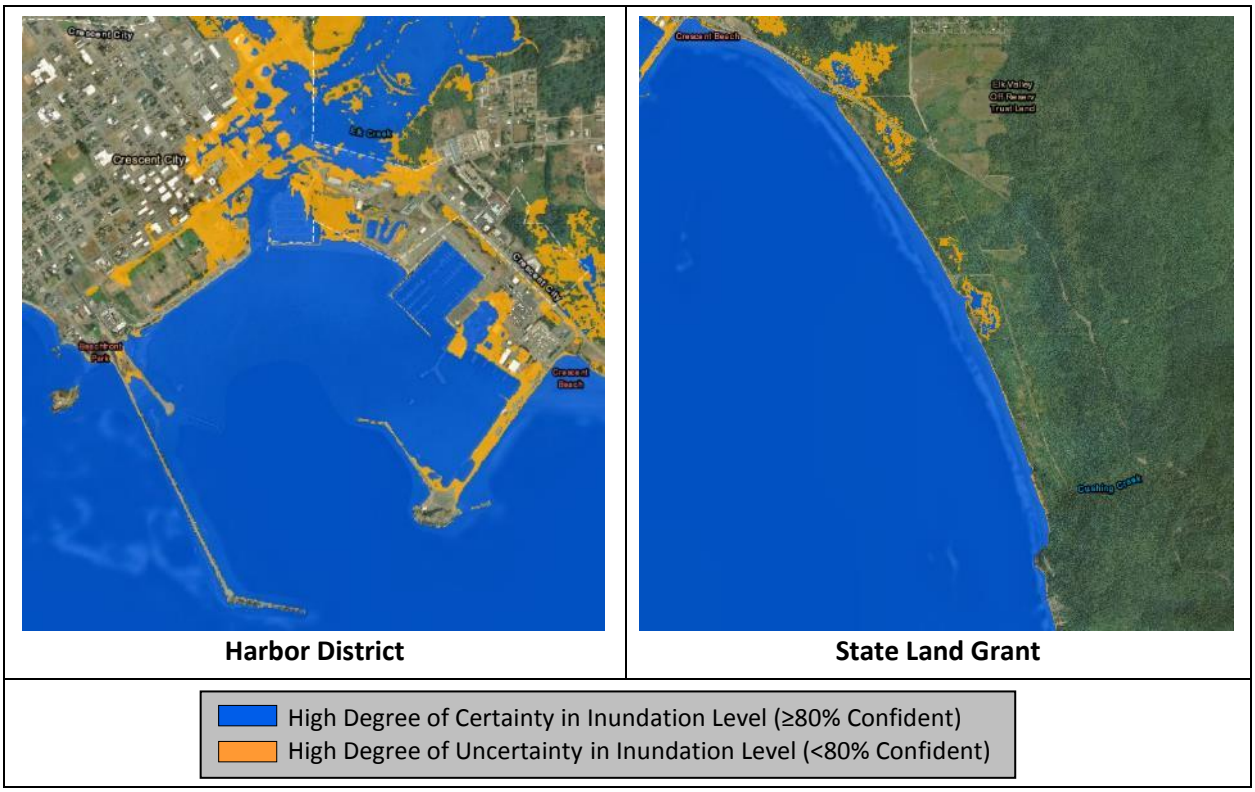


Figure 8: Sea-Level Rise of 6 Feet (Projection Year ~2100)

3. Estimate of financial costs of sea-level rise

a. Replacement or repair costs of resources and facilities that could be impacted by sea-level rise and climate change processes

The estimated replacement costs of resources and facilities that could be impacted by SLR and climate change processes are presented in Table 4. Further detail on these valuations is provided in Appendix A - Cost Estimate Details and Appendix B - Breakwater Quantities Estimate Figures.

Table 4: Estimated Replacement Costs of Resources and Facilities

No.	Harbor Critical Facilities	Value
1	Administrative Dock and Pump-Out Station	$889,000
2	Anchor Way Boat Ramps	$800,000
3	Anchor Way Breakwater	$2,700,000
4	Beaches (3 total)[1]	--
5	CCHD Boat Ramps	$5,200,000
6	Citizen's Dock	$20,900,000
7	Dredge Ponds	$250,000
8	Inner Boat Basin Docks	$30,000,000
9	Inner Breakwater	$3,200,000
10	Lighthouse Way Breakwater[1]	$9,730,000
11	Maintenance/Storage Buildings (5 total)	$543,000
12	Marina Breakwater	$3,160,000
13	Office/Retail Buildings (13 total)	$1,630,000
14	Restroom Buildings (5 total)	$889,000
15	Roads and Parking Areas	$12,600,000
16	Seafood Processing Plants (2 total)	$1,410,000
17	Shipyard Building	$695,000
18	Solar Array[1]	$1,650,000
19	South Beach Seawall	$70,000
20	Syncrolift, Travelift, and Dock	$2,500,000
21	Utilities (Power, Sewer, Water)	$12,200,000
22	Whaler Island Groin	$1,100,000
	Total	**$112,116,000**

[1]*Asset not owned by the CCHD.*

b. Non-market values, including recreation and ecosystem services, of public trust resources that could be impacted by climate change and sea-level rise processes

Establishing a dollar value for the ecological conditions, aesthetics, cultural and heritage existence, storm-buffering capacity, recreation potential, etc., of the CCHD's beaches requires consideration of both economic and non-economic impacts of these highly valued natural features. Collecting and evaluating all the potential data to determine these values would be extremely time consuming and costly. Therefore, potential non-market losses due to SLR are estimated for recreational and ecotourism activities only. The recreational and ecotourism value of these beaches will exclude all storm and extreme event impacts and additional climate change impacts that are outside this report's scope (e.g., ocean acidification).

The Environmental Protection Agency released a guidance document in 2009 that helps establish the economic value of coastal ecosystems in California (Raheem et al. 2009). This document estimates a value of $16,946 ($20,185.41 present day value) per acre per year for activities associated with recreation and ecotourism. The estimated non-market losses based on this value are summarized in Table 5.

[1] See Section 3b for further details.

Table 5: Non-Market Loss due to SLR impacts to the CCHD Beaches

Beach Name	2030		2050		2100	
	Approx. Beach Loss (acres)	Asset Value[1]	Approx. Beach Loss (acres)	Asset Value[1]	Approx. Beach Loss (acres)	Asset Value[1]
Crescent and South Beach	13	$1,000,000	65	$11,000,000	130	$32,000,000
Harbor Beach	0.75	$58,000	1.5	$248,000	3	$732,000
Total	**13.75**	**$1,058,000**	**66.5**	**$11,248,000**	**133**	**$32,732,000**

[1] Values based on rounded present day dollars with a Consumer Price Index of 3.2%. Half of the total value lost was take off to account for acreage that will remain between present day and the target date.

c. Consider costs of 2030, 2050, and 2100 high sea-level rise projections with a 100-year storm

A detailed breakdown of the cost of exposed resources and facilities that could be impacted by SLR are summarized in Table 6. When a portion of the asset in question is exposed to SLR, then only a fraction of the functionality of that asset is considered impacted. Further detail is provided in Appendix A - Cost Estimate Details and Appendix B - Breakwater Quantities Estimate Figures.

Table 6: Estimated Asset Value Exposed to Projected Sea-Level Rise for Years 2030, 2050, & 2100

No.	Harbor Critical Facilities	2030 Asset Value[1]	2050 Asset Value[1]	2100 Asset Value[1]
1	Administrative Dock and Pump-Out Station	--	--	$889,000
2	Anchor Way Boat Ramps	--	--	$800,000
3	Anchor Way Breakwater	$270,000	$1,350,000	$2,700,000
4	Beaches (3 total)	$1,058,000	$11,248,000	$37,732,000
5	CCHD Boat Ramps	--	--	$5,200,000
6	Citizen's Dock	--	$20,900,000	$20,900,000
7	Dredge Ponds	--	--	$250,000
8	Inner Boat Basin Docks	--	--	$30,000,000
9	Inner Breakwater	$320,000	$3,200,000	$3,200,000
10	Lighthouse Way Breakwater[2]	$970,000	$4,870,000	$9,730,000
11	Maintenance/Storage Buildings (5 total)	--	--	$543,000
12	Marina Breakwater	--	$1,580,000	$3,160,000
13	Office/Retail Buildings (13 total)	--	--	$1,630,000
14	Restroom Buildings (5 total)	--	--	$889,000
15	Roads and Parking Areas	--	--	$8,200,000
16	Seafood Processing Plants (2 total)	--	--	$1,410,000
17	Shipyard Building	--	--	$695,000
18	Solar Array[2]	--	--	$1,650,000
19	South Beach Seawall	$70,000	$70,000	$70,000
20	Syncrolift, Travelift, and Dock	--	$2,500,000	$2,500,000
21	Utilities (Power, Sewer, Solar, Water)	--	--	$8,100,000
22	Whaler Island Groin	$110,000	$550,000	$1,100,000
	Total	**$2,798,000**	**$56,268,000**	**$141,348,000**

[1] Values based on present day dollars.

[2] Asset not owned by the CCHD.

i. Cost of sea-level rise in 2030

A portion of South Beach is expected to endure the greatest impact from the 2030, 0.5-foot SLR projection. Impacts to this natural resource may result in a loss of visitors, resulting in a loss of tourist spending in the region. Additionally, the South Beach Seawall may be scoured by a modest rise in sea levels, coupled with a high tide and/or storm surge scenario.

Another significant impact to the CCHD is potential damage to the existing breakwaters protecting the harbor. The Anchor Way Breakwater, Whaler Island Breakwater Groin, Inner Harbor Breakwater, and Lighthouse Way Breakwater are subject to coastal processes of waves and storm surge that will be magnified by rising sea levels. For the 0.5-foot SLR projection, a 10% repair cost is considered in the future asset values. The marina breakwater is not considered to be impacted by a 0.5-foot projection due to the rebuild that took place in 2011 to resist tsunami surge conditions.

ii. Cost of sea-level rise in 2050

The SLR projection of 1.5 foot will have its largest impact on CCHD assets located directly on the waterfront. These assets include the breakwaters, fixed docks, and beaches. A value of 50% of the breakwaters' asset cost is incorporated into the 2050 timeframe to account for the need to repair and raise the protective breakwaters around the harbor. SLR in 2050 will also directly impact the harbor's fixed docks. These docks are rigid in elevation, and do not rise and fall with the tide level. As sea levels rise, these structures become subject to larger wave forces, not only on the piles, but also on the deck and utilities under the superstructure. Fixed docks are not traditionally designed to resist uplift forces from high water levels and will likely be damaged from rising sea levels. The impact of SLR is considered to be the full present-day value of the fixed docks. CCDH beaches will also continue to be impacted by SLR in 2050 and one-half of the non-market asset value of the beach is considered impacted by 2050.

iii. Cost of sea-level rise in 2100

The SLR projection of 6 feet will directly impact all of the CCHD's assets within the land grant area. The total asset value of the breakwaters, fixed and floating docks, beaches, and buildings have been incorporated into the cost estimations. The floating docks will not have sufficient pile length to support the floats during a high tide coupled with an additional 6 feet of elevation. The inner harbor floating docks have additional pile length to support the facility during a tsunami event; however, the projected SLR in 2100 will diminish the ability of the floating docks to resist the design tsunami event, since the wave will effectively 'launch' from a higher sea level elevation. The estimates also incorporate the total asset cost of all the breakwaters, because a rise of 6 feet will overtop and damage the resources during high tides, storms, and storm surge events. Additionally, the total asset value of the CCHD's beaches is incorporated into the impact total from SLR in 2100. Based on the mapping for the projected SLR in 2100, the upland buildings and facilities will be inundated during a high-tide event coupled with higher sea levels. Therefore, the total asset value for all the buildings has been incorporated into the impact value.

The CCHD parking areas, roads, and utilities were the only resources not completely projected to be inundated in 2100. Two-thirds of the asset values were incorporated into the impact

value for this time frame. This fraction of the asset value reflects the rough percentage of the asset inundated by rising seas in 2100.

d. Include anticipated costs of adaptation/mitigation measures, and potential benefits of such strategies and structures

Table 2 in Section 1g summarizes the priorities to be addressed in response the threat of SLR. As noted in the table, the highest priorities to be addressed are vulnerabilities and adaptation measures that repair critical deficiencies in the existing infrastructures and help the CCHD continue to carry out its core mission. Since the core mission of the CCHD requires a physical presence of infrastructure along the coast, retreating options are not considered practical. Instead, protection and accommodation strategies should take precedence.

i. Protection adaptation/mitigation measures

Strengthening and raising the existing harbor breakwaters are primary strategies for the CCHD to protect its resources against SLR-related impacts. It is expected that all of the existing armored breakwaters will need to be strengthened and raised to protect against the projected 6 feet of SLR over the next 80 years. In additional to raising and strengthening the breakwaters, the seawall at the end of Citizens Dock Road will need to be raised in order to protect the upland buildings and resources. A potential benefit of raising the breakwaters and seawall is that this measure can also be designed to protect against tsunamis and severe waves and storm surges. Estimated costs for protection mitigation and adaption measures are provided in (Table 7).

Table 7: Estimated Cost for Protection Mitigation/Adaption Measures

No.	Mitigation/Adaptation Measure	Estimated Cost
1	Raise/Strengthen Lighthouse Way Breakwater[1]	$10,500,000
2	Raise/Strengthen Whaler Island Groin	$1,100,000
3	Raise/Strengthen Anchor Way Breakwater(s)	$4,400,000
4	Raise/Strengthen Inner Breakwater	$3,200,000
5	Raise/Strengthen Marina Breakwater	$2,600,000
6	Strengthen South Beach Armored Seawall	$400,000
7	Replace Citizens Dock Seawall	$2,850,000
	Total	**$25,505,000**

[1] *Asset not owned by the CCHD.*

ii. Accommodation Adaptation/Mitigation Measures

The primary method for accommodating resources for projected rises in sea levels is to increase the elevations of the fixed docks. The potential benefit of accommodating SLR in this manner is the potential to service deeper draft vessels at the CCHD without additional dredging. However, as previously mentioned, a physical impact of SLR is a change in sedimentation patterns. The Citizen's Dock is the featured fixed pier within the CCHD; to raise the deck of the structure the entire dock will need to be replaced. The remaining life-span of the dock is approximately 10-20 years. The Travelift dock and Syncrolift docks will also need to be raised to accommodate future, projected SLR estimates. Similar to the Citizen's Dock, both of these structures will need to be replaced in order to raise to deck to accommodate

future SLR. The other existing waterfront resources that can accommodate for future SLR are the floating docks, including the inner basin docks, the administrative dock, the boat ramps, and docks along Anchor Way. The piles supporting these docks can be extended and strengthened to resist SLR-related impacts. The inner basin docks were replaced in 2012 with piles that account for a tsunami surge elevation of 7.5 feet. While this additional height will accommodate the projected future SLR by 2100, the ability to withstand both SLR and a tsunami will be diminished. Therefore, the inner boat basin dock piles will need to be strengthened and extended once again to accommodate both the constant higher future sea level and a tsunami. A potential benefit of accommodating the floating docks is a lower cost than full replacement or relocation strategies.

As for the CCHD's natural resources, a possible accommodation strategy could be beach nourishment. As sea levels rise, beach nourishment can slow erosion and inundation by strategically placing sand to provide a buffer against wave action and flooding. Completed beach nourishment projects have been shown to last between three and ten years (Weggel, 1995 as cited by NOAA's Beach Nourishment Programs (2000)). Trembanis and Pilkey (1999), as cited by NOAA's Beach Nourishment Programs (2000), estimated the cost to maintain nourished beaches along developed shorelines for a decade to range from $3.3 million to $17.5 million per mile. Accounting for inflation, these costs increase to $5 million and $26.7 million per mile, respectively (U.S. Inflation, 2019). These amounts are on par with the findings of Parsons et al. (2001), which concludes beach nourishment project costs to be around $15 million per mile. Within the CCHD there are approximately 4.2 miles of beach, which equates to such a project costing around $63 million without accounting for maintenance or permitting costs. It should also be noted that beach nourishment projects a highly uncertain longevity and steep long-term maintenance costs. However, the CCHD has a potential source of beach re-nourishment material in the dredged material from on-going maintenance dredging of the inner and outer harbors. Re-use of this material as beach re-nourishment may help to alleviate some cost associated with the adaptation measure. A 25% reduction in the cost of the beach re-nourishment is incorporated to account for re-use of dredged material for beach re-nourishment.

Careful consideration and verification of SLR trends should be incorporated into any design of future shoreline resources. Estimated costs for accommodation mitigation and adaption measures are provided in (Table 8).

Table 8: Estimated Cost for Accommodation Mitigation/Adaption Measures

No.	Mitigation/Adaptation Measure	Estimated Cost
1	Raise/Strengthen Anchor Way Boat Ramp Float Piles	$130,000
2	South Beach Re-nourishment	$47,000,000
3	Replace and Raise Citizen's Dock	$20,900,000
4	Raise/Strengthen Inner Basin Boat Dock Piles	$2,500,000
5	Replace and Raise Syncrolift and Travelift Dock	$2,500,000
	Total	**$73,030,000**

4. Description of how trustee proposes to protect and preserve resources and structures that would be impacted by sea-level rise

a. Proposed mitigation/adaptation measures and how vulnerabilities will be addressed

Proactive solutions to maintain the CCHD's resources for the next 100 years are likely to encompass a variety of adaption strategies. However, given the CCHD's previously mentioned mission statement, there are few opportunities within the District's boundaries to retreat inland without compromising said mission. Exceptions to this may include the relocation of buildings, structures, and utilities that are no longer viable in supporting the CCHD's mission. Alternatively, a pragmatic, hybrid approach of protection and accommodation strategies can be used, and such an approach may even diverge over time based on the resource in question and its protection goals. For example, the CCHD could implement redevelopment restrictions in hazard-prone areas or retrofit a dock in the short-term, then replace and raise the dock in the long-term. For older critical assets exposed and vulnerable to SLR, the replacement structures should incorporate provisions for adapting to SLR along with potential tsunami and storm conditions.

A cost-benefit analysis for each inventoried resource or facility should be evaluated to provide a metrics-based approach to protection and accommodation options. This assessment highlights the need for constructive discussions between CCHD decision makers, tenants, and State and Federal agencies to establish measures that allocate priority and reasonable costs.

Table 9 and Figure 9 outline the general adaptation and mitigation strategies for the resources and facilities vulnerable to the impacts of SLR in the land grant area.

Table 9: Adaptation/Mitigation Measures

Adaptation/Mitigation Measure	Strategy	Description or Example
Develop Sea-Level Rise mitigation plans and structure elevation program.	Accommodation	• Elevate Citizen's Dock. • Elevation Syncrolift and Travelift. • Extend and strengthen floating dock piles.
Repair areas of seawall where armor-stone has slipped into harbor compromising the integrity of the wall.	Protection	• All rubble-mound breakwaters and slopes.
Replace and elevate steel seawall that supports Citizens Dock, the CCHD Office, the Public Hoist and the Seafood freezers. Investigate a raised levee to protect adjacent CCHD properties and assets.	Accommodation and Protection	• Use quay wall to replace existing seawall and an earthen levee where a quay wall is not required.
Damage pile replacement program.	Accommodation	• Use stronger replacement pile to resist damage from increased debris and forces from SLR.
Evaluate littoral drift and beach nourishment options to maintain beaches.	Accommodation	• Investigate reuse of harbor dredged material to re-nourish beaches, to the extent allowed in California State.
Develop and implement a program to capture perishable data after significant events to support future mitigations efforts including the implementation and maintenance of the hazard mitigation plan.	Retreat, Accommodation, and Protection	• Develop and track water surface elevations, damage, and impact locations from significant events such as tsunamis, storm surge, or king tides.
Develop a debris management plan.	Accommodation	• Develop plan, process, and personnel responsible for removal and disposal of marine debris.
Where appropriate, support retro-fitting, purchase or relocation of structures located in high hazard areas, prioritizing those structures that have experienced repetitive losses and/or are located in high or medium ranked hazard.	Retreat	• Relocation of older buildings and structures in the zone of inundation which no longer support CCHD mission at a competitive cost.
Develop green infrastructure: solar and wind power alternatives. Develop alternative sources of energy to get CCHD functioning quickly after a disaster or high storm surge event without having to wait for county-wide power grid to become operational after a natural disaster.	Accommodation and Protection	• Solar panels in the parking lot and wind power to serve critical harbor infrastructure. • Green power infrastructure provides accommodation to climate change to reduce reliance on greenhouse gas-generating sources and provides protection against future extreme events exasperated by climate change.
Replace and elevate Syncrolift and Travelift Docks.	Accommodation	• Replace and elevation the docks at the end of their useful design life to an elevation to above the threat of future sea-level rise.
Elevate Concrete Seawall along the Anchor Way breakwater.	Protection	• Concrete seawall may include taller concrete wall, pile foundations, and additional armor rock.
Repair, elevate Whaler Island Groin Seawall	Protection	• Raise rubble-mound breakwater to protect harbor from significant storm and wave events coupled with sea-level rise.
In case of power utility disruption, purchase generators for critical facilities and infrastructure that lack adequate back-up power including Harbor Maintenance Shop, Harbor Office, Harbor owned/operated Redwood RV Park.	Accommodation and Protection	• Provide accommodation to climate change by providing back up protection against future extreme events exasperated by climate change.
Limit new development in mapped hazard area	Retreat	• Limit new development in zones mapped in the inundation zone unless protection or elevated area can be provided.

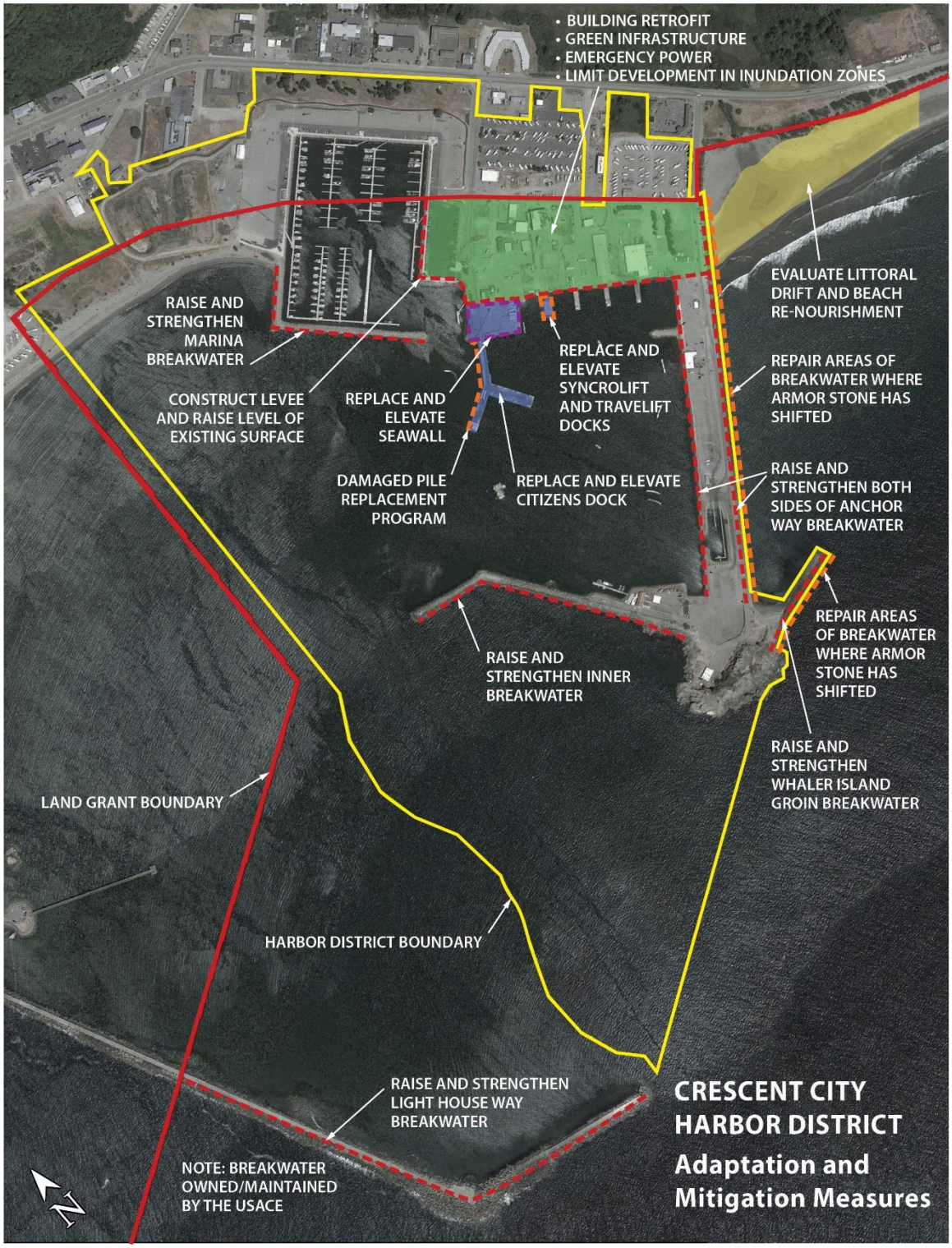


Figure 9: CCHD Adaptation and Mitigation Measures
For further details see Appendix C - Adaptation/Mitigation Measures.

b. Timeframe of implementation of such measures

Table 2 in Section 1g includes the general timeframe for implementation of each adaption measure. Implementation of each measure is dependent on development of project financing, available grant funding, and on-going measurements of SLR trends. In general, planning for and monitoring the impacts of long-term SLR has already begun, and the CCHD has implemented a Green Power Initiative to cut down on its GHG emissions and provide resiliency to the power system to the CCHD tenants. The CCHD has begun installation of solar panels in the parking lot areas around the CCHD office and to seven building within the CCHD. Other items listed as short-term adaptation measures are expected to occur within one to five years.

Beyond the inner harbor docks and marina breakwater, the CCHD owns and maintains several maritime resources that are approaching the end of their useful life. Items in Table 2 listed as medium-term adaptation measures are expected to occur in the next five- to ten-year time horizon. This includes the replacement and raising of the Travelift dock. Long term adaptation measures will occur in the next 10- to 20-year time horizon, although planning for these adaptations can begin in the near term. Repair and raising of the seawalls and breakwaters may be phased as funding becomes available and damage occurs in storm events.

c. Plans to monitor impacts of sea-level rise and climate change, as well as effectiveness of mitigation/adaptation measures

Crescent City Harbor District participates in NOAA's National Buoy Data Center,[1] which provides observations that help support the understanding and predicting of changes in weather, climate, oceans, and coastlines. The specificity this data provides is a valuable tool for the CCHD to correlate SLR and tidal information with impacts on the maritime assets. This tidal gauge along with regional gauges are integral in updating SLR projections and evaluating the interaction between SLR and tectonic uplift. Changes to the rate of tectonic uplift will alter to projections of SLR, and it will be important for the CCHD to stay informed of any changes in these trends.

The CCHD continues to monitor the long-term trends in SLR using the NOAA tidal gauge in the harbor and will continue to monitor changes to existing protective structures. The CCHD will also monitor existing non-protective resources and facilities to evaluate the design life of each and incorporate SLR adaptation strategies as previously discussed.

d. Regional partnerships to address sea-level rise, climate change vulnerability, or increase resiliency

In light of the 2011 tsunami triggered by the Tohoku earthquake, the CCHD focuses much of its efforts towards disaster preparedness and post-disaster recovery plans. Prepare Del Norte hosts an annual Tsunami Preparedness Week during which it tests the Emergency Alert system and educates the public on the local tsunami hazards and how to prepare emergency plans for families. Given these current partnerships that have been developed for disaster preparedness, the discussion of SLR can be incorporated into regional planning and coordination. Additionally, the CCHD currently relies on its Board of Harbor Commissioners, the City of Crescent City, Del Norte County, the Redwood Coast Tsunami Work Group, the NOAA tidal gauge, its vast network of businesses, technical consultants, academic institutions,

[1] NOAA's National Buoy is located near Citizen's Dock.

and public agencies to monitor and address other climate resilience goals. After all, SLR adaption strategies not only benefit the CCHD, but also Crescent City.

5. Summary

If tectonic uplift trends shift, SLR-related impacts will threaten the majority of the CCHD's granted sovereign tide and submerged lands and the critical resources and facilities supported by these lands. The strategies and goals presented herein help ensure that the CCHD is taking and will continue to take reasonable steps to keep control of and preserve the trust lands given the potential impacts from sea-level rise.

6. References

A.B 691, 2013 Biennium, 2013 Regular Session (Cal. 2013). Accessed via www.leginfo.ca.gov/pub/13-14/bill/asm/ab_0651-0700/ab_691_bill_20131005_chaptered.pdf.

California Coastal Commission. (2018). California Coastal Commission Sea Level Rise Policy Guidance: Interpretative Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits. Revised 7 November 2018.

Del Norte County Local Hazard Mitigation Plan. (2018). Operational Area Agency Review Volumes I and II. Prepared by Tetra Tech. Accessed via www.co.del-norte.ca.us/hmp/documents.

Economic Development Plans. (2018). Crescent City Harbor District.

Federal Emergency Management Agency (FEMA). (2017). Flood Insurance Study for Del Norte County, CA. Revised 2017.

Gill, S. and J. Schultz. (2001). Tidal datums and their applications, Special Publication NO. CO-OPS1, NOAA, National Ocean Service Center for Operational Oceanographic Products and Services, 111p, appendix.

Harbor Improvement Report No 2017-DN-01. (2017). Maritime Tsunami and Coastal Hazard Mitigation Guidance for Harbor Engineers and Emergency Managers. Completed by the California Geological Survey, University of Southern California, California State Lands Commission, and California Governor's Office of Emergency Services. June 2017.

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva, Switzerland.

Kopp RE, Horton RM, Little CM, Mitrovica JX, Oppenheimer M, Rasmussen DJ, et al. (2014). Probabilistic 21st and 22nd century sea level projections at a global network of tide gauge sites. Earth's Future. 2:383–406.

National Academies Press. (2016). Attribution of Extreme Weather Events in the Context of Climate Change. National Academies of Sciences, Engineering, and Medicine. Washington, DC: The National Academies Press. doi: 10.17226/21852.

NOAA Sea Level Rise and Coastal Flooding Impacts Viewer. (2018). Accessed via https://coast.noaa.gov/slr/#/layer/slr

NOAA Tides and Currents. (2018) Crescent City, CA - Station ID: 9419750. Access via https://tidesandcurrents.noaa.gov/stationhome.html?id=9419750.

Parsons, George R. and Michael Powell. "Measuring the Cost of Beach Retreat". Coastal Management, 29:91-103, 2001

Raheem, N., J. Talberth, S. Colt, E. Fleishman, P. Swedeen, K. J. Boyle, M. Rudd, R. D. LOPEZ, T. O'Higgins, C. Willer, AND R. M. Boumans. The Economic Value of Coastal Ecosystems in California. U.S. Environmental Protection Agency, Washington, DC, EPA/600/F-09/046, 2009.

State, Territory, and Commonwealth Beach Nourishment Programs. (2000.) National Oceanic & Atmospheric Administration. A National Overview OCRM Program Policy Series. Technical Document No. 00-01.

Statutes of California. (1963). Regular Session 1963 Chapter 1510. Accessed via www.slc.ca.gov/Programs/Granted_Lands/G03_Del_Norte/G03-02_Crescent_City_Harbor_District/S1963_Ch1510%20.pdf.

Surging Seas Risk Zone Map. (2018) Climate Central. Access via https://riskfinder.climatecentral.org/place/crescent-city.ca.us?comparisonType=place&forecastType=NOAA2017_int_p50&impact=Population_highSV&level=4&unit=ft.

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler and CZ. (2017). Global and Regional Sea Level Rise Scenarios for the United States.

Trembanis, A.S., and Pilkey, O.H. Comparison of Beach Nourishment Along the US Atlantic, Great Lakes, Gulf of Mexico, and New England Shorelines. Coastal Management. Vol. 27 (1999). Pp. 329-340

U.S. Inflation Calculator. (2019). Accessed via www.usinflationcalculator.com

Appendix A - Cost Estimate Details

Appendix A: Crescent City Harbor District Existing Asset Cost Estimate Table

Element	Unit	Quantity	Unit Cost	Amount
Boat Ramps				
Fashion Blacksmith Pier	SQ.FT.	7000	$ 357	$ 2,499,000
South Three Ramps	SQ.FT.	10500	$ 260	$ 2,730,000
			Subtotal =	**$ 5,200,000**
Anchor Way Boat Ramp				
Docks	SQ.FT.	4000	$ 125.00	$ 500,000
Basin	LS	1	$ 300,000	$ 300,000
			Subtotal =	**$ 800,000**
Dredge Pond Levees				
Levees	CY	8400	$ 30.00	$ 252,000
			Subtotal =	**$ 250,000**
Inner Harbor Breakwater Cost				
1200 # Rock	CY	6700	$ 120.00	$ 804,000
1 Ton Rock	CY	13100	$ 100.00	$ 1,310,000
Core Rock	CY	13100	$ 80.00	$ 1,048,000
			Subtotal =	**$ 3,200,000**
Anchor Way Breakwater Cost				
1200 # Rock	CY	5600	$ 120.00	$ 672,000
1 Ton Rock	CY	11000	$ 100.00	$ 1,100,000
Core Rock	CY	11000	$ 80.00	$ 880,000
			Subtotal =	**$ 2,700,000**
Whaler Island Groin Breakwater Cost				
1200 # Rock	CY	2300	$ 120.00	$ 276,000
1 Ton Rock	CY	4500	$ 100.00	$ 450,000
Core Rock	CY	4500	$ 80.00	$ 360,000
			Subtotal =	**$ 1,100,000**
South Beach Seawall				
1 Ton Rock	CY	700	$ 100.00	$ 70,000
			Subtotal =	**$ 70,000**
Water Sewer Utilities				
Water (4" PVC)	LF	1600	$ 250	$ 400,000
Water (4" ACP)	LF	500	$ 250	$ 125,000
Water (6" PVC)	LF	700	$ 400	$ 280,000
Water (6" ACP)	LF	3400	$ 400	$ 1,360,000
Water (8" PVC)	LF	350	$ 500	$ 175,000
Water (8" ACP)	LF	3200	$ 500	$ 1,600,000
Sewer (6 VCP)	LF	5000	$ 400	$ 2,000,000
Sewer (8" VCP)	LF	1000	$ 500	$ 500,000
Sewer (10" VCP)	LF	2000	$ 550	$ 1,100,000
Sewer (12" VCP)	LF	500	$ 600	$ 300,000
Water Vault	EA	27	$ 15,000	$ 405,000
Water Valves	EA	13	$ 500	$ 6,500
Lift Station	EA	2	$ 10,000	$ 20,000
Electrical Utilities				
Electrical	LS	1	$ 3,900,000	$ 3,900,000
			Subtotal =	**$ 12,200,000**
Roads and Parking Lots				
Roads and Parking Lots	SQFT	1400000	$ 9	**$ 12,600,000**

Appendix A: Crescent City Harbor District Protective Cost Estimate Table

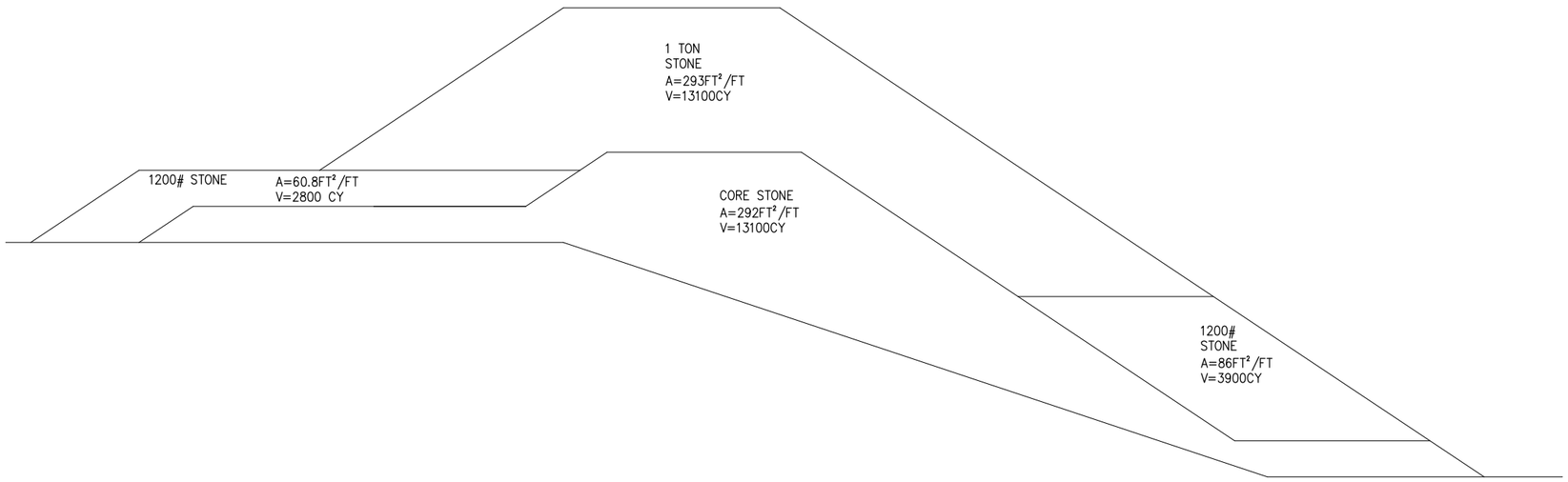
Item No.	Element	Unit	Quantity	Unit Cost	Amount
1	Raise/Strengthen Lighthouse Way Breakwater*	CY	105000	$ 100	$ 10,500,000
2	Raise/Strengthen Whaler Island Groin	CY	12000	$ 100	$ 1,200,000
3	Raise/Strengthen Both Side of Anchor Way Breakwater	CY	52000	$ 100.00	$ 5,200,000
4	Raise/Strengthen Inner Breakwater	CY	32000	$ 100.00	$ 3,200,000
5	Raise/Strengthen Marina Breakwater	CY	26000	$ 100.00	$ 2,600,000
6	Strengthen South Beach Armored Breakwater	CY	4000	$ 100.00	$ 400,000
7a	Raise/Strengthen Citizens Dock Seawall (Steel Wall)	LS	1	$ 2,400,000.00	$ 2,400,000
7b	Raise Levee Around Harbor District	CY	9000	$ 50.00	$ 450,000

* Note: Lighthouse Way Breakwater Owner and Maintained by USACE

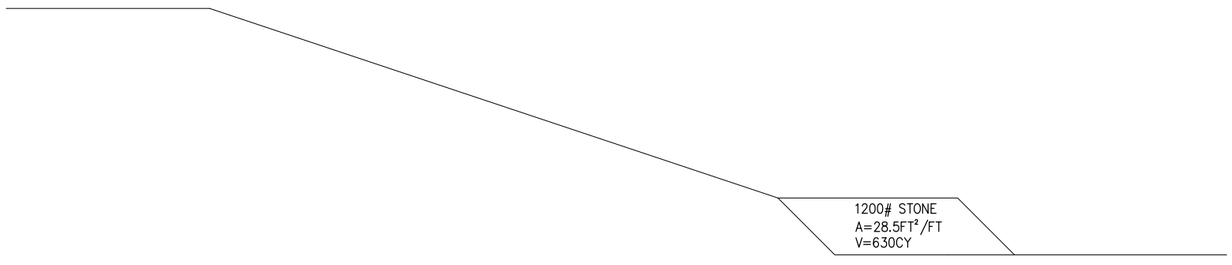
Appendix A: Crescent City Harbor District Adaptive Asset Cost Estimate Table

Item No.	Element	Unit	Quantity	Unit Cost	Amount
1	Raise/Strengthen Anchor Way Boat Ramp Piles	EA	13	$ 10,000	$ 130,000
2	South Beach Re-nourishment	LS	1	$ 47,000,000	$ 47,000,000
3	Citizen's Dock	LS	1	$ 20,900,000.00	$ 20,900,000
4	Inner Basin Docks	EA	246	$ 10,000.00	$ 2,500,000
5	Syncrolift and Dock	LS	1	$ 2,500,000.00	$ 2,500,000

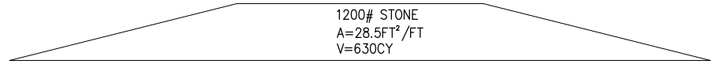
Appendix B - Breakwater Quantities Estimate Figures



EXISTING INNER HARBOR, MARINA, AND WHALER ISLAND WAY GROIN BREAKWATERS



EXISTING SOUTH BEACH RUBBLEMOUND SEAWALL



EXISTINGDREDGE TAILING LEVEE SECTION

FOR ESTIMATE ONLY

P N D
ENGINEERS, INC.
1736 Fourth Avenue S., Suite A
Seattle, Washington 98134
P: 206.624.1387
www.pndengineers.com

REVISIONS		
REV	DATE	DESCRIPTION

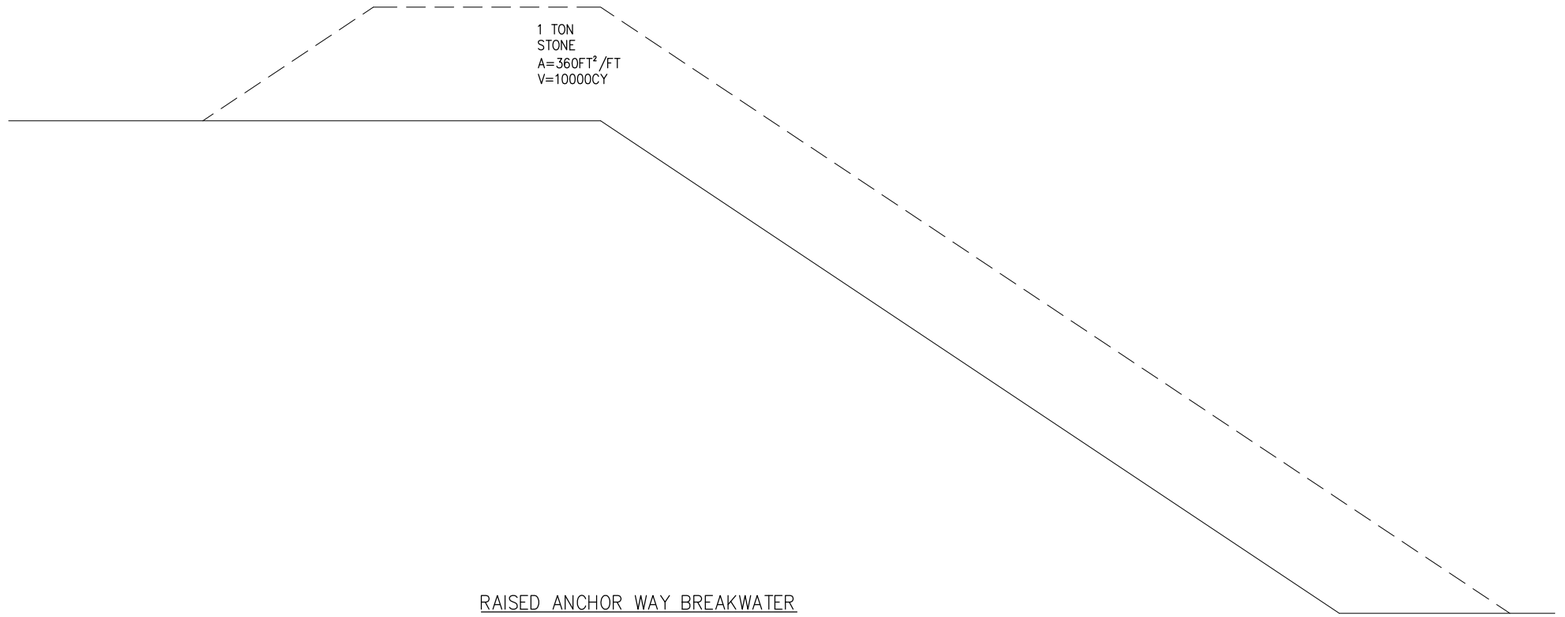
PROJECT: **CRESCENT CITY HARBOR DISTRICT SEA-LEVEL RISE ASSESSMENT**

TITLE: **ASSET ASSESSMENT AND ESTIMATE**

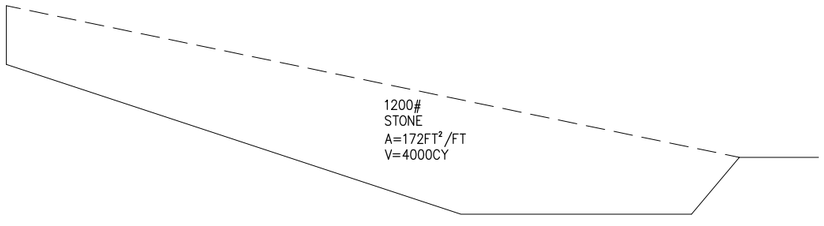
DESIGNED BY:		PROJECT NO:	184062.01
DRAWN BY:	RJ	DATE:	MAY 2019
CHECKED BY:		SCALE:	NTS

SHEET NO: 1 OF 3

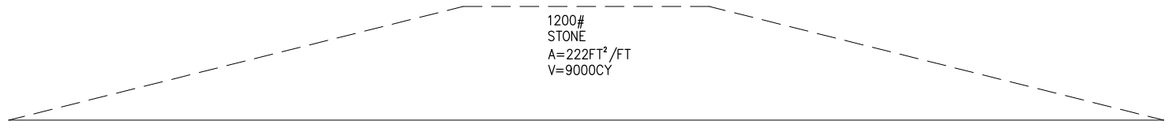
03/13/09
XXX



RAISED ANCHOR WAY BREAKWATER



POTENTIAL SOUTH BEACH RUBBLEMOUND BREAKWATER REBUILD



POTENTIAL HARBOR DISTRICT PROTECTIVE LEVEE SECTION

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ENGINEERS, INC.
1736 Fourth Avenue S., Suite A
Seattle, Washington 98134
P: 206.624.1387
www.pndengineers.com

REVISIONS		
REV	DATE	DESCRIPTION

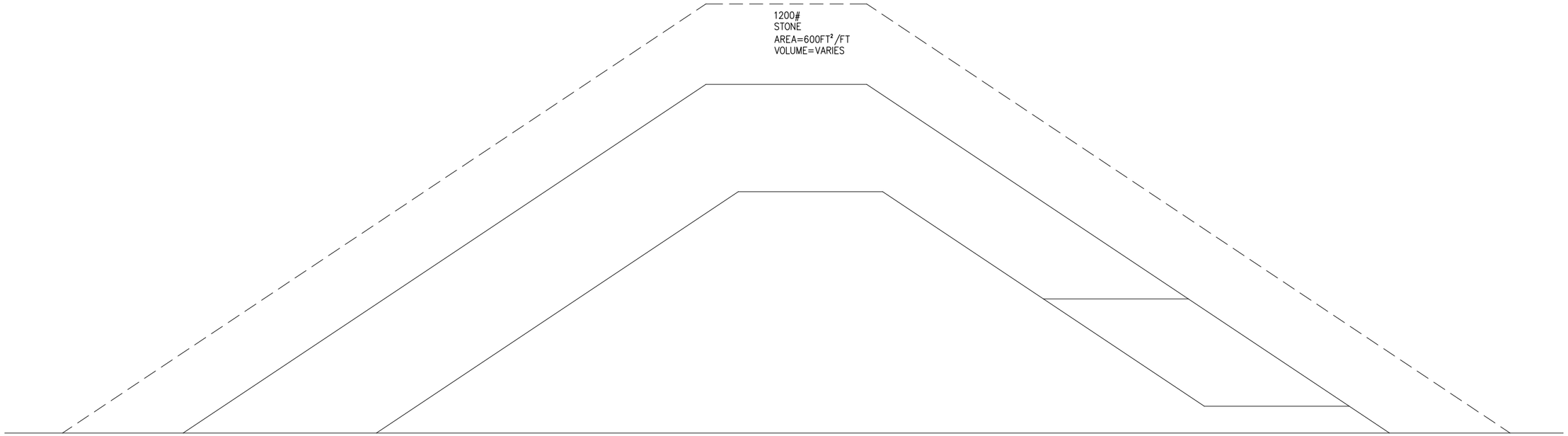
PROJECT: **CRESCENT CITY HARBOR DISTRICT SEA-LEVEL RISE ASSESSMENT**

TITLE: **PROTECTIVE MEASURES ESTIMATE (1 OF 2)**

DESIGNED BY:		PROJECT NO:	184062.01
DRAWN BY:	RJ	DATE:	MAY 2019
CHECKED BY:		SCALE:	NTS

SHEET NO: 2 OF 3

03/13/09
XXX



RAISED LIGHTHOUSE JETTY, INNER HARBOR, AND WHALER GROIN BREAKWATERS

FOR ESTIMATE ONLY

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1736 Fourth Avenue S., Suite A
Seattle, Washington 98134
P: 206.624.1387
www.pndengineers.com

REVISIONS

REV	DATE	DESCRIPTION

PROJECT: **CRESCENT CITY HARBOR DISTRICT SEA-LEVEL RISE ASSESSMENT**

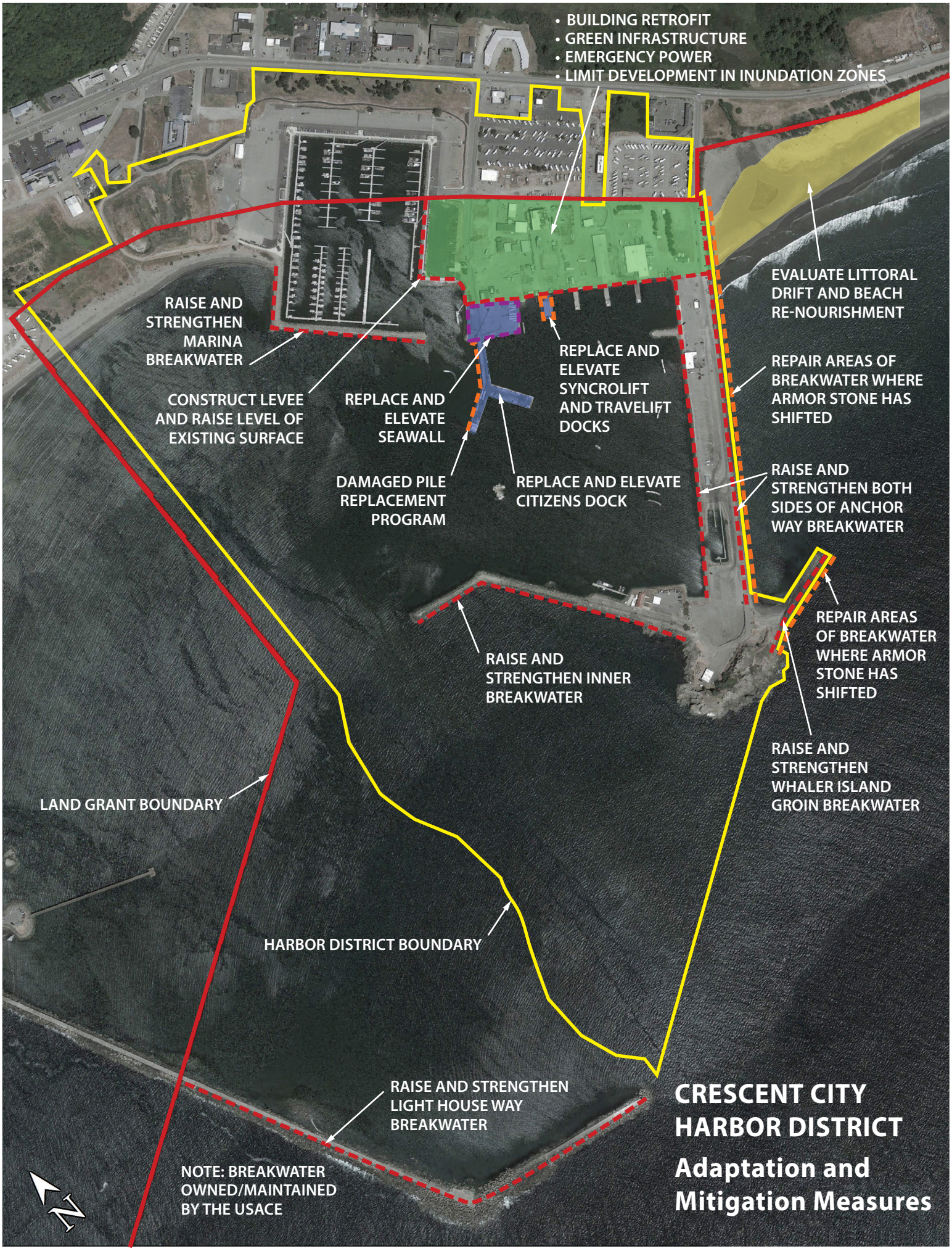
TITLE: **PROTECTIVE MEASURES ESTIMATE (2 OF 2)**

DESIGNED BY:		PROJECT NO:	184062.01
DRAWN BY:	RJ	DATE:	MAY 2019
CHECKED BY:		SCALE:	NTS

SHEET NO: 3 OF 3

03/13/09
XXX

Appendix C - Adaptation/Mitigation Measures Figure


• BUILDING RETROFIT
• GREEN INFRASTRUCTURE
• EMERGENCY POWER
• LIMIT DEVELOPMENT IN INUNDATION ZONES
EVALUATE LITTORAL DRIFT AND BEACH RE-NOURISHMENT
RAISE AND STRENGTHEN MARINA BREAKWATER
CONSTRUCT LEVEE AND RAISE LEVEL OF EXISTING SURFACE
REPLACE AND ELEVATE SEAWALL
REPLACE AND ELEVATE SYNCROLIFT AND TRAVELIFT DOCKS
REPAIR AREAS OF BREAKWATER WHERE ARMOR STONE HAS SHIFTED
DAMAGED PILE REPLACEMENT PROGRAM
REPLACE AND ELEVATE CITIZENS DOCK
RAISE AND STRENGTHEN BOTH SIDES OF ANCHOR WAY BREAKWATER
REPAIR AREAS OF BREAKWATER WHERE ARMOR STONE HAS SHIFTED
RAISE AND STRENGTHEN INNER BREAKWATER
RAISE AND STRENGTHEN WHALER ISLAND GROIN BREAKWATER
LAND GRANT BOUNDARY
HARBOR DISTRICT BOUNDARY
RAISE AND STRENGTHEN LIGHT HOUSE WAY BREAKWATER
NOTE: BREAKWATER OWNED/MAINTAINED BY THE USACE
N
CRESCENT CITY HARBOR DISTRICT
Adaptation and Mitigation Measures