Exhibit A

AB-691 State Public Trust Lands Sea Level Rise Assessment City of Monterey, California

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Disclaimer

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Executive Summary

This document provides a sea level rise (SLR) assessment of tidelands granted to the city of Monterey, California in accordance with Assembly Bill (AB) 691 criteria. The AB 691 criteria requires the following subjects be addressed in the assessment:

- Assessment of impacts of SLR
- Maps of 2030, 2050, and 2100 impacts
- Estimate of financial costs of SLR
- Description of how trustee proposes to protect and preserve resources and structures that would be impacted by SLR

The scope of this assessment was developed to complement previous studies with a focus on the Tidelands of Monterey which are generally located between Wharf 2 and the Monterey Bay Aquarium. The findings from this assessment should be viewed in combination with the findings from previous local and regional studies by Revell Coastal, The Nature Conservancy and ESA.

Sea Level Rise Projections

The *State of California Sea Level Rise Guidance,* released by the Ocean Protection Council (OPC) in March 2018 has high confidence in estimates for SLR to around year 2050, after which emissions scenarios cause predictions to diverge. Three SLR scenarios, listed in Table ES-1 were evaluated in this study to satisfy the AB 691 Criteria and provide consistency with the 2016 City of Monterey Sea Level Rise and Vulnerability Analyses (Revell Coastal, 2016). The SLR scenarios selected align closely with the "medium-high" risk aversion profile which provides a precautionary projection for use on less adaptive, more vulnerable projects or populations in which medium to high consequences would be expected from sea level rise (OPC, 2018).

Table ES-1: Sea Level Rise Scenarios

Time Horizon	SLR Projection, inches (feet)	Probability of occurrence for each scenario based on high emissions OPC, 2018
2030	8.8 (0.73)	Probability of exceedance <5% by 2030
2060	28.3 (2.36)	Probability of exceedance <2% by 2060
2100	62.6 (5.22)	Probability of exceedance <2% by 2100

Impacts to Tidelands Resources from Sea Level Rise

Cannery Row Waterfront Development:

The natural topography along Cannery Row provides a vertical buffer against permanent or prolonged inundation of waterfront structures, even when considering a 5 foot SLR scenario. With most finish floor elevations of ~20 ft NAVD 88 or higher, these structures will remain 8 feet above still water levels, even during the highest tides of the year. However, extreme storm conditions combined with sea level rise could pose a threat to some waterfront structures within the short-term planning horizon (2050).

The threshold for damage to a particular structure is dependent on building characteristics including foundation type, age and condition of the structure. For example, an older timber pile supported structure (e.g. Taste of Monterey Restaurant) with horizontal bracing below deck and corroded connections would have a lower threshold for coastal storm damage and SLR than a new reinforced concrete pile supported structure (e.g. Aquarium). Figure ES-1 illustrates the difference between these types of structures.

Older structures, especially timber pile structures, are more vulnerable to lower SLR scenarios due to the cumulative effects of ongoing deterioration from the marine environment and the higher water levels and wave energy associated with sea level rise. Newer structures may have the adaptive capacity to accommodate lower SLR increments but would likely require structural upgrades to mitigate higher wave runup and uplift forces under a 5 foot SLR scenario.

Taste of Monterey Restaurant

Monterey Bay Aquarium

Figure ES-1: Waterfront Structures along Cannery Row

Monterey Harbor:

Given the poor state of repair (COWI, 2017) both the Old Fisherman's Wharf (Wharf 1) and Municipal Wharf II (Wharf 2) are most vulnerable to damage from sea level rise. Although sheltered from most wave energy the current and surge within the harbor during an extreme event could be problematic for deficient foundation elements and corroded connections of Wharf 1. The outer end of Wharf 2 would be exposed to more wave energy than Wharf 1 since it's only partially sheltered by the breakwater.

Estimates of storm damage in combination with each sea level rise scenario indicate both structures could experience damages on the order of 20% of the structures value for a ~1 foot SLR scenario. The estimated potential damage could increase to ~30% for a 2 foot SLR scenario. A 5 foot SLR scenario combined with an extreme storm event is expected to result in total loss of the existing structure.

Lower platforms of Wharf 1 like the Monterey Bay Whale Watching Center and other concessions with lower level decks (Figure ES-2), or deficient structural elements would be most susceptible to this damage. Note, the Sandbar and Grill, located below the main deck of Wharf 2 would likely experience complete total loss under a 1 foot SLR scenario.

Whale Watch Center – Wharf 1

Sandbar & Grill – Wharf 2

Figure ES-2: Vulnerable Structures in Monterey Harbor

The floating docks, guide piles and utility infrastructure of the marinas are perhaps the most adaptive infrastructure in the Harbor since they are designed to function with the ~8 foot tide range. The service life of the existing docks will likely expire before SLR becomes a major concern. The Coast Guard Pier breakwater and wave wall around the municipal marina provide essential protection for these elements. This infrastructure has capacity to accommodate 1-2 feet of SLR while still performing well. However, a SLR of 5 feet would be problematic as the breakwater crest would be submerged at high tide resulting in a significant increase in wave energy transmitted into the harbor.

Coastal Habitat:

Rocky and sandy intertidal habitats are prevalent along the Monterey waterfront. These transition zones provide important habitat areas for a diverse array of marine invertebrates and plant life. An essential element of what maintains the high levels of biodiversity found in rocky intertidal areas is the dynamic environment provided by tidal cycles, wave action, and sediment movement. SLR has the potential to disrupt this ecological balance, reducing benefits to surrounding ecosystems and diminishing shoreline protection functions. Coastal habitats may be able to adapt to smaller increments of SLR (1-2 feet) if suitable environment exists at a higher elevation. The slope of the shoreline increases with higher elevations, which indicates a limited adaptive capacity for a 5 foot SLR scenario.

Beaches and Coastal Access:

Higher water levels from SLR and erosion associated with storm events would result in the loss of dry beach area impacting recreational beach users, swimmers, kayakers, and paddle boarders. A 2 foot sea level rise would result in loss of ~70% of the San Carlos Beach area. Similar impacts, though to a lesser extent, would occur along the Plaza Hotel Beach and McAbee Beach. A 5 foot rise in sea level would most likely eliminate the existing sandy beaches throughout the study area.

Economic Analyses of Sea Level Rise

An economic analysis was performed to describe the market and non-market losses to the City of Monterey, and to an extent the entire county, from sea level rise (SLR) for granted public trust lands in the city. Table ES-2 below provides a summary of all direct revenue losses to City government in the Tidelands Trust area and citywide during each of the three scenarios.

The following summary of economic loss is based on impacts of a 100-year storm event and the loss of revenue as facilities are restored. As sea level rises over time, the severity of physical damage and the resulting economic losses increase. The year 2100 losses are substantially greater as full recovery could require five or more years, resulting in an extended period of revenue losses. If multiple 100-year storm events should occur within the planning horizon, the losses described below could increase substantially.

Impacts from a 1 foot SLR scenario (2030) and 2 foot SLR scenario (2060) are largely due to loss of revenue streams from Wharf 1 and 2 in addition to citywide loss of transient occupancy taxes (TOT) and sales tax from loss of these attractions. The impacts from a 5 foot SLR scenario (2100) reflect the direct and indirect economic output and job losses due to the loss of visitor-days and sales caused by closure of one or both major attractions in Monterey—the aquarium and the wharves—from damage associated with the 2100 SLR scenario. It is assumed that after such an event there would be an extended closure period (assumed to be 5 years) during which the damaged facilities are repaired or replaced. The values in the table below include the 5-year extended loss from the wharves.

The loss of one or more of the three beaches due to sea level rise would result in the non-market value losses indicated. From a citywide perspective these values should be combined with the non-market impacts identified in previous studies to account for the beach loss north of Wharf 2.

Table ES-2: Summary of Market and Non-Market Valuation

Economic Loss Type	**2030**	**2060**	**2100**[a]
Market Valuation			
Revenue loss to City Government, within Tidelands	$1,030,808	$2,061,760	$34,105,989
Revenue loss to City Government, outside of Tidelands	$519,000	$784,000	$26,542,000
Total Revenue Loss to City Government	$1,549,808	$2,845,760	$60,647,989
Trickle-down economic loss in City	$13,266,000	$20,940,000	$484,626,000
Market Valuation Total	**$14,815,808**	**$23,785,760**	**$545,273,989**
Non-Market Valuation (beach loss)	$185,000	$1,021,000	$1,558,000

[a.] Includes the five-year extended loss for impacts to wharves in the 2100 scenario.

Adaptation Strategies to Protect and Preserve Resources

Sea level rise is unique among other hazard because it's a slow moving disaster that will develop over the span of decades. The vulnerabilities identified for sea level rise projections at the end of the century are overwhelming but the slow moving nature of climate change and sea level rise allows for time to plan, fund and mitigate these impacts.

Waterfront Structures – Cannery Row and Monterey Harbor:

Waterfront structures along Cannery Row and in Monterey Harbor are exposed to physical, chemical and biological deterioration from the marine environment. Some of these structures are at or near the end of their service life and will be subject to increasing water levels and wave energy due to SLR. Regular inspection, maintenance and repair are vital to the resilience of these waterfront structures and will grow more important for each increment of sea level rise.

Depending on the type, condition and location of the structure a pro-active maintenance and repair strategy may be sufficient to mitigate impacts from sea level rise through mid-century. However, over longer time horizons the combination of aging structures and increasing hazards will likely result in damage to many of the existing waterfront structures, especially Wharf 1 and 2.

The threshold for when to switch from a repair strategy to a replacement strategy will vary by structure. Before making a long-term investment in above deck facilities or below deck repairs, a focused study should be performed to determine if the structure has capacity to support the proposed use over the duration of the lease or building life span. If determined that the structure is not adequate, then a comparison of the repair versus replacement costs and benefits should be performed to determine the best course of action.

Coastal Habitat:

A nature-based approach that incorporates rocky intertidal habitat restoration and artificial reef construction could be employed to offset some of the adverse impacts of sea level rise and provide multiple benefits to natural and built resources of the waterfront. The design of these features could also be fine-tuned to provide additional benefits such as sediment retention or wave protection, and applications could vary to mimic the different nearshore rocky intertidal habitat types along Monterey.

Beaches and Coastal Access:

The pocket beaches within the study area are confined by rocky outcroppings, small headlands, or breakwaters which act as barriers to sediment movement in the longshore direction. The beaches are also limited from landward migration by existing development. Therefore, the natural sources of sediment from cliff erosion or fluvial discharge are no longer providing a significant amount of sediment to these beaches which prohibits their ability to naturally adapt to sea level rise.

An opportunistic beach nourishment program could be an effective measure to supply sediment to these pocket beaches to help adapt to rising sea levels. This program would designate receiver beaches and describe requirements for sediment compatibility that have been subject to the environmental review process. Given the relatively small pocket beaches and sheltered wave climate even a small amount of beach quality sediment (i.e. 1,000 to 5,000 cubic yards) could offer significant and lasting benefits.

1. Introduction

This document provides a sea level rise (SLR) assessment of tidelands granted to the City of Monterey, California in accordance with Assembly Bill (AB) 691 criteria. The California State Lands Commission (CSLC) has jurisdiction over public lands, which include tidelands. Tidelands are a type of sovereign land held by the state of California where land is covered and uncovered by the ebb and flow of tides. The landward limit of tidelands is defined as the intersection of the mean high tide line with the shore (SLC 2015). Tidelands can be granted to local trustees for purposes of commerce, navigation, and fisheries as well as other public trust purposes.

In 2013 the California legislature passed Assembly Bill 691, Chapter 592, which requires local trustees with average annual gross revenue greater than $250,000 from their public trust lands to prepare and submit an assessment of how they propose to address SLR to the CSLC by July 1, 2019.

In accordance with AB 691 assessment criteria this study includes the following:

- **Assessment of SLR impacts:** Inventory of potentially vulnerable resources and facilities, assessment of storms and extreme events (100-Year/1% annual chance event), evaluation of changing shorelines, trends in local sea level, and potential impacts to public access, commerce, recreation, coastal habitats, and navigability.
- **Maps of 2030, 2050, and 2100 impacts:** Plan view mapping is provided in the 2016 City of Monterey study, where the year 2050 is replaced by year 2060. Due to the vertical nature of areas in this assessment, profile views are used to map SLR impacts.
- **Estimate of financial costs of SLR:** Replacement and repair costs of resources and facilities, including non-market values of resources and costs of adaptation and mitigation measures.
- **Description of how trustee proposes to protect and preserve resources and structures that would be impacted by SLR:** Mitigation, adaptation, and resiliency measures including hazard monitoring and mitigation implementation triggers.

1.2 Previous Studies

Southern Monterey Bay has been the subject of several regional studies that have assessed coastal flooding, shoreline erosion hazards, and sea level rise. These regional studies are listed below and generally focus on the sand beaches north of the Monterey Harbor.

- SCC Climate Ready Grant #13-107 Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay (The Nature Conservancy, March 2016)
- Climate Ready – Southern Monterey Bay Coastal Hazards Analysis to Assess Management Actions (ESA, January 2016)
- Monterey Bay Sea Level Rise Vulnerability Assessment (ESA PWA, June 2014)
- Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay (ESA PWA, May 2012)

Most of these studies were led by ESA (formerly ESA PWA) and built on one another to evaluate coastal erosion and flooding along the beaches of Southern Monterey Bay for a range of sea level rise scenarios. The Nature Conservancy report (March 2016) provides an economic analysis of several possible adaptation strategies that could be implemented along the Del Monte Beach segment such as beach nourishment, coastal armoring, managed retreat, and structural elevation. These studies provide useful information for planning purposes within the study area; however, Wharf 2 was the southern limit of these regional studies, and therefore limited information is available regarding the tidelands in Monterey Harbor and along Cannery Row.

Revell Coastal (March 2016) prepared the study *Sea Level Rise and Vulnerability Analyses, Existing Conditions and Issues Report for the City of Monterey* to inform an update of the City's Local Coastal Program. This report provides a summary of sea level rise vulnerabilities within the City based largely on hazard modeling from ESA PWA (2014) combined with cliff erosion projections along Cannery Row. The results of this assessment were presented by sector (e.g. land uses and structures, roads and parking, public transportation, etc.) and identified the low lying Del Monte Avenue corridor in the vicinity of El Estero and lower Downtown as the area most vulnerable to an extreme coastal storm event combined with sea level rise.

The Federal Emergency Management Agency (FEMA) recently completed the California Coastal Analysis and Mapping Project, Open Pacific Coast Study (CCAMP), which updated Flood Insurance Rate Maps (FIRMs) along the coast of California. The County of Monterey FIRMs became effective June 21, 2017 and depict the water surface elevation and flood extents of the 100-year (1% annual chance) coastal flood event. The analysis and resulting hazard maps (FIRMs) do not take sea level rise into account, but the technical documents associated with the study provide a detailed assessment of historic waves, water levels, and runup along the City of Monterey waterfront.

1.3 Study Area and Scope

The scope of this assessment and the study area are intended to complement previous studies by focusing on the waterfront parcels along Cannery Row and Monterey Harbor. While the study area encompasses all of the leased tidelands managed by the City, not all waterfront parcels are located on leased tidelands. The study area and tideland parcel boundaries are shown in Figure 1-1 and Figure 1-2. The analysis provides continuous coverage between the Monterey Bay Aquarium and Wharf 2 regardless of whether a parcel is located on leased tidelands.

The most recent oceanographic information for this study comes from the FEMA CCAMP study, which evaluated flood hazards at eight transects spaced along the study area. A detailed hindcast database of waves, water levels, and resulting runup is available at each transect along with the 100-year base flood elevation. This transect data and the methods described in the CCAMP study for estimating total water levels are applied in our analysis to evaluate how each sea level rise scenario would affect the base flood elevation (total water level) and the maximum wave crest elevation, which is important for evaluating pile supported structures. This additional hazard analysis is used to complement prior studies that focused on bluff erosion hazards along the study reach and coastal erosion and flooding north of Wharf 2.

Given the scope of this study the findings from this assessment should be viewed in combination with the findings from the Revell Coastal (2016) study and prior studies by The Nature Conservancy and ESA.

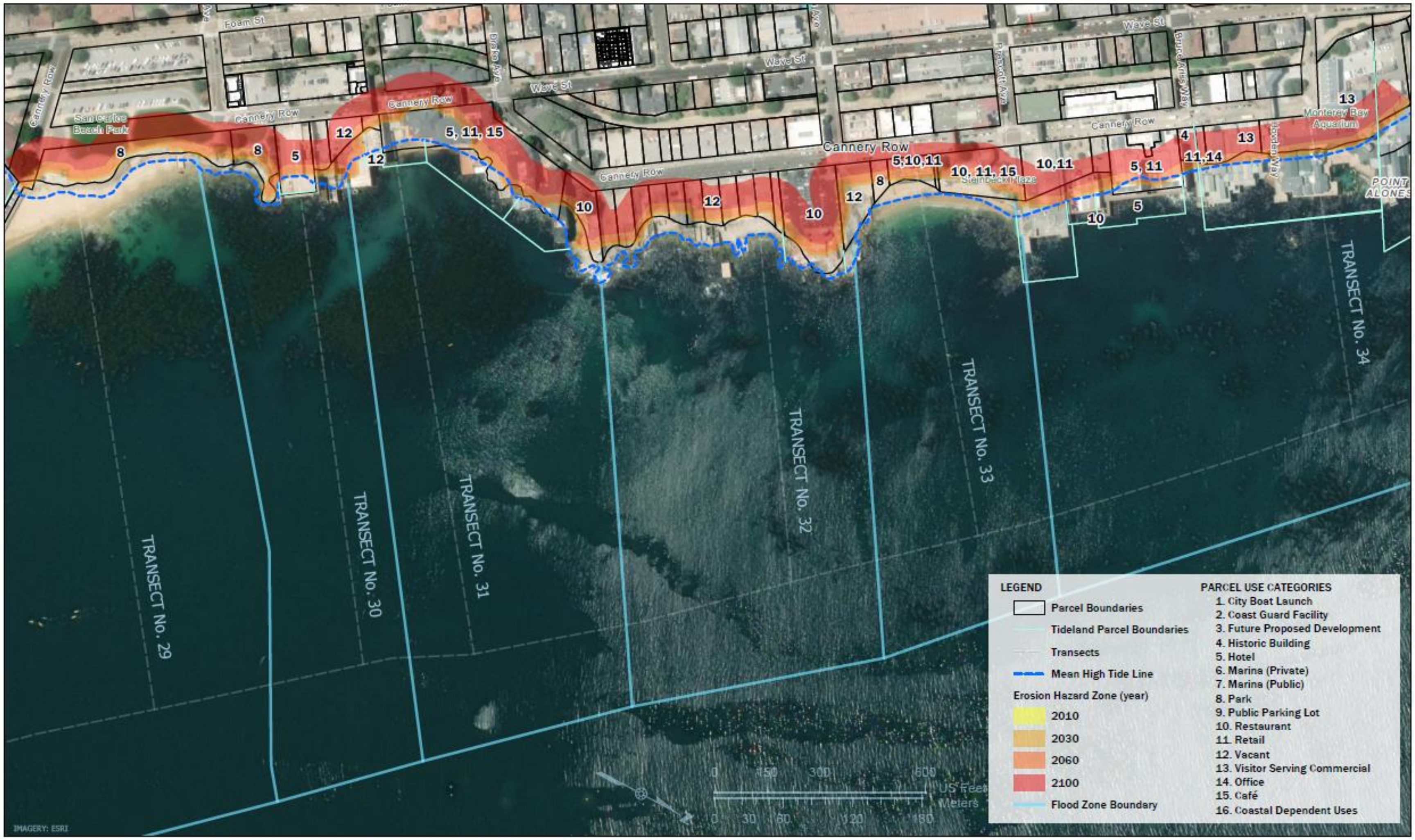


Figure 1-1: Study Area Map – Cannery Row

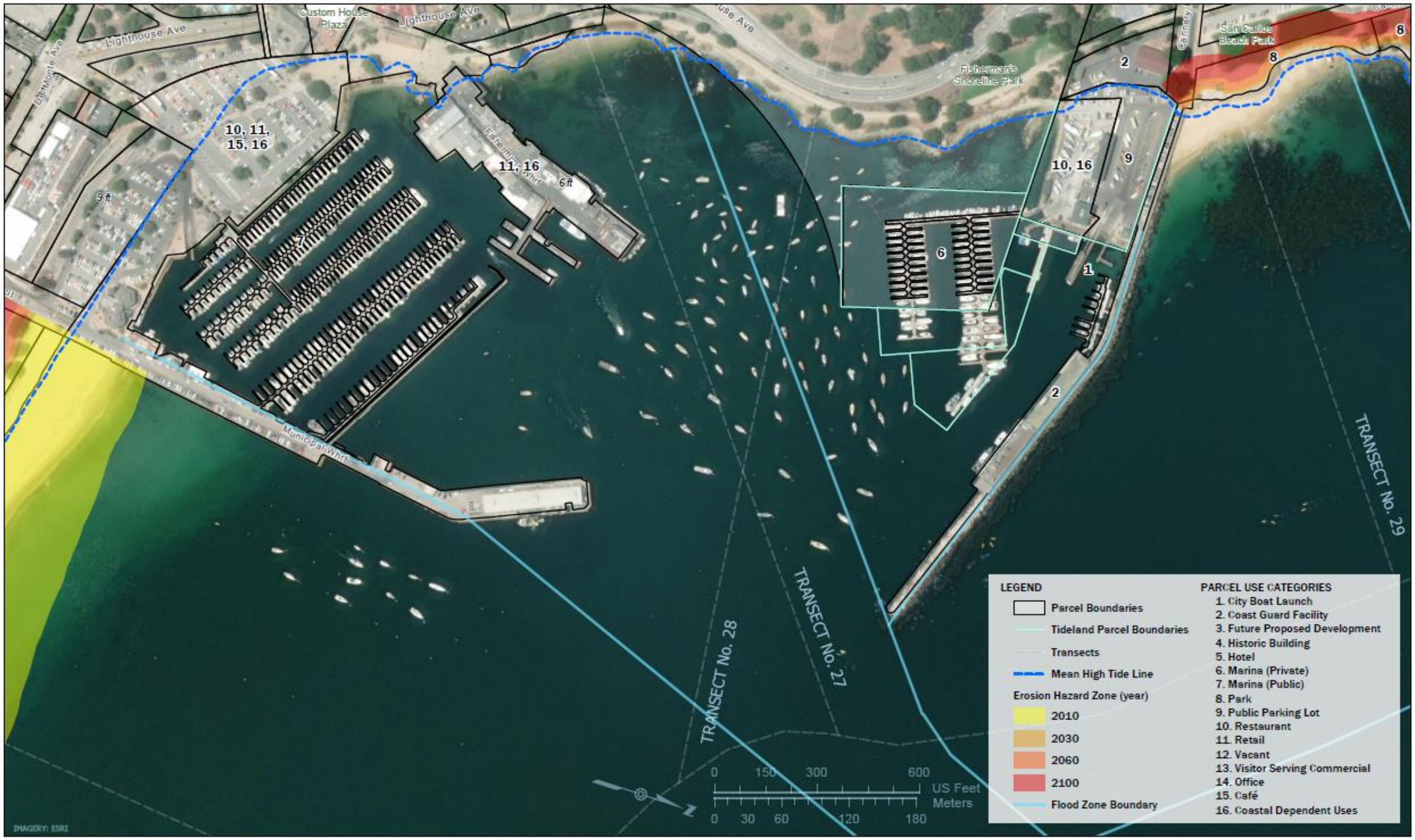


Figure 1-2: Study Area Map – Monterey Harbor

2. Sea Level Rise Projections

2.1 What is Sea Level Rise?

Sea level rise science involves both global and local physical processes, as illustrated in Figure 2-1. Models are created based on the current best scientific understanding of these processes from global to local scales and are therefore dynamic and periodically updated to reflect these changes. On a global level, the most recent SLR projections come from the International Panel on Climate Change's 5th assessment report released in 2013. The 5th assessment projections for sea level rise were 50% higher than the previous assessment (released in 2007) due to the addition of melting ice sheet dynamics to sea level rise modeling efforts. At the state level, the California Coastal Commission presently recommends using projections from the Ocean Protection Council (OPC) report *State of California Sea Level Rise Guidance* (OPC 2018) that was released in March 2018.

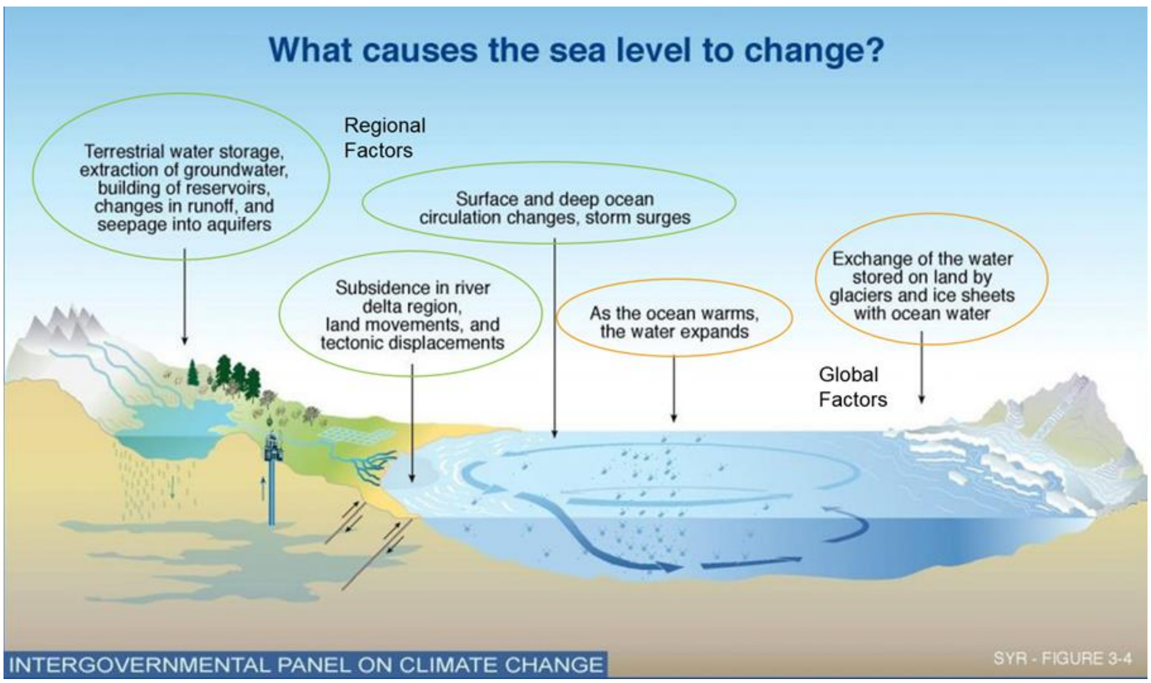


Figure 2-1: Regional and Global Factors that can Contribute to Changes in Sea Level (IPCC 2013)

2.2 Best-Available Sea Level Rise Projections

The OPC 2018 guidance provides SLR projections for multiple emissions scenarios and uses a probabilistic approach based on Kopp et al. 2014 to generate a range of projections at a given time horizon. For the 2030 time horizon the "likely range" of SLR is between 0.3 and 0.5 feet. Kopp et al. 2014 estimated there is a 66% probability that SLR will fall within this likely range. The likely range of SLR at the 2060 time horizon is 0.5 - 1.2 feet for a low emissions scenario and 0.7 - 1.4 feet for a high emissions scenario. The likely range of SLR at the 2100 time horizon is 0.9 - 2.3 feet for a low emissions scenario and 1.5 - 3.3 feet for a high emissions scenario. The upper end of the likely range is recommended for low risk aversion situations where impacts from SLR greater than this amount would be insignificant or easily mitigated. This low risk aversion curve is shown in orange in Figure 2-2.

For medium-high risk aversion situations more conservative (lower probability) projections for SLR are recommended. There is a 1-in-200 chance (0.5% probability) that SLR will meet or exceed these levels at the given time horizon, and so these projections are appropriate for use on projects where damage from coastal hazards would carry a higher consequence. The medium-high risk aversion curve is shown in red in Figure 2-2.

The OPC guidance also includes a singular extreme SLR scenario, called H++, which represents recent scientific findings of potential faster rates of SLR due to changes in glacial dynamics described by Sweet et al. 2017.Under an H++ scenario SLR is projected to reach 10 ft by year 2100. Because the H++ scenario is not a result of probabilistic modeling, the likelihood of this scenario cannot be determined. Due to the extreme and uncertain nature of the H++ scenario, it is most appropriate to consider when planning for long-term, critical, and non-adaptable use and development decisions (OPC 2018). The H++ extreme risk aversion curve is shown in purple in Figure 2-2.

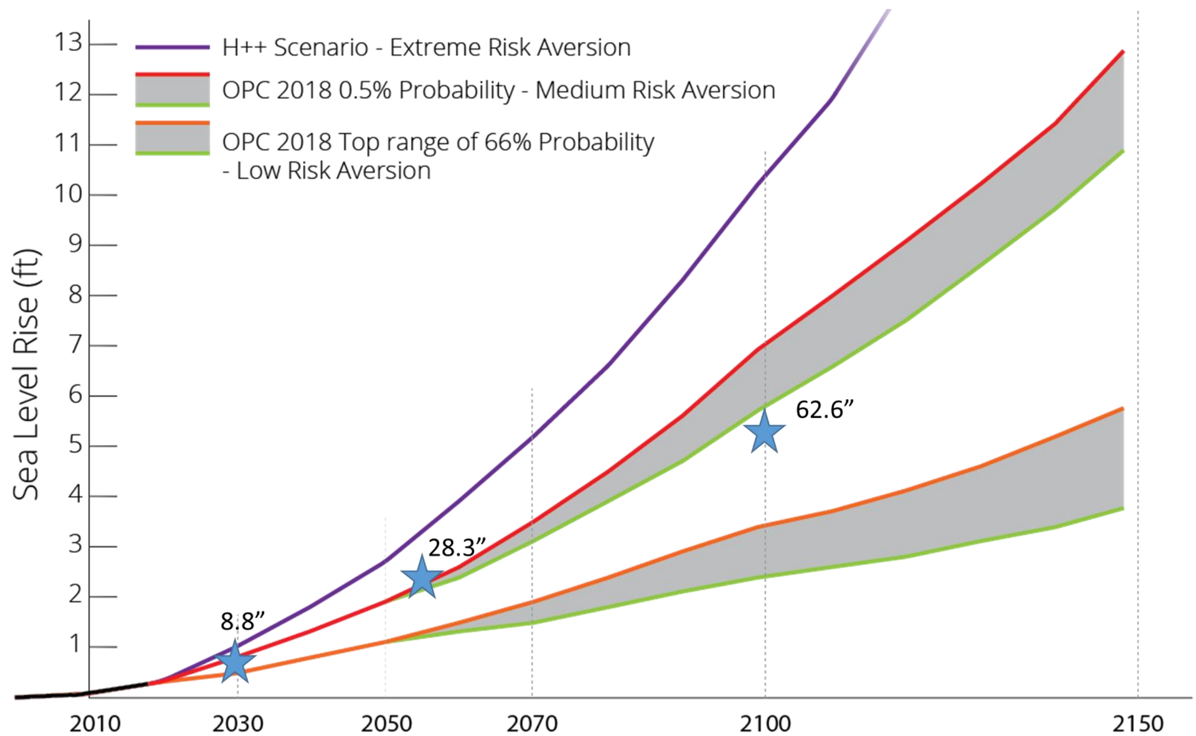


Figure 2-2: Approximate Sea Level Rise Projections for Three Risk Aversion Levels (OPC 2018)

2.3 Sea Level Rise Scenarios Evaluated

Climate science is a constantly changing field, often with high degrees of uncertainty. In the case of SLR in California, the OPC has high confidence in estimates to around the year 2050, after which uncertainties surrounding emissions scenarios cause predictions to diverge. The SLR scenarios applied in this assessment are indicated with stars in Figure 2-2. These scenarios were selected for the following reasons:

- These scenarios were applied in the 2016 City of Monterey Sea Level Rise and Vulnerability Analyses (Revell, 2016), and therefore impacts identified at each increment of SLR can be easily cross-referenced to findings from the 2016 analyses.

- The 2030 (8.8") and 2060 (28.3") scenarios align well with the "medium-high risk aversion" curve through 2060, providing a conservative assessment of impacts at these time horizons.
- The projection of 62.6" (~5 feet) at 2100 is below the medium-high risk aversion curve, but still represents a conservative projection. The OPC guidance indicates there is a 2% chance that SLR will meet or exceed 5 feet this century.

3. Coastal Hazards

Coastal hazards assessed within the study area include tidal flooding, waves, and shoreline change. These hazards were evaluated along 8 segments of the study area shoreline. Each segment is characterized by a two-dimensional transect (elevation and horizontal distance). These segments and transect locations are shown in Figure 1-1 and Figure 1-2. Transect plots and locations are also shown on the SLR summary sheets. Transect locations and accompanying data are from the recent FEMA California Coastal Analysis and Mapping Project Open Pacific Coast Study (CCAMP OPC), which was used to create the latest Flood Insurance Rate Maps (FIRMs) that became effective June 21, 2017. . Additional analysis was performed for this assessment using FEMA data and methods adapted to consider coastal storms with SLR. Tidal flooding and shoreline change from the Revell Coastal (2016) study is also discussed below.

3.1 Tides

The mean high water line (MHW) is plotted on the SLR summary sheets for each transect in this assessment to show changes in the landward boundary of tidelands for each SLR scenario. The 100-year (1% annual chance) still water elevation (SWEL) is plotted for an auxiliary transect at the municipal marina to characterize the low-relief, sheltered nature of this area not captured in the nearest FEMA transect. Elevation data for the municipal marina transect is from the 2014 USACE NCMP Topobathy Lidar DEM.

Tidal flooding was mapped for the entire City in the Revell Coastal study (2016) using the same SLR scenarios in this assessment. Analysis from this study shows combined tidal and fluvial (river/precipitation) flooding in the El Estero area extending toward the municipal marina waterfront.

The National Oceanic and Atmospheric Administration (NOAA) tide station for Monterey, CA (NOAA Station ID: 9413450) is located on Municipal Wharf 2 and is representative of tides in the study area. Tidal datums for this station are shown in Table 3.1. The FEMA CCAMP OPC study also performed a tide frequency analysis, involving statistical calculations using historic gauge data, to determine the 100-year still water elevation, which was used as a base water level for sheltered areas in the study.

Table 3.1: Tidal Datums for Monterey, CA

Tidal Datum	ft, NAVD 88			
	Current	+8.8 in. SLR (2030)	+28.3 in. SLR (2060)	+62.6 in SLR (2100)
***100-year Still Water Elevation (SWEL)**	8.6	9.3	11.0	13.8
Highest Observed Tide (HOT)	8.02	8.75	10.38	13.24
Highest Astronomical Tide (HAT)	7.15	7.88	9.51	12.37
Mean Higher High Water (MHHW)	5.48	6.21	7.84	10.70
Mean High Water (MHW)	4.78	5.51	7.14	10.00
Mean Tide Level (MTL)	3.01	3.74	5.37	8.23
Mean Sea Level (MSL)	2.97	3.70	5.33	8.19
Mean Low Water (MLW)	1.24	1.97	3.60	6.46
Mean Lower Low Water (MLLW)	0.14	0.87	2.50	5.36

Note: *The 100-year still water elevation is a statistical calculation from the FEMA CCAMP OPC study.

3.2 Wave Conditions

For the purposes of this study and other coastal hazard analyses wave setup refers to the increase in water level elevation in the surf zone as deepwater wave momentum is transferred into shallower water. Wave runup is the maximum elevation that water from a breaking wave could reach on an infinite slope. The FEMA CCAMP OPC study conducted a detailed analysis of wave conditions along the Pacific Coast. The results, methods, and data used in the FEMA study were used to inform this assessment and were adapted to consider SLR. The FEMA study used deepwater wave modeling of the Northwest Pacific Ocean basin to create a 50-year hindcast of deepwater wave conditions along the California coast. The deepwater waves were then transformed to the nearshore region using a spectral refraction model. Nearshore wave conditions were applied to shoreline transects to calculate wave setup and wave runup for a series of extreme events from the hindcast. A statistical extreme value analysis was then performed on these results to calculate the 100-year total water level (TWL) for each transect, which corresponds to the 100-year event mapped on the FIRM for each transect.

The nearshore wave conditions and transect data from the FEMA study were used in this assessment to estimate TWLs for SLR conditions. SLR was added to the still water level (SWL) of each event in the nearshore hindcast series. Wave setup and wave runup were then calculated for each event, and an extreme value analysis was performed to yield the 100-year TWL for each transect. Wave setup, wave runup, and TWLs were calculated using the same methodology described in the FEMA CCAMP OPC study.

Due to the prevalence of pile supported structures throughout the study area, wave crest elevations were calculated from the maximum and minimum events in the nearshore hindcast series to provide a range of wave crest elevations at applicable transects. The controlling wave height where pile supported structures exist at the transect location was determined from the minimum of the depth limited wave height or the maximum breaking wave height. The depth limited wave height assumed a breaking wave coefficient of 0.9. The breaking wave height was calculated using the methodology described in the FEMA CCAMP OPC study. The maximum breaking wave height was calculated using the 2002 Coastal Engineering Manual (CEM) formula II-1-132 (USACE, 2002), $H_{max}=1.86\ H_{1/3}$. 70% of the controlling wave height was then added to the SWL with SLR to yield the wave crest elevation.

3.3 Shoreline Change

Shoreline change can consist of relative changes due to SLR and physical changes due to erosive processes. Relative changes due to SLR are straightforward and can be realized by elevating the tidal datum and moving the shoreline position landward to account for a given rise in sea levels. Physical changes due to erosive processes can be difficult to project into the future when considering SLR as they rely on geologic information and historic erosion rates, often at a regional scale.

For mild sloping beach areas, relative shoreline changes can be significant. The pocket beaches included in this assessment are relatively narrow and constrained by coastal structures along the back beach; thus, it was assumed that a similar beach profile would exist under future SLR scenarios but with a decreased beach area due to rising sea levels. The progression of the MHW datum is plotted on the profiles of the SLR summary sheets along with projected beach area changes. These changes are less apparent in areas with steep slopes, high-relief, pile supported structures, or vertical seawalls. In these areas most of the change is in the vertical direction without significant changes to the landward extent of the shoreline.

The shoreline within the study area is heavily engineered, which complicates future projections of erosion rates. Historically, seawalls, wharves, and other coastal structures were built along the shoreline to support the fishing and canning industry. Many of these historic structures remain in place today in various states of repair, modification, and expansion. Due to the man-made nature of these structures, shoreline changes in these areas will be largely dictated by repair, maintenance, and modification efforts in the future. Barring any changes to city development regulations, it can be assumed that the current extents of the shoreline would be maintained in the future.

Erosion hazard zones were provided in an additional submittal to the 2016 City of Monterey study. Documentation is not available for these zones. Based on their appearance it is assumed that a single erosion rate was applied for the entire Cannery Row shoreline. The erosion hazard zones could possibly represent future shoreline conditions if coastal structures were not present. These zones are included in Figure 1-1 and Figure 1-2 for reference.

4. Tidelands and Coastal Resources

The impacts that storm events and SLR can have on public trust tidelands resources and other coastal resources in the study area are summarized in five general categories within this section. Technical and site-specific aspects of these impacts are described in the Sea Level Rise Summary Sheets (Section 5). The market and non-market economic impacts to these resources are described in the Economic Analysis of Sea Level Rise sections.

4.1 Public Access

Tidelands and coastal resources in the study area provide opportunities for public access to the coast. Storm events impact these resources through flooding, damage, erosion, and increased operational downtime (closures). Higher levels of SLR are associated with greater and more frequent impacts.

4.1.1 Waterfront Pedestrian Facilities

These resources include the waterfront recreation trail, wharves, promenades, walkways, and sidewalks open to the public. The recreation trail connects Seaside to Pacific Grove and runs the length of the study area, serving as a key pedestrian and bicycle transportation corridor between Fisherman's Wharf (Wharf 1) and Cannery Row (City of Monterey, 2016). Wharf 1 is heavily trafficked by pedestrians with up to 20,000 persons visiting on a peak day (City of Monterey, 2016).

Flooding from wave runup and overtopping can result in temporary impacts during storm events. Lower elevation facilities are especially susceptible to flooding. Some areas may need to be closed for pedestrian safety during storm events, and SLR would increase the frequency and severity of flood events throughout the study area.

Wave energy can damage structures depending on their elevation and state of repair. Natural features such as can also be eroded and undermine pedestrian facilities. SLR will result in increased wave impacts to structures and other features at higher elevations.

4.1.2 Beach Access Points

Formal beach access points within the study area include McAbee Beach, Monterey Plaza Hotel Beach, San Carlos Beach, and Monterey Harbor Beach. Higher water levels, beach area loss, and erosion could damage these locations, making beach access more difficult and less desirable.

4.1.3 Boating

The marinas within the study area provide boat owners access to Monterey Bay. The wharves along with the marinas provide the public with access to tour and charter boats. Use of the wharves also includes tall ship berthing and cruise ship shuttle landings. These facilities can be damaged by wave energy during storm events. SLR would result in more frequent and severe damage, increasing downtime while repairs are made.

4.2 Commerce

Businesses along the waterfront would be impacted by damages to their facilities such as wave impact damage to structures or flooding, repair costs, and revenue loss due to any downtime. These businesses support a thriving tourism economy and therefore any damage to hotels, restaurants, or shops would have a direct economic impact. Sections 6 and 7 describe the potential storm damage to these waterfront facilities and the potential economic impact to commerce.

4.3 Recreation

The beaches within the project area provide recreation opportunities on the sand and also provide access for swimmers, divers, kayakers, and paddle boarders. Higher water levels from SLR and erosion associated with storm events would result in the loss of dry beach area, impacting these recreational beach user groups. Beach slopes could also become steeper with erosion. Steeper beach slopes could be problematic for divers who use San Carlos Beach as a staging and launch area. San Carlos Beach Park is rated as the number one beach cold water access spot in the world for divers, with approximately 65,000 divers utilizing this location each year (City of Monterey, 2016).

Potential beach width loss is shown in Table 4.1. Existing beach width is measured from the mean high water (MHW) tide elevation to the back of the beach based on the elevation data used in the FEMA transects. The MHW elevation was increased linearly with SLR. Monterey Harbor beach is not included since the MHW line already extends to the back of the beach.

Table 4.1: Beach Width Change with SLR

Location	Beach Width, ft (Percent Loss from Existing)			
	Current	+8.8 in. SLR (2030)	+28.3 in. SLR (2060)	+62.6 in SLR (2100)
San Carlos Beach	73	63 (-14%)	22 (-70%)	0 (-100%)
Plaza Hotel Beach	54	43 (-20%)	25 (-54%)	4 (-93%)
McAbee Beach	77	75 (-3%)	57 (-26%)	42 (-45%)

4.4 Coastal Habitats

For the purposes of this analysis, coastal habitats in the project area are defined as those within the tidal range. SLR would result in a vertical shift in the tidal range. Coastal habitats may be able to adapt to this shift if a suitable environment exists at a higher elevation. Factors such as different shoreline slopes or the presence of coastal structures at higher elevations could hinder the adaptive capacity of certain coastal habitats. As shown in Table 4.1, the size of sandy beach habitat will be significantly reduced as sea levels rise. Coastal storms would continue to drive seasonal erosion processes resulting in natural coastal habitat variability.

4.5 Navigability

Monterey is an important harbor to boaters due to its location and distance from other harbors. The harbor is officially recognized by the State as one of a number of "harbors of refuge" along the California coast. Monterey Harbor also includes facilities utilized by the US Coast Guard. The US Coast Guard-owned breakwater and a city-owned 2.4-acre former landfill site make up the Coast Guard Pier and Breakwater located in the northwest portion of Monterey harbor (City of Monterey, 2016).

Monterey Harbor, given its protected location on the north side of the Monterey Peninsula, can be entered in any weather condition (City of Monterey, 2016). The rubble mound breakwater provides crucial wave protection to the inner harbor infrastructure and allows for safe navigation within the harbor. As sea level rises, the structure will be exposed to greater wave heights and water levels and will eventually fail to serve its function if it is not maintained properly under the projected SLR scenarios. The effects of SLR can also alter the wave transmission that occurs within the harbor due to wave penetration through a rubble-mound structure and overtopping of the breakwater (Figure 4-1).

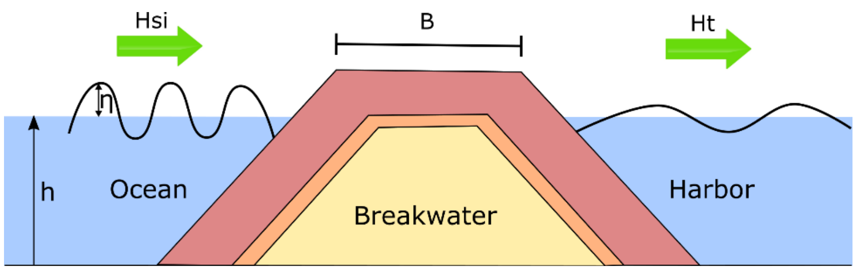


Figure 4-1: Conceptual sketch of wave transmission through a Breakwater

The potential impacts from increased wave transmission were evaluated for each SLR scenario. FEMA CCAMP OPC provides some description of the Monterey Harbor breakwater and wave conditions outside the breakwater. Model output numbers MO758-001, MO758-002, and MO758 corresponding to FEMA transects #27-29 (Figure 1-2) were selected to evaluate the breakwater transmission within the harbor. After careful examination, two types of wave conditions were identified and selected for this analysis as representative of typical storm wave conditions that could impact harbor navigation. These wave conditions correspond to local wind induced waves with short peak wave periods (H_s= 5 feet, T_P= 8 second) and swell type waves with longer peak wave periods but lower wave heights (H_s= 2 feet, T_P= 19 second).

Transmitted wave heights were calculated using the same methodology employed in the FEMA study, and a MHHW elevation was selected to define still water level conditions in Monterey Harbor and calculate the breakwater freeboard. Table 4.2 and Table 4.3 show the computed wave transmitted heights under different sea level rise scenarios for both assumed wave conditions.

Table 4.2: Breakwater Wave Transmission for Swell Waves (long period)

SLR Scenario (in)	Still Water Level (ft)	Significant Wave Height (ft)	Breakwater Freeboard (ft)	Transmitted Wave Height (ft)
No SLR	5.5	2.0	4.5	0
8.8	6.2	2.2	3.8	0
28.3	7.9	2.4	2.1	0
62.6	10.7	2.6	-0.7	1.2

Table 4.3: Breakwater Wave Transmission for Wind Waves (short period)

SLR Scenario (in)	Still Water Level (ft)	Significant Wave Height (ft)	Breakwater Freeboard (ft)	Transmitted Wave Height (ft)
No SLR	5.5	5.0	4.5	0.1
8.8	6.2	5.2	3.8	0.5
28.3	7.9	5.4	2.1	1.2
62.6	10.7	5.6	-0.7	2.4

For lower SLR scenarios (1-2 foot) the breakwater would continue to provide effective wave protection under both assumed wave conditions. However, results indicate that the efficiency of the breakwater could be significantly reduced under the ~5-foot SLR scenario. The potential 1- to 2-ft increase in wave heights within the harbor under this high SLR scenario would be very problematic for vessels moored on the Coast Guard Pier and the Breakwater Cove Marina. Although the wave heights are relatively small, this type of long period wave energy can result in damage to docks and mooring infrastructure.

The municipal marina would also experience an increase in wave energy under this scenario but to a much lesser degree than the boating infrastructure near the Coast Guard Pier. The elevation of the crest of the existing wave wall was estimated to be roughly 12.5 feet NAVD88 based on a measurement from the deck of Wharf 2. This is roughly 2.5 feet higher than the crest of the breakwater and therefore provides an added level of protection for this marina under the high SLR scenario evaluated.

5. Sea Level Rise Impacts – Transect Summary Sheets

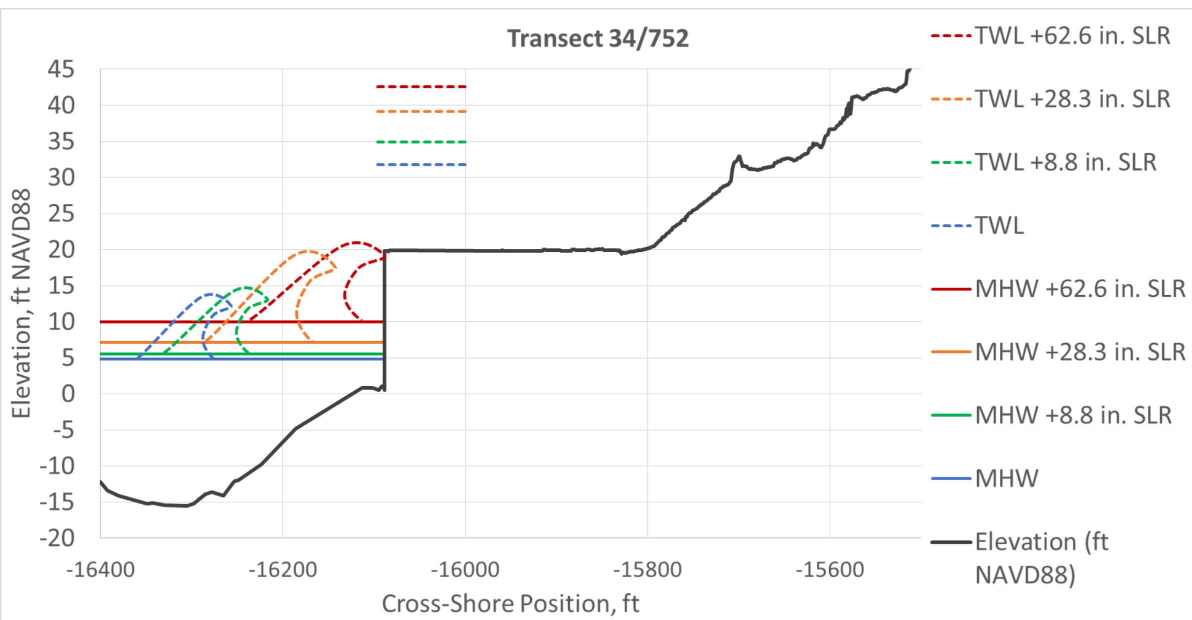
The SLR summary sheets provide the results of hazard analyses for each FEMA transect reach or major feature within the study area. Coastal hazard features are briefly described here and discussed more thoroughly in the Coastal Hazards section. These sheets generally include:

- An oblique aerial image of the reach or feature, with the transect location and major features labeled.
- A site description of the shoreline and types of structures along the reach.
- A transect plot displaying:
    - Topographic features (elevation and cross-shore position) used in analyses.
    - The mean high water (MHW) line, which represents the landward limit of tidelands.
    - The total water level (TWL), which represents the 100-year event wave runup elevation.
    - The wave crest elevation, shown as a dashed wave above the MHW line. This is the elevation of a wave that could break on the shoreline under a range of extreme wave events.
- The SLR summary includes:
    - The numerical values of the TWL and wave crest elevation shown in the transect plot.
    - Transect reach or feature specific impacts for each SLR scenario, general impacts are described in the Tidelands and Coastal Resources section.

5.1 Steinbeck Plaza to Monterey Bay Aquarium

1. Site Description

Cannery Row waterfront visitor serving commercial parcels with aquarium, lodging, retail and restaurant uses. Pile supported structures (varying condition/construction) and seawalls.



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 32 ft at seawall | Wave crest elevation 9-14 ft at pile supported structures

Impacts: Seawall fronted portion of structure is most vulnerable to wave runup forces with up to 12 ft of runup above the top of the seawall (+20, ft NAVD). Wave runup in this area could flood adjacent deck areas; however, the recurved shape likely directs runup seaward. The first level of pile supported structures are above (assumed EL +20) the wave crest elevation. Wave runup forces act on the piles and other foundation elements. The structure will experience uplift forces as wave energy travels up the bluff slope below the deck. Deficient foundations could be damaged during a significant wave event. Older structures with timber piles and bracing in deteriorated condition may be more susceptible to damages compared to newer concrete structures in good condition. Building damage could result in flooding, closure, repair costs, and financial losses for these businesses while repairs are made.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 35 ft at seawall | Wave crest elevation 11-15 ft at pile supported structures

Impacts: Rising sea levels will result in higher wave runup elevations, causing wave forces to act at higher elevations on the foundation and increasing the frequency and potential for damage to structures that cannot withstand wave runup forces. The coastal habitats experience a shifting intertidal zone.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 39 ft at seawall | Wave crest elevation 15-20 ft at pile supported structures

Impacts: Wave runup forces act at a higher elevation on the structures and waves may break near the fist level of structures increasing structural damage potential and frequency. The intertidal zone continues to shift.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 43 ft at seawall | Wave crest elevation 18-21 ft at pile supported structures

Impacts: Wave runup forces act at a higher elevation on the structures and waves may break at the fist level of structures. Breaking waves could result in flooding of deck areas and damage to structures. Structural damage may require more substantial repairs or retrofits with increased costs and downtime. Coastal habitats along the rocky shore would be impacted by a substantial shift in the intertidal zone.

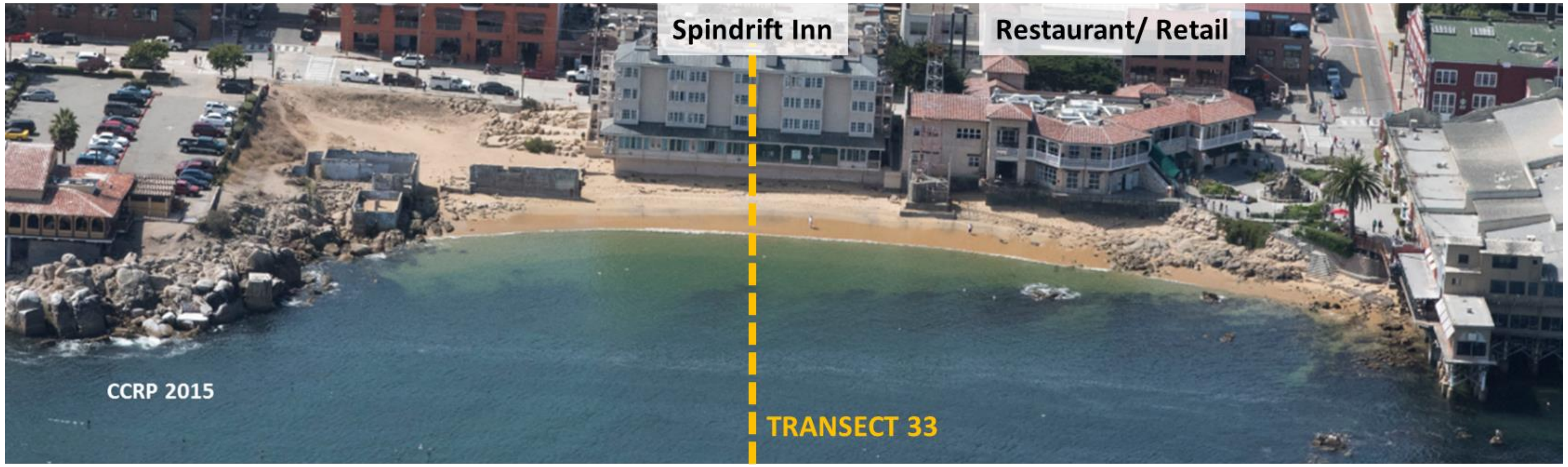
3. Impact Threshold (Trigger)

The first level of these structures is vulnerable to breaking wave forces between 2 and 5 ft of SLR, these conditions could warrant replacement, repairs, retrofits, and changes to operations (deck use). Older timber pile structures and those in poor condition, with lower critical foundation elements will reach damage thresholds sooner.

4. Adaptation

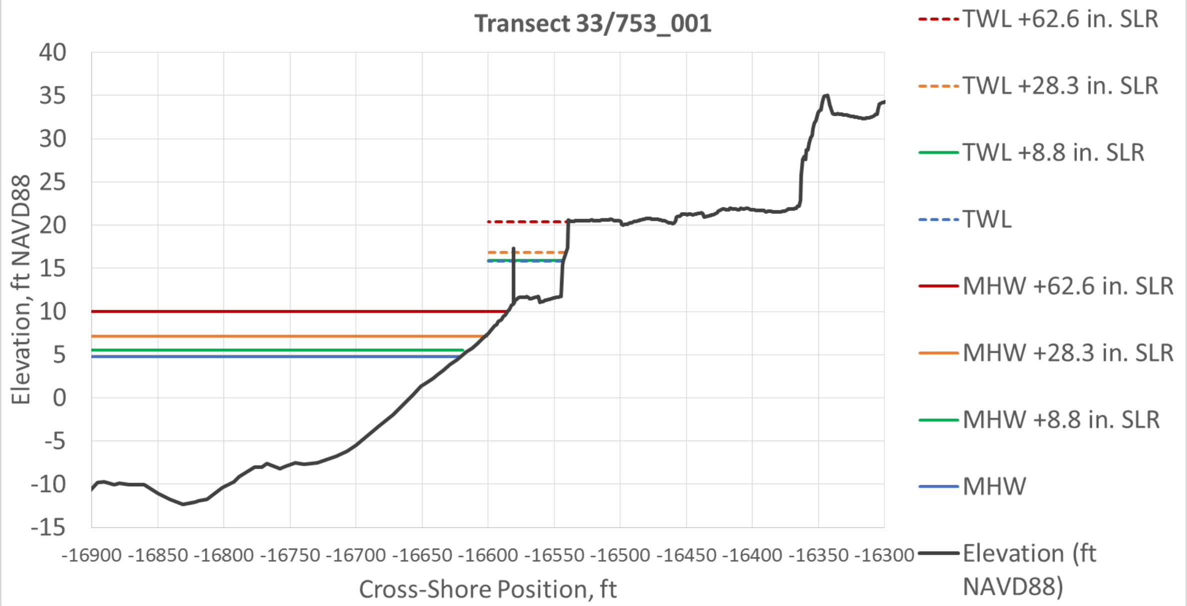
A pro-active inspection, maintenance and repair program will be vital to the resilience of these waterfront structures and may be sufficient for lower SLR increments (1-2 feet). Significant structural upgrades will be required to maintain a high level of protection against extreme storms in combination with a 5 foot SLR scenario.

5.2 McAbee Beach



1. Site Description

Cannery Row waterfront visitor serving commercial parcels with, lodging, retail and restaurant uses. Sandy pocket beach bound by rocky headlands/reef, remnant historic structures, backed by structures with seawalls. ADA beach access from the roadway/sidewalk to the pocket beach.



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 16 ft at structure seawall

Impacts: Episodic beach erosion following significant wave events can result in loss of sand and steep beach slopes. Public access for recreational beach use is limited or becomes more difficult with eroded conditions due to difficulties for beach users navigating steeper slopes and the loss of dry beach space for activity. The sandy beach may be an attraction for lodging, restaurant, and retail patrons and its loss could impact surrounding businesses. Waterfront activities like kayaking, swimming, and diving and their associated revenue streams could be impacted by difficulties in access from this site. Coastal habitats could be impacted by the loss of sandy beach.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 16 ft at structure seawall

Impacts: Rising sea levels shift the sandy shoreline landward, further limiting public access and recreational beach use area. A retreating shoreline provides less of a buffer for storm erosion, impacting sandy shore coastal habitats and shifting the intertidal zone.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 17 ft at structure seawall

Impacts: Public access, recreation, erosion, and coastal habitat impacts progress with rising sea levels.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 20 ft at structure seawall

Impacts: Public access along the shoreline and recreational beach use is lost as a dry beach no longer exists, some sand may be retained behind the remnant structure foundations. Wave runup elevations extend to the edge of the road/first floor of structures, which could result in minor flooding from splash over conditions. Structures along the back of the beach and the roadway are susceptible to erosion and undermining from scour as wave energy reaches higher elevations and frequently impacts the vertical seawalls along the backshore. Coastal habitats are impacted by the loss of sandy beach and large changes to the intertidal zone.

3. Impact Threshold (Trigger)

Coastal squeeze from 1-2 feet of SLR impacts coastal access, beach width and coastal habitat along this reach. Impacts from SLR greater than 2 feet could be problematic for overhanging deck at the Spindrift Inn. Wave runup elevations are at the edge of the road/first floor of structures during the highest SLR scenario and could result in minor flooding from splash over conditions.

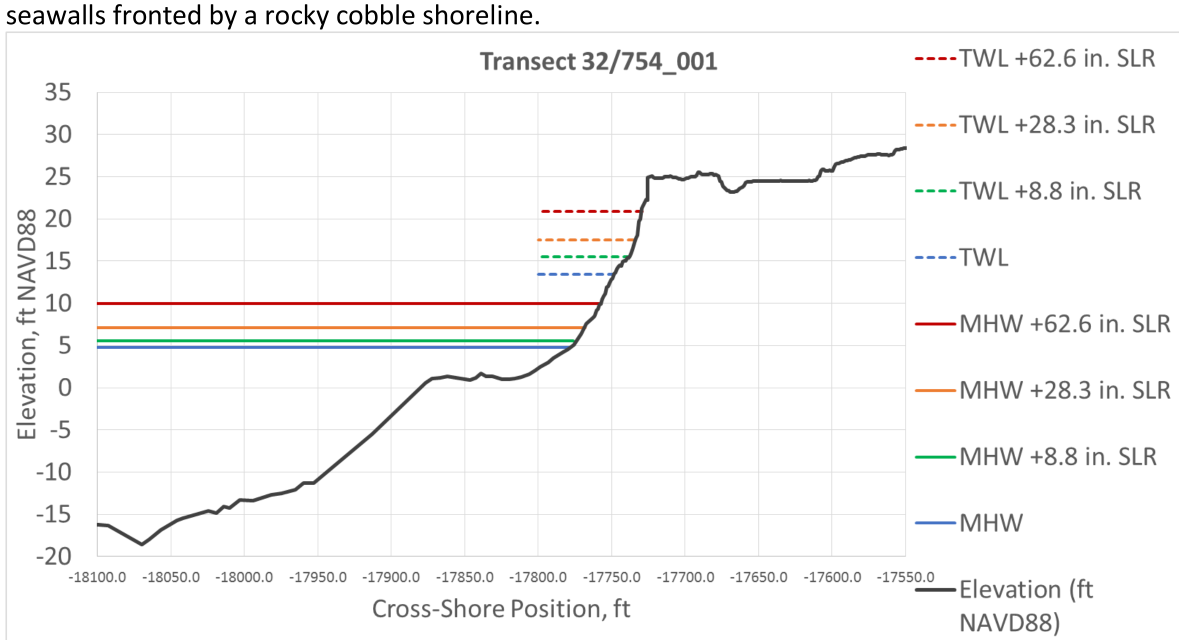
4. Adaptation

Beach nourishment could be implemented to maintain a sandy beach at this location. Existing seawalls must be maintained in a good state of repair. Upgrades will probably be likely for long-term protection of the Spindrift Inn. Beach widths, erosion and coastal habitat should be monitored at the site. These observations can be used to determine the need for future beach nourishment or habitat restoration efforts.

5.3 Chart House to El Torito

1. Site Description

Cannery Row waterfront visitor serving commercial parcels with restaurant uses. Potential development of vacant lots in the future. Rocky bluff headlands/reef bound this transect with structures on piles at both ends. Vacant lots have remnant historic structures/foundations and seawalls fronted by a rocky cobble shoreline.



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 13 ft at shoreline

Impacts: Structures are subject to wave runup forces on piles and other foundation elements. Structures can experience uplift forces as wave energy travels up the bluff slope and encounters the bottom of the deck. The pile supported structure on the right side of this zone is fronted by a steeper slope compared to other areas and runup elevations are likely closer to those at transect 34 (TWL 32 ft). Anecdotal evidence indicates past damage to windows during significant wave events. Building damage could result in flooding, closure, repair costs, and financial losses for these businesses while repairs are made.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 16 ft at shoreline

Impacts: Rising sea levels will result in higher wave runup elevations, increasing the frequency and potential for damage to structures that cannot withstand wave runup forces. The rocky shore coastal habitat begins to experience a shifting intertidal zone. Steeper portions of this zone may have higher runup elevations close to those at transect 34 (TWL 35 ft).

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 18 ft at shoreline

Impacts: Structural damage potential and frequency continues to increase with rising sea levels and the intertidal zone continues to shift. T Steeper portions of this zone may have higher runup elevations close to those at transect 34 (TWL 39 ft).

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 21 ft at shoreline

Impacts: Wave runup forces act at a higher elevation on the structures but remain below the first floor and roadway elevation (assumed to be ~25-30 ft). Structural damage may require more substantial repairs or retrofits with increased costs and downtime. Coastal habitats along the rocky shore would be impacted by the intertidal zone occupying a steeper portion of the bluff. Steeper portions of this zone may have higher runup elevations close to those at transect 34 (TWL 43 ft).

3. Impact Threshold (Trigger)

Impacts to coastal habitat and minor damage to El Torito from wave runup is a concern for lower sea levels rise increments (1-2 feet SLR). Other impact thresholds depend on type of development planned for the site.

4. Adaptation

Existing structures can be retro-fitted to become more resilient to damage from wave runup. New development should be designed to mitigate SLR impacts from lower SLR increments along with an adaptation plan to mitigate impacts from higher amounts of SLR.

5.4 Monterey Plaza Hotel

2. Sea Level Rise Summary

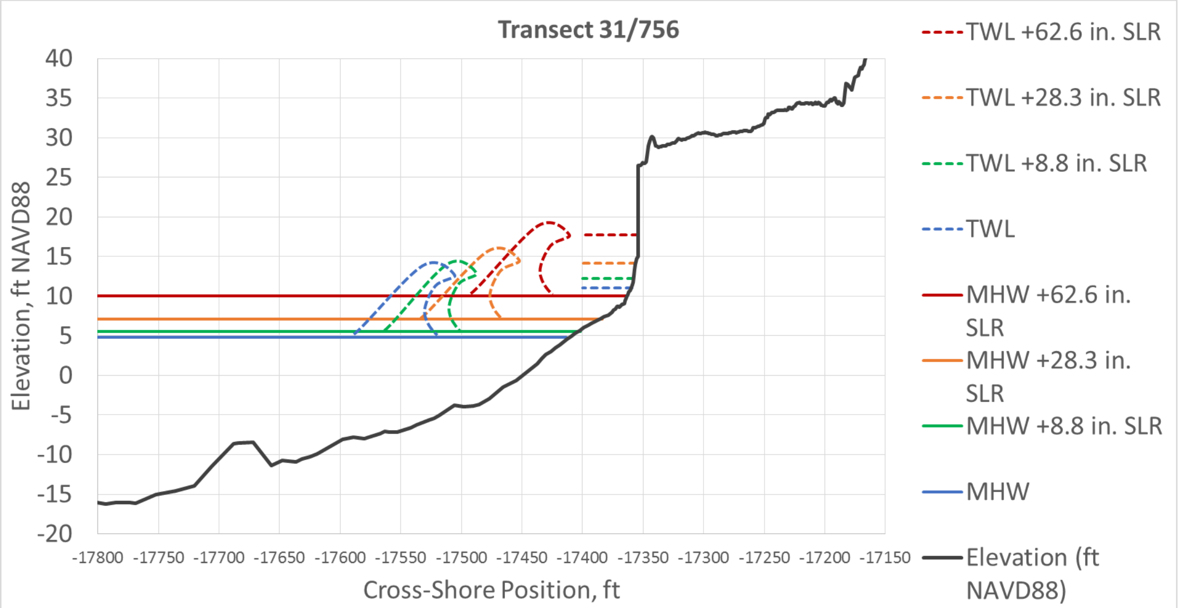
Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 11 ft at seawall | Wave crest elevation 8-14 ft at pile supported structures

Impacts: Episodic beach erosion following significant wave events can result in loss of sand, steep beach slopes, and eroded access ways (existing stairs) at the pocket beach impacting public access and businesses that benefit from being located near the beach. Waterfront activities like kayaking, swimming, and diving and their associated revenue streams could be impacted by difficulties in access from this site. Coastal habitats could be impacted by the loss of sandy beach. The first floor and deck levels of the pile supported structures are estimated to have an EL of +15-18 ft and lower deck/foundation elements are vulnerable to damage from breaking waves. Waves that break on or below the deck will impart forces on piles, and other foundation elements. Waves breaking below the deck will result in uplift forces on the deck.

1. Site Description

Cannery Row waterfront visitor serving commercial parcels with lodging uses. Large, pile supported structures with a small sandy pocket beach backed by a seawall.



2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 12 ft at seawall | Wave crest elevation 9-14 ft at pile supported structures

Impacts: Rising sea levels shift the sandy shoreline landward, further limiting public access and recreational beach use area. A retreating shoreline provides less of a buffer for storm erosion, impacting sandy shore coastal habitats and shifting the intertidal zone. Lower deck/foundation elements are vulnerable to damage from breaking waves. Building damage could result in flooding, closure, repair costs, and financial losses for these businesses while repairs are made.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 14 ft at seawall | Wave crest elevation 11-16 ft at pile supported structures

Public access, recreation, erosion, and coastal habitat impacts progress with rising sea levels. The first floor and deck levels of the pile supported structures could experience up to 1 ft of inundation from breaking waves, increasing vulnerability to damage, repair costs and downtime.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 18 ft at seawall | Wave crest elevation 14-19 ft at pile supported structures

Impacts: Public access along the shoreline and recreational beach use is lost as a dry beach no longer exists. Wave runup is not expected to overtop the seawall; however, the first floor and deck levels of the pile supported structures could experience up to 4 ft of inundation from breaking waves during a 100-Year event. The extent and severity of damage is expected to significantly increase as wave energy is encountered at higher elevations. Repairs may be substantial under these conditions and result in extended periods of downtime. Coastal habitats are impacted by the loss of sandy beach and large changes to the intertidal zone.

3. Impact Threshold (Trigger)

Wave uplift forces and flooding could be problematic for the pile supported structures for an extreme event combined with ~1 ft of SLR. These hazards increase substantially when wave crest elevations approach the deck level with ~5 ft of SLR. Feasibility of beach access will decline with rising sea levels and be completely eliminated under the highest SLR scenario. Public access, recreation (and associated revenue streams), and coastal habitats are impacted by the loss of beach as sea levels rise.

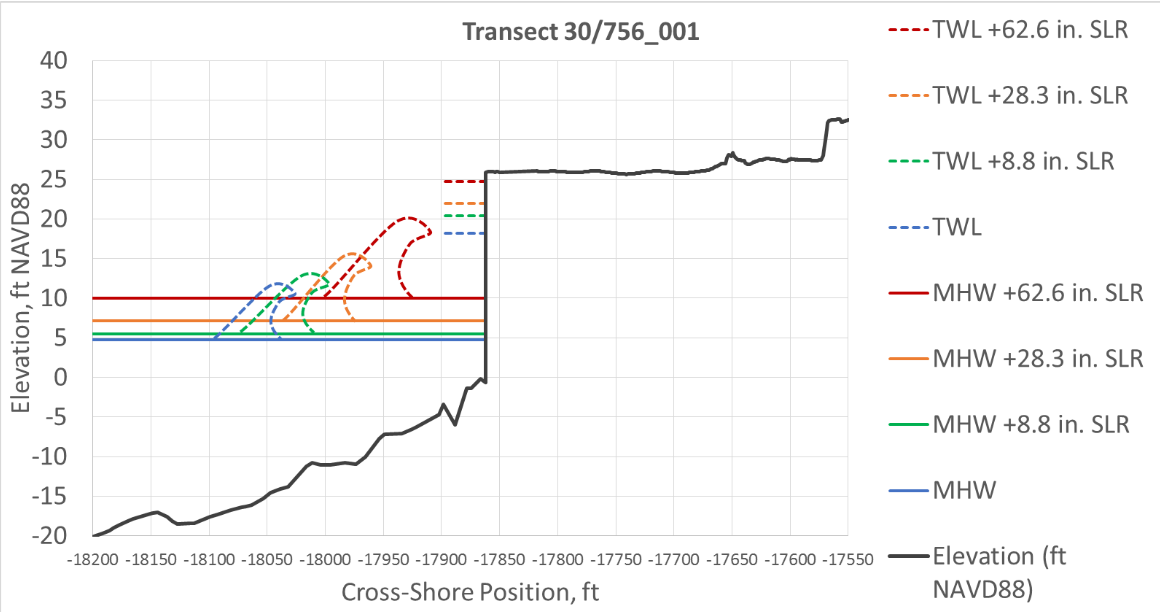
4. Adaptation

Deck areas will need to be closed (and furniture secured/removed) for safety during significant wave events, the frequency of closure will increase with SLR. Beach nourishment could be implemented to maintain a sandy beach at this location; however, sand retention will become more difficult with rising sea levels.

5.5 Monterey Bay Inn

1. Site Description

Cannery Row waterfront visitor serving commercial parcels with lodging, park and miscellaneous uses. Pile supported and seawall fronted structures with a park fronted by rocky cobble bluffs. A public restroom and sewer lift station are located at this site (left end of transect).



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 18 ft at seawall | Wave crest elevation 8-12 ft at pile supported structures

Impacts: Waves break directly on the rocky cobble bluff fronting the park, on the seawall that fronts the Monterey Bay Inn, and on/below the pile supported structure. Wave runup and crest elevations are below the first level of both structures (assumed EL +26 ft for both) with about 8 ft of freeboard. The rocky bluff fronting the park is at a lower elevation; however, the roadway beyond the park is above (assumed EL +26) the wave runup elevation. The rocky bluff and park could experience erosion during a significant wave event but this is not expected to impact use of the space during ambient conditions. Deficient foundations, like the pile supported structure to the right of the transect could be damaged during a significant wave event. Building damage could result in flooding, closure, repair costs, and financial losses for these businesses while repairs are made.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 20 ft at seawall | Wave crest elevation 9-13 ft at pile supported structures

Impacts: Wave runup and crest elevations increase but do not overtop structures, forces associated with waves will act at a higher elevation on these structures. Erosion potential of the rocky bluff increases. Intertidal habitats begin to shift in elevation.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 22 ft at seawall | Wave crest elevation 10-16 ft at pile supported structures

Impacts: Wave hazards increase in elevation but still remain below structure and roadway elevations. Intertidal habitats continue to shift.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 25 ft at seawall | Wave crest elevation 15-20 ft at pile supported structures

Impacts: Wave runup elevations are approximately 1 ft below the first floor elevation of structures which could result in minor spray/splash conditions. Erosion of the rocky bluff and park areas is likely but the roadway is still above the wave runup elevation. Intertidal habitats have shifted significantly. The public restroom and lift station are assumed to be at an elevation ranging from 24-26 ft and could be vulnerable to flooding from wave runup under this scenario.

3. Impact Threshold (Trigger)

The first floor elevation of structures in this reach are above the highest SLR wave runup elevation. Adequately elevated, well-designed structures, maintained in good repair could accommodate up to 5 ft of SLR. SLR could result in some erosion along the rocky bluff shoreline fronting the park, this area provides a buffer for the roadway.

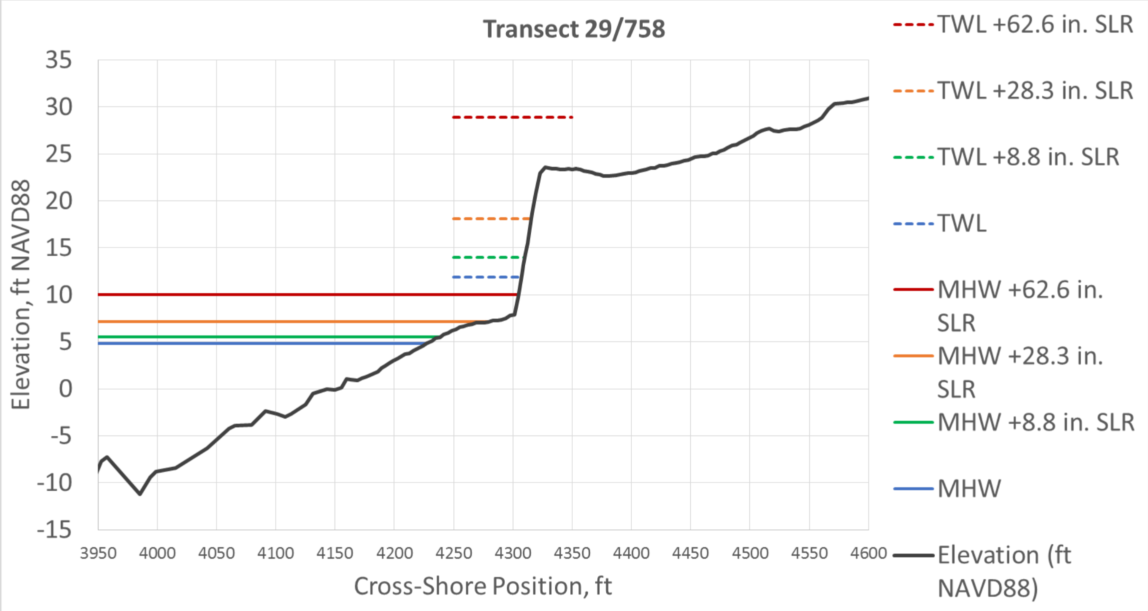
4. Adaptation

Maintenance and repair of seawalls / building foundations will be most important for the Monterey Bay Inn and Lift Station structures. Erosion should be monitored along with the potential for undermining of the lift station structure. The extent and severity of erosion could be a trigger for measures to improve the lift station or re-configure the bluff top park areas.

5.6 San Carlos Beach Park

1. Site Description

Sandy pocket beach backed by a grouted revetment. Beach is bound by the Coast Guard Pier and a cobble bluff/headland. This is a popular location for recreational diving and other beach use.



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 12 ft

Impacts: Episodic beach erosion following significant wave events can result in loss of sand and steep beach slopes impacting public access for recreation due to difficulties for beach users navigating steeper slopes and the loss of dry beach space for activity. The sandy beach may be an attraction for lodging, restaurant, and retail patrons in the vicinity and its loss could impact surrounding businesses. Waterfront activities like kayaking, swimming, and diving and their associated revenue streams could be impacted by difficulties in access from this site. Coastal habitats could be impacted by the loss of sandy beach.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 14 ft

Impacts: Rising sea levels shift the sandy shoreline landward, further limiting public access and recreational beach use area. A retreating shoreline provides less of a buffer for storm erosion, impacting sandy shore coastal habitats and shifting the intertidal zone. Increased wave runup elevations and water levels could undermine or damage the revetment.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 18 ft

Impacts: Public access, recreation, erosion, and coastal habitat impacts progress with rising sea levels. The mean high water line is near the toe of the revetment.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 29 ft

Impacts: Public access along the shoreline and recreational beach use is lost as a dry beach no longer exists, Wave runup elevations overtop the revetment and could flood or erode the park and lower parking areas. The revetment would likely be damaged by a significant wave event. Coastal habitats are impacted by the loss of sandy beach and large changes to the intertidal zone.

3. Impact Threshold (Trigger)

Beach erosion is a problem under all sea level scenarios with an estimated loss of 70% of beach area with 2 feet of SLR. Wave runup elevations could overtop the revetment under the 5 ft SLR scenario resulting in flooding and erosion at the park. Public access, recreation (and associated revenue streams), and coastal habitats are impacted by the loss of beach as sea levels rise.

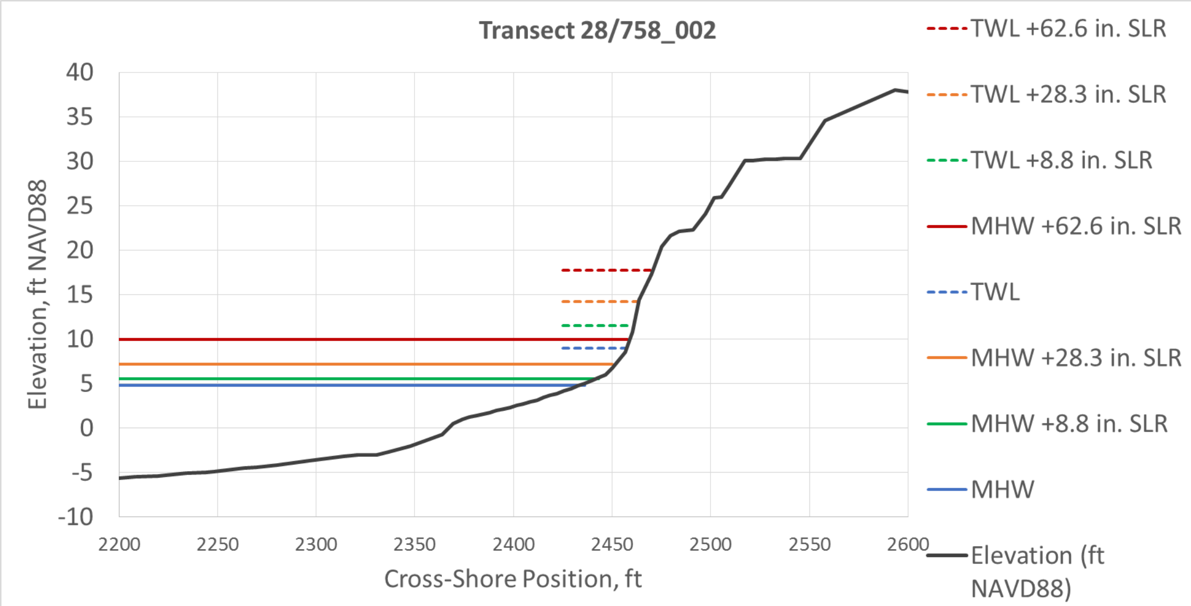
4. Adaptation

Beach nourishment could be implemented to maintain a sandy beach at this location; however, sand retention will become more difficult with rising sea levels. The upper park/revetment could be reconfigured to better accommodate SLR while maintaining access to the beach. Beach widths and erosion should be monitored at the site, these parameters can be used to determine thresholds for beach nourishment or the need for a larger scale adaptation project such as park re-configuration.

5.7 Monterey Harbor Recreation Trail

1. Site Description

Monterey Harbor recreation trail behind the Coast Guard pier and breakwater. Rock, cobble, and earthen bluffs with engineered retaining walls along some sections. Major thoroughfare for pedestrian traffic between the Harbor amenities and Cannery Row.



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 9 ft

Impacts: Wave runup elevations are below the recreation trail elevation (+22 ft). Portions of the recreation trail bluffs are engineered and resistant to erosion.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 12 ft

Impacts: Wave runup elevations increase by 3 ft but are still below the recreation trail. Intertidal habitats begin to shift.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 14 ft

Impacts: Wave runup elevations are still below the trail elevation but increase by 5 ft compared to current conditions, which may result in erosion of non-engineered bluff reaches and undermining of the recreation trail. Damage to the recreation trail would impact public access, tourism and associated revenue streams as this is a major thoroughfare for pedestrian access between the marina and Cannery Row. Intertidal habitats continue to shift.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave runup TWL 18 ft

Impacts: Wave runup elevations are approximately 4 ft below the recreation trail. Non-engineered bluff reaches will experience erosion that could undermine the recreation trail. Intertidal habitats have shifted significantly.

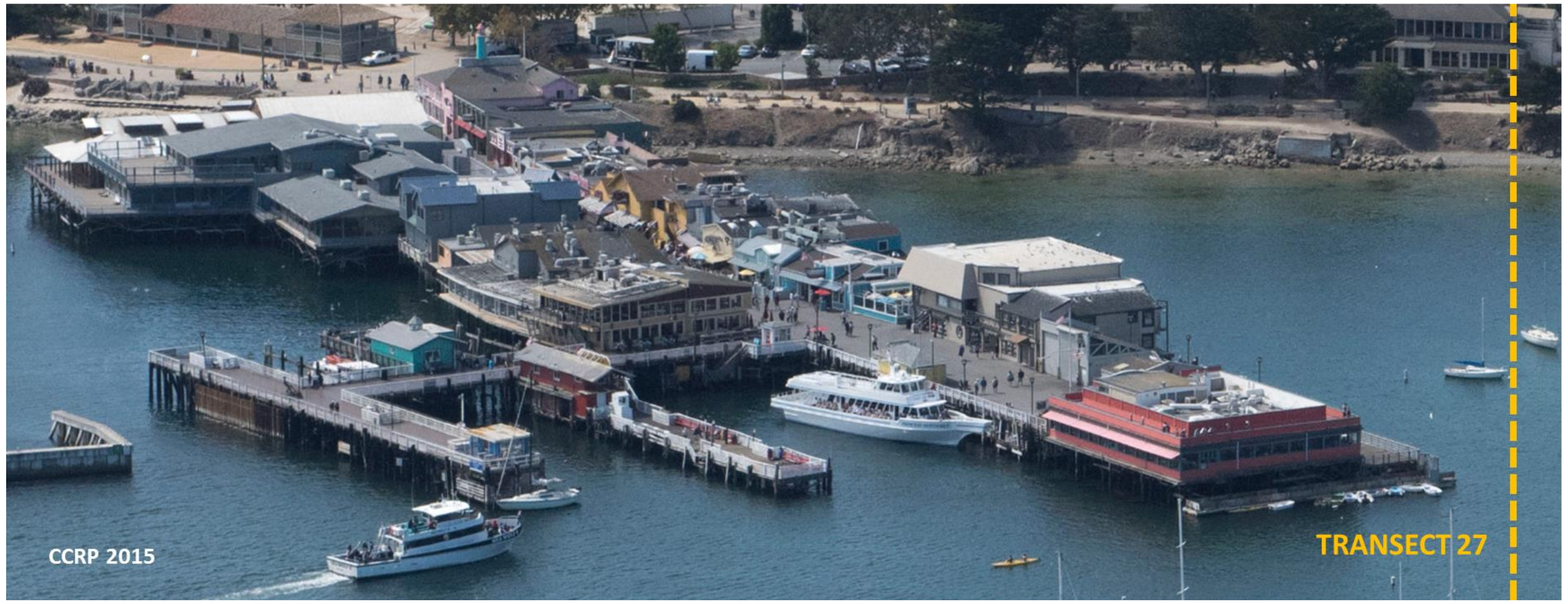
3. Impact Threshold (Trigger)

Additional reaches of the recreation trail shoreline could become vulnerable to erosion as sea levels rise. There are too many unknowns with historic erosion rates and future erosion rates to identify a SLR based trigger. SLR will also result in “coastal squeeze” impacts on intertidal habitat due to the steep slopes and engineered bluffs along this stretch of shoreline.

4. Adaptation

Erosion should be monitored along this shoreline to identify triggers for adaptation measures to preserve this major thoroughfare for public access and tourism. Bluff protection through a sculpted concrete retaining wall could be implemented along other reaches. Other measures could include nearshore reefs and rocky intertidal habitat restoration to protect the bluff toe and provide opportunity for intertidal habitat to adapt with SLR.

5.8 Old Fisherman's Wharf (Wharf 1)

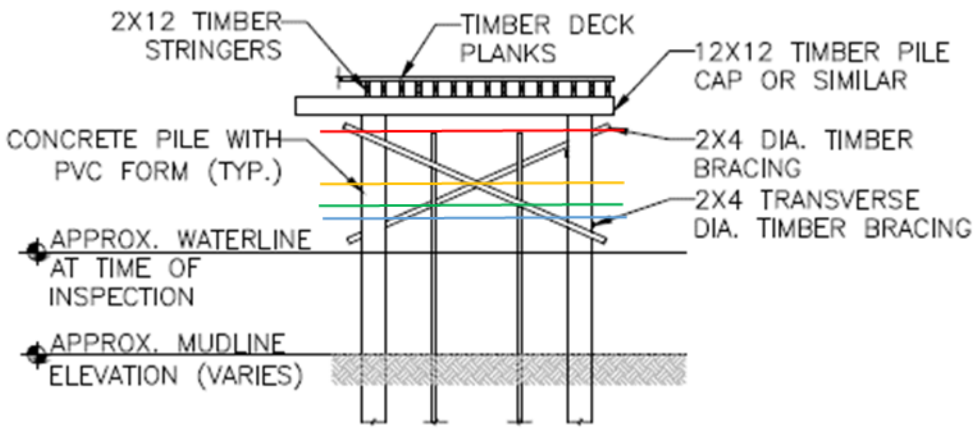


1. Site Description

Visitor serving commercial parcels with recreation, retail and restaurant uses. Pile supported wharf within Monterey Harbor.

Analysis Features – FEMA Transect 27/28

Main Pier Deck Elevation	~15 ft and Varies
Lower Pier Deck Elevations	~8-10 ft
Other	Floating Docks



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 5-8 ft at wharf

Impacts: The wharf is in a poor state of repair (COWI 2017). The deck and deficient foundation elements are vulnerable to damage during a significant wave event due to their state of repair and low elevations in some areas. This wharf is used heavily by tourists and also by commercial vessels.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 6-9 ft at wharf

Impacts: Damage and lower deck flooding increases with rising sea levels. Increased damages impact commercial operations and public access. Damages from a significant wave event could lead to an extended period of closure while inspections and repairs are made. The pier may be able to accommodate this level of SLR if regular maintenance is performed, additional maintenance may be needed due to higher water levels accelerating degradation.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 8-11 ft at wharf

Impacts: Potential for storm related damage continues to increase with rising sea levels, impacting commercial operations and public access. Lower foundation elements are subject to increased degradation from higher water levels requiring continuous maintenance which may not be feasible and partial/full replacement of damaged concessions.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 11-14 ft at wharf

Impacts: The main deck is still above wave crest elevations but lower deck sections and deficient foundation elements would likely result in substantial damage during a significant wave event and require exorbitant levels of maintenance during ambient conditions. Wave transmission will increase substantially if the breakwater is not raised. Public access, operations and commercial navigation uses of the wharf will be impacted by these conditions.

3. Impact Threshold (Trigger)

The wharf is in need of substantial repairs as described in a recent inspection report (COWI 2017). This structure is currently vulnerable to damage during a significant wave event and these vulnerabilities increase as sea levels rise. Lower deck levels could experience damage with ~1-2 feet of SLR. Maintenance of the current pier will likely be impractical for 2 to 5 ft of SLR.

4. Adaptation

Regular inspection, maintenance and repair are vital to preserving Wharf 1 in the short-term and will grow more important for each increment of sea level rise. A pro-active maintenance and repair strategy may be sufficient to mitigate impacts from ~1-2 feet of SLR. However, over longer time horizons the combination of aging structures and increasing hazards will likely result in significant damage to Wharf 1 triggering a phased replacement program to maintain the current use and function of the wharf.

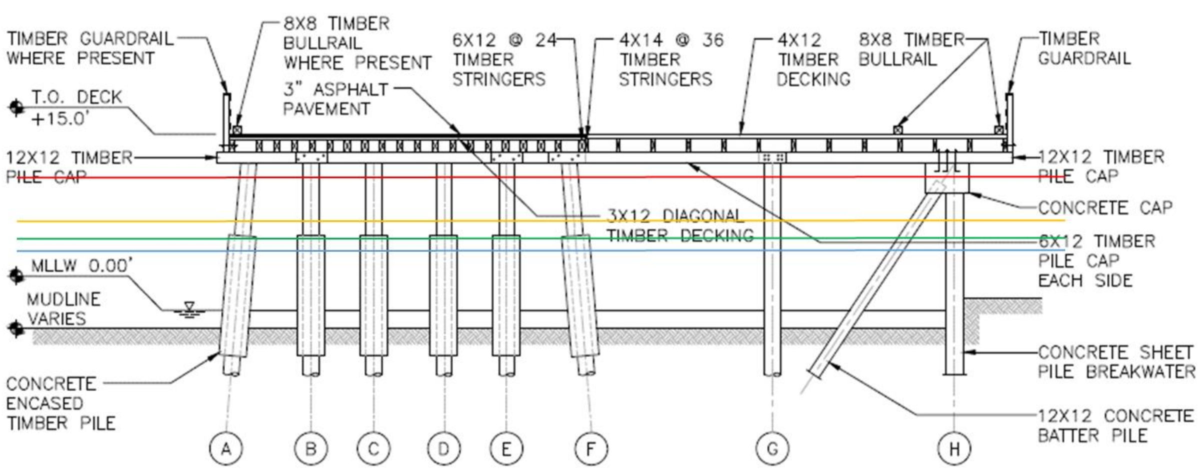
5.9 Municipal Wharf 2

1. Site Description

Operational commercial fishing wharf with vehicular traffic.

Analysis Features – FEMA Transect 27/28

Deck Elevation	+15 ft



2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 8-15 ft at wharf

Impacts: The wharf is in a poor state of repair (COWI 2017). Deficient foundation elements are vulnerable to damage during significant wave events. The wharf is used for commercial activity, which would be impacted by damages.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 9-16 ft at wharf

Impacts: Wave energy reaches higher elevations at the foundation elements as sea levels rise increasing vulnerability in deficient areas. Increased damage and sea conditions could impact commercial ship operations.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation 9-17 ft at wharf

Impacts: Wave crest elevations increase but are still below the deck elevation. Deficient foundation elements remain vulnerable with rising sea levels potentially impacting commercial ship operations.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) wave crest elevation12-20 ft at wharf

Impacts: During a significant wave event, wave crest elevations could result in 1 ft of flooding and damage the wharf; the building on the wharf could also be damaged. Damages to the wharf would impact commercial ship operations while repairs are made. Sea conditions and water levels under this scenario may impact ship operations.

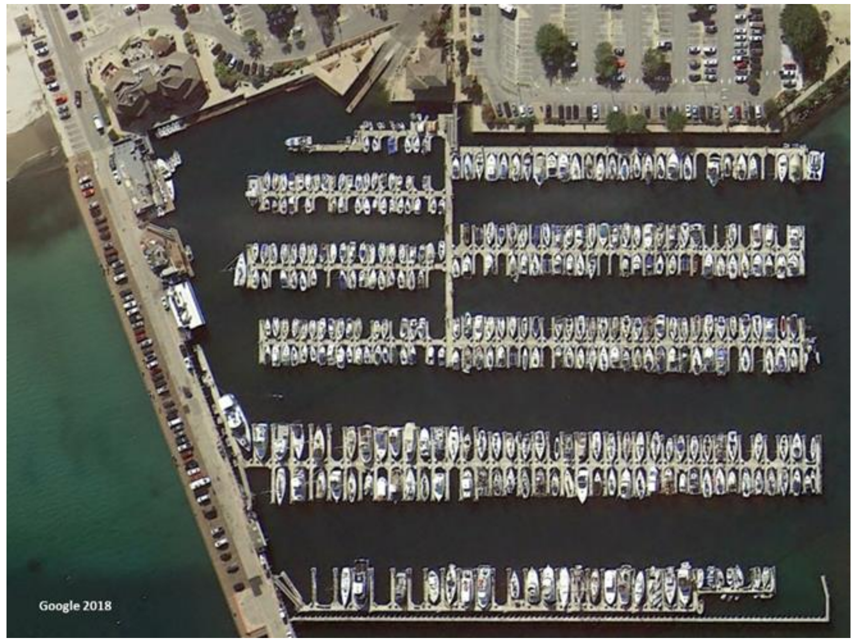
3. Impact Threshold (Trigger)

Wharf 2 is in need of substantial repairs as described in a recent inspection report (COWI 2017). This structure is currently vulnerable to damage during a significant wave event and these vulnerabilities increase as sea levels rise. The outer end of the pier could experience damage due to wave impacts in an extreme storm combined with ~1-2 feet of SLR. Maintenance of the current pier will likely be impractical for 2 to 5 ft of SLR.

4. Adaptation

Regular inspection, maintenance and repair are vital to preserving Wharf 2 in the short-term and will grow more important for each increment of sea level rise. A pro-active maintenance and repair strategy may be sufficient to mitigate impacts from ~1-2 feet of SLR. However, over longer time horizons the combination of aging structures and increasing hazards will likely result in significant damage to Wharf 2 triggering a phased replacement program to maintain the current use and function of the wharf.

5.10 Monterey Harbor Marinas



1. Site Description

The Municipal Marina is large marina with floating docks bound by Municipal Wharf 2 and a concrete sheet pile wave wall. The City also operates and maintains the mooring field between Wharf 1 and the Coast Guard Pier. Breakwater Cove is a smaller, privately owned and operated marina with floating docks behind the Coast Guard Pier and breakwater.

Analysis Features – FEMA Transect 27/28

Municipal Marina Pile Top EL	~13-14 ft
Breakwater Cove Pile Top EL	~10-12 ft
Municipal Marina Wave Wall EL	~12-13 ft
Coast Guard Pier Breakwater EL	+10 ft

2. Sea Level Rise Summary

Current (No SLR)

Coastal Storm: 100-YR (1% annual chance) water surface elevation 5-9 ft at marina

Impacts: A significant wave event can result in surging conditions at the marina but has not resulted in any significant damages.

2030: < 1 ft SLR (8.8 in.)

Coastal Storm: 100-YR (1% annual chance) water surface elevation 6-9 ft at marina

Impacts: If the breakwater is not raised, wave transmission will increase, which can result in more wave energy at the marinas potentially impacting navigation, commercial operations and public access.

2060: ~2 ft SLR (28.3 in.)

Coastal Storm: 100-YR (1% annual chance) water surface elevation 8-11 ft at marina

Impacts: Increased hazards during a significant wave event. Water levels inside of the marina during a significant wave event are approaching the top of pile elevation at the Breakwater Cove marina. There could be potential for floating docks to break free resulting in significant damage to boats, docks, and other marina infrastructure. If the breakwater is not raised, wave transmission will increase, potentially causing damage to marina infrastructure.

2100: ~5 ft SLR (62.6 in.)

Coastal Storm: 100-YR (1% annual chance) water surface elevation 11-14 ft at marina

Impacts: Substantial hazards during a significant wave event with water levels above the top of pile elevation. Floating docks will break free, the marina and boats will be severely damaged. Marina infrastructure like utility connections, gangways, and boat launch ramps may be damaged or dysfunctional during high tide conditions. If the breakwater is not raised, increased wave transmission will be a problem causing more frequent damage and downtime impacting navigation, commercial operations and public access.

3. Impact Threshold (Trigger)

The assessment indicates the marinas will continue to be effective for sea level rise up to 2 feet provided they are well maintained and repaired as necessary. SLR above 2 feet could be problematic for marina infrastructure at the Breakwater Cove marina assuming the top of pile elevations range from 10-12 ft NAVD 88. SLR of 5 feet would be problematic for the existing wave protection infrastructure resulting in marina damages during an extreme event.

4. Adaptation

The service life of the existing docks will likely expire before SLR becomes a major concern. Therefore, SLR adaptation strategies for marina infrastructure can be incorporated into planning and design of future marina upgrades. A key question will be whether the existing piles could remain, or if new (higher) guide piles will be needed to accommodate SLR over the facilities service life.

6. Damage Estimates

The potential for storm related damage under each sea level rise scenario was estimated using physical depth damage functions developed by a panel of experts for ten prototype coastal structures, incorporating data and information collected on coastal structures damaged by Hurricane Sandy. Their findings and recommended depth-damage functions were published in the North Atlantic Coast Comprehensive Study (NACCS): Resilient Adaptation to Increasing Risk, Physical Depth Damage Function Summary Report (USACE, 2015). This NACCS report provides separate depth-damage relationships for inundation, erosion, and wave impacts which are intended for use in cost-benefit analyses of Coastal Storm Risk Management (CRSM) projects.

These physical depth-damage functions were used to estimate a rough order of magnitude for potential storm damages under the future sea level rise scenarios evaluated in this study. The most vulnerable structures along the study area are the pile supported structures along Cannery Row and within the Harbor that are subject to increasing water levels and wave heights as sea level rises. The type of buildings along the Cannery Row tidelands range from 1-2 story restaurants such as the Fish Hopper (Figure 6-1) to multi-story hotels like the Monterey Plaza Hotel (Figure 6-2). Many of these buildings are supported on open pile/pier foundations where the building footprint extends seaward of the mean high tide line.

Figure 6-1: Fish Hopper Restaurant (1-2 stories) supported on Open Pile Foundation

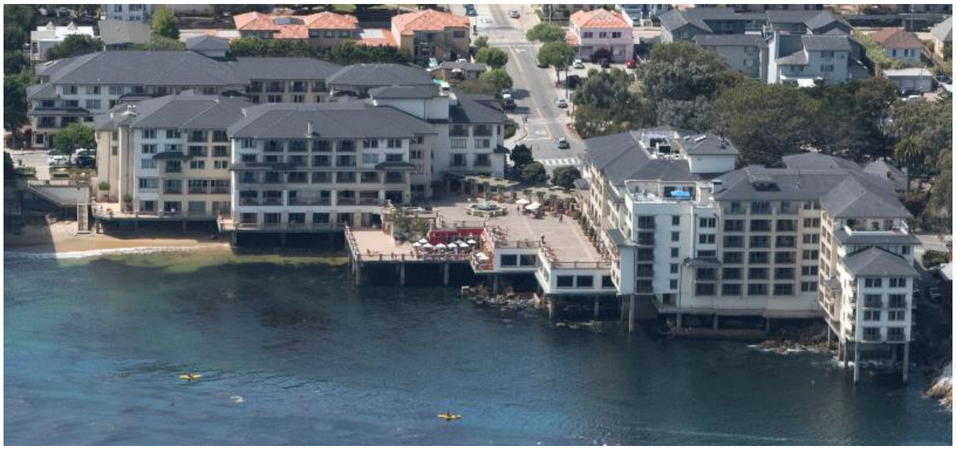


Figure 6-2: Monterey Plaza Hotel (5-7 stories) supported on Open Pile Foundation

One of the challenges in applying the depth damage functions to the Monterey study area is to identify the most representative prototype structures. The prototypes evaluated in the NACCS report that are most representative of structures in the Monterey study area are type 4A (10 story Beach High Rise) and 7A (Single story on Open Pile Foundation). Examples of these structure types are shown in Figure 6-3. For each prototype considered in the NACCS report a minimum, maximum, and most likely depth damage function is provided.

Many of the single story pile supported buildings along the Cannery Row waterfront and Wharf 1 and 2 in the harbor are well represented by Prototype 7A. The depth-damage functions for this type of structure indicate that the potential for damage increases significantly as the wave crest elevation approaches the finished floor elevation (FFE) of a given structure.

The multi-story hotels along Cannery Row are not well represented by a single prototype in the NACCS report. The hotels typically are in the range of 4-6 stories with some buildings partially supported on open pile foundations. For these hotels the depth-damage functions of a "Beach High Rise" building (Prototype 4A) help illustrate how damages experienced at the first floor represent a smaller percentage of the overall structure value as indicated by the relatively flat curves in Figure 6-3. The depth-damage functions for this prototype assume a first floor at grade and therefore no damage is expected until the wave crest exceeds the FFE. This assumption may underestimate the potential for the start of damage where multi-story buildings are supported on pile foundations (e.g. Monterey Plaza Hotel and Monterey Bay Aquarium).

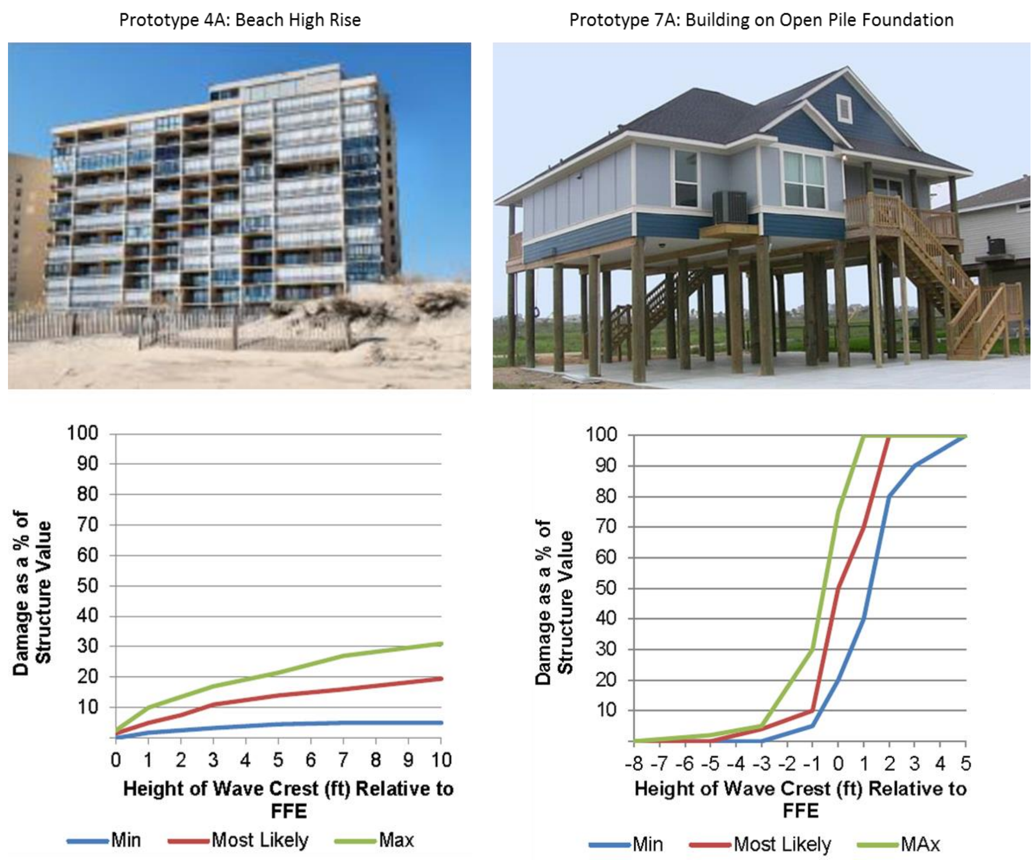


Figure 6-3: NACCS Prototype 4A and 7A Depth Damage Functions

The range of expected damage is also a function of several building characteristics including structure type, age, utility location, and condition of connections. The influence of these characteristics on damage potential are described in Table 6.1. For example, an older timber pile supported structure with horizontal bracing below deck and corroded connections (Figure 6-4) would experience a higher level of damage than a newer reinforced concrete pile supported structure (Figure 6-5). A thorough investigation of these characteristics at the parcel scale was beyond the scope of this study, therefore the estimated damage percentages relied on limited field observations at sites that are easily accessible to the public.

Table 6.1: Damage Potential based on Building Characteristics, Adapted from NACCS (USACE, 2015)

Building Characteristic	**Damage Potential**		
	Minimum	**Most Likely**	**Maximum**
Type of structure	Reinforced Concrete	Reinforced Timber	Timber
Age (years)	0-10	15-30	>30
Condition of connections	Good	Fair	Poor
Utilities	Elevated	Elevated	Below deck

Figure 6-4: Building Characteristics with Higher Potential for Storm Damage

Figure 6-5: Building Characteristics with Lower Potential for Storm Damage

6.1 Storm Damage Estimates for each Sea Level Rise Scenario

The potential storm damage estimates for parcels identified as vulnerable to increasing water levels and wave heights as sea level rises are listed in Table 6.2. The event of record from the FEMA data, which is generally close to the 1% annual chance exceedance probability, was used to evaluate potential damage from an extreme event. The maximum wave crest elevation evaluated at each transect was the main parameter used to relate current and future coastal hazards to damage as a percentage of structure value. For select transects shoreline erosion, wave runup, and uplift forces were also considered in estimating the potential for storm damage under each scenario.

Table 6.2: Extreme Storm Damage Estimates as a Percentage of Structure Value

Parcel Description	Analysis Transect	Assessor Parcel Number (APN)	Sea Level Rise Time Horizon			
			Current	2030	2060	2100
Aquarium	T34	1017002000	0%	0%	3%	30%
Aquarium	T34	1017003000	0%	0%	3%	30%
Clement Hotel	T34	1011013000	0%	0%	3%	30%
Cannery Row Co. (Bubba Gump, Fish Hopper, etc.)	T34	1011008000	1%	2%	5%	50%
Cannery Row Co. (Misc Café/Restaurant/Retail)	T33	1011009000	0%	0%	3%	30%
Spindrift Inn	T33	1021002000	0%	0%	10%	30%
El Torito	T32	1021005000	5%	10%	20%	50%
Monterey Plaza Hotel	T31	1031011000	0%	3%	8%	30%
US Coast Guard Pier	T28	GOV000004	4%	7%	10%	100%
Wharf 1	T27	GOV000003	5%	20%	30%	100%
Wharf 2	T27	GOV000002	5%	20%	30%	100%

Notes & Assumptions:

1) Damage estimates are intended to show how the rough order of magnitude of structural storm damage increases under each sea level rise scenario evaluated.
2) Damage estimates reported are a percentage of structural value. Content damage is not included in these estimates.
3) Damage estimates assume structural type & condition is constant for each time horizon (i.e. future degradation of existing structures is not factored into future damage estimates)

6.1.1 Transect 34 – Steinbeck Plaza to Monterey Bay Aquarium

Some damage may occur with ~1 foot of SLR to the timber pile/pier foundation of the Cannery Row Company parcel supporting restaurants such as Bubba Gumps Shrimp Company, Fish Hopper and Taste of Monterey. The damage estimates elsewhere along this reach are relatively low (<10%) until the 2100 time horizon (5 feet of SLR). Under this scenario the estimated wave crest elevation is at or very close to the FFE of most parcels along this reach. The NACCS depth damage functions indicate significant damage (20-80%) would result to pile supported structures from this type of hazard. Given that most of these structures are multi-story and only partially supported on open pile foundations, the estimated damage under this scenario ranges from 30-50%.

6.1.2 Transect 33 – Spindrift Inn to Steinbeck Plaza

These parcels are relatively well protected from coastal hazards over the near term (~ 1 ft SLR) due to their elevation of ~20 feet NAVD and the storm protection benefits provided by the sandy beach. With ~2 feet of sea level rise the benefits of the sandy beach will be reduced and wave runup will likely interact with the vertical walls of the Spindrift Inn and Cannery Row Company building. Wave runup against these structures could result in problematic uplift forces against the timber return wall and deck of the Spindrift Inn (Figure 6-6). Similar to the adjacent transect there is potential for significant storm damage under an extreme storm event in combination with a 5 foot rise in sea levels.

Figure 6-6: Spindrift Inn Timber Return Wall below Deck

6.1.3 Transect 32 – El Torito

The FEMA transect data indicates the FFE of the El Torito restaurant parcel is at ~25 feet NAVD and therefore less susceptible to damage from extreme coastal storms when comparing potential maximum wave crest elevations with FFE. However, anecdotal reports indicate the site has experienced damage from coastal storm events in the past. Given the restaurants location on a relatively steep rocky point, there may be some additional wave energy focused here resulting in runup (splash) elevations that could have damaged the restaurant. This potential for wave runup was a key factor considered in estimating potential for damage under an extreme event combined with sea level rise.

6.1.4 Transect 31 – Monterey Plaza Hotel

The lower level FFE of the Monterey Plaza Hotel was estimated to be at 18 feet NAVD. Based on this assumption we estimate some damage (<10%) could occur during an extreme storm combined with 1 and 2 foot of SLR. The damage estimates become much greater under the 5 ft SLR scenario because the estimated wave crest elevation could exceed the FFE of the lower hotel, resulting in structural damage and flooding. The damage for this scenario was estimated to be about 30% of the structure value given that most of the damage would occur on the lower level of a 5-6 story hotel and only a portion of the structure is pile supported. It should be noted that this damage estimate assumes the pile foundation would largely remain intact. However, no structural assessment or analysis was performed as part of this study to determine the validity of this assumption.

6.1.5 Transect 30 – Monterey Bay Inn

The FEMA transect data indicates the FFE of the Monterey Bay Inn parcel is at ~25 feet NAVD and therefore less susceptible to damage from extreme coastal storms when comparing potential maximum wave crest elevations with FFE. Applying the NACCS depth damage functions to this site indicates very low potential for damage under all sea level rise scenarios. However, field observations of the seawall foundation indicate evidence of corrosion and spalling raising the question about the life span of this structure (Figure 6-7). The compounding effects of an aging structure that will be subject to increasing coastal hazards could be problematic for buildings supported on aging foundations. Facilities like the Monterey Bay Inn will likely require total replacement of the seawall/foundations to last through 2060 or 2100 time horizons.

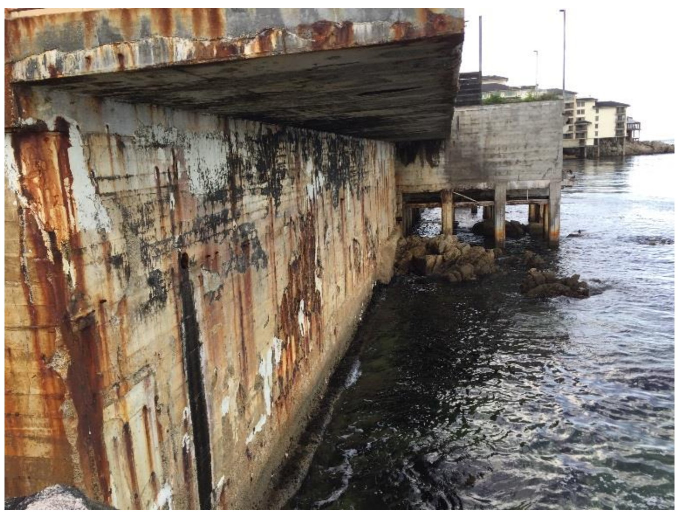


Figure 6-7: Monterey Bay Inn Seawall / Foundation

6.1.6 Transect 28 – United States Coast Guard (USCG) Pier

The deck of the USCG Pier was estimated to be at an elevation of 11 feet NAVD for purposes of this analysis. Given the relatively low freeboard the NACCS depth damage functions indicate there would be potential for some damage (<10%) during an extreme storm event combined with 1 foot of SLR. The extent of damage could range from 5-30% for a 2 foot SLR scenario and would depend on the condition of the piles, connections and utility location. A 5 foot SLR scenario combined with an extreme storm is assumed to result in total structural loss; however, the increased wave transmission and overtopping potential would be problematic for lower SLR amounts. Most likely some adaptation of the breakwater and USCG Pier would be required to accommodate SLR in excess of 2 feet.

6.1.7 Transect 27 – Wharf 1

The deck elevations along Wharf 1 could not be determined from available information but are estimated to be about 15 feet NAVD (+/- 1 foot). There are portions of Wharf 1 with lower platforms estimated to range from 10-11 feet NAVD. Given the poor state of repair (COWI, 2017) some damage would be expected under an extreme storm event today. Although sheltered from most wave energy, the current and surge within the harbor during an extreme event could be problematic for deficient foundation elements and corroded connections of Wharf 1. The estimated potential damage could increase to ~20% for a 1 foot SLR scenario and ~30% for a 2 foot SLR scenario. Although the wave crest elevations remain below the main deck for these scenarios, the additional energy within the harbor will be problematic for deficient structural elements of Wharf 1 and especially the lower platforms like the Monterey Bay Whale Watching Center (Concession 18) and other concessions with lower level decks. A 5 foot SLR scenario combined with an extreme storm event is expected to result in total loss of the existing structure as the majority of the horizontal bracing and connections would be within the tidal range and subject to increased wave impacts during an extreme event.

The damage estimates for Wharf 1 are only intended to provide an estimated magnitude of financial impact due to SLR as required by AB 691. The estimates provided are based on our knowledge of coastal hazards and experience working on aging timber structures in similar marine environments. However, a key challenge in estimating damage at Wharf 1 is the non-uniform structural characteristics which vary in type, state of repair and age from concession to concession. Because of this variation in structural characteristics, there will not be a uniform percentage of damage throughout Wharf 1 in a given storm event. In reality, the percentage of damage could vary significantly from concession to concession based on the factors listed in Table 6.1.

6.1.8 Transect 27 – Wharf 2

The deck elevation of Wharf 2 is assumed to be 15 feet NAVD based on the drawings provided in the COWI Inspection Report (2017) concluded Wharf 2 was also in a poor state of repair. The outer end of Wharf 2 would be exposed to more wave energy than Wharf 1 since it's only partially sheltered by the breakwater. The FEMA data at the offshore end of Transect 27 indicate a maximum wave crest elevation could reach 12 feet NAVD during an extreme event, providing a freeboard of 3 feet to the deck under current sea levels. Each increment of SLR brings that maximum wave crest elevation closer to the deck resulting in an estimated damage potential of 20% of a 1 foot SLR scenario and 30% for a 2 foot SLR scenario. Note, the Sandbar and Grill, located below the main deck of Wharf 2 would likely experience complete total loss under a 1 foot SLR scenario. A 5 foot SLR scenario combined with an extreme storm event is expected to result in total loss of the Wharf 2 structure as the maximum wave crest elevation would likely exceed the deck elevation resulting in significant damage due to wave impacts and flooding.

6.2 Maintenance and Repair

A key assumption of these estimates is the structure type and condition was assumed to remain constant regardless of the time horizon evaluated. This assumption was necessary because the depth-damage functions have been developed to estimate damage to existing structures from current hazards and do not factor in the combination of an aging structure with increased coastal hazards.

The financial impact of this assumption is that routine inspection, maintenance and repairs will be performed throughout the design life of each structure. As existing structures age and are subject to increased water levels and wave energy the cost of these maintenance and repair activities will also increase. Marine structures typically experience structural deterioration in a zone that extends from the mudline (seafloor) up to the splash zone (a few feet above high tide). Each increment of sea level rise will increase the vertical extent of this high maintenance zone. If we assume this zone of degradation has a height of roughly 8 feet, a 2 foot rise in sea level will increase this zone by 25% and a 5 foot rise in sea level will increase this zone by over 60%. Under these scenarios a significant increase in maintenance and repair cost would be expected as the splash zone would extend above the existing repair measures in place such as pile wraps and encasements visible on most pile supported structures in the harbor.

7. Economic Analysis of Sea Level Rise

This chapter describes the economic loss to the City of Monterey, and to an extent the entire county, from sea level rise (SLR) for granted public trust lands in the city. Two methods of monetizing the loss are used: a market valuation and a non-market valuation. The market value method assesses revenue loss to the City from both direct and indirect economic perspectives from adverse impact to infrastructure along the tidelands that will have a ripple effect on the local and regional economy, including from property damage and subsequent loss of tourism. The non-market valuation accounts for public values not measured through the normal methods of market analysis. In this case, non-market valuation is used for placing monetary value on the loss of recreational beach use due to sea level rise. The results from the economic analysis are described below. A summary table of the economic loss is provided below and at the end of the chapter.

Fiscal and Economic Loss Summary

Economic Loss Type	Scenario 2030 Corresponding to an 8.8-inch rise in sea level	Scenario 2060 Corresponding to a 28.3-inch rise in sea level	Scenario 2100[a] Corresponding to a 62.6-inch rise in sea level
Market Valuation			
Revenue loss to City Government, within Tidelands (Tables 7.1 and 7.3)	$1,030,808	$2,061,760	$34,105,989
Revenue loss to City Government, outside of Tidelands (Tables 7.6, 7.7 and 7.8)	$519,000	$784,000	$26,542,000
Total Revenue Loss to City Government	$1,549,808	$2,845,760	$60,647,989
Trickle-down economic loss in City (Tables 7.11, 7.14 and 7.17)	$13,266,000	$20,940,000	$484,626,000
Market Valuation Total	**$14,815,808**	**$23,785,760**	**$545,273,989**
Non-Market Valuation			
Beach Loss (Tables 7.18, 7.19 and 7.20)	$185,000	$1,021,000	$1,558,000

[a] Includes the five-year extended loss for impacts to wharves in the 2100 scenario

The market impacts in the above table refer to the fiscal impacts to City government and the economic losses to businesses in the City of Monterey from the damage due to the projected sea-level rise and 100-year storm events occurring during the three scenarios. The fiscal impacts to the City general fund are analyzed in this report section in a build-up of lost revenues including: 1) directly within the Tidelands Trust area—rents, sales tax, transient occupancy tax and property tax; and 2) reduced visitor spending, throughout the City, on accommodations, food, retail and other services that would result from extended closure of the major tideland attractions - the Aquarium and Fisherman's Wharves. In addition to these revenue losses to City government, there are trickle-down losses to the local economy including loss of business income and jobs. The non-market impact is loss of beach area from sea level rise translating into lost value to potential beach visitors. This lost benefit is derived from studies that measure what people are willing to spend for a day at the beach.

7.1 Market Valuation

7.1.1 Direct Loss of Income Stream from Tidelands

In 2017, the City of Monterey received a total of approximately $2.7 million in Tidelands Trust rental income. After tidelands-related expenditures (security services, property management, maintenance and repairs, etc.), net revenue was $1.1 million.[1]

The City's Marina Fund (Fund 600) projected net revenue is $900,000 off a projected income of $3.0 million.[2] The Marina Fund collects mooring fees at the City-owned marina and disburses funds for marina operations and maintenance of the City's marina facilities.

The Parking Fund operates the waterfront parking lots and metered spaces along adjacent streets. Projected revenue net of expenses is $400,000 for 2017–19 (projected parking revenue of $8.9 million and expenditures of $8.5 million).

Sales taxes and transient occupancy taxes (TOT) derived from the Tidelands Trust properties represent a significant revenue source for the City. Approximately 15 percent of the City's total sales tax revenue of approximately $8.5 million[3] and 25 percent of the City's total TOT revenue of $21.5 million, or approximately $5.4 million, are generated in the Trust Properties directly affected by SLR. In addition, the sales-based rent going to the Tidelands Trust Fund is determined by the retail sales generated by the businesses in the Tidelands Trust area. A loss of sales in the tidelands properties will directly result in a loss of tidelands rental income.

7.1.2 Tidelands Revenues at Risk

2030 and 2060 Scenarios Assessment

The damage assessment for the 2030 scenario indicates damage to Cannery Row properties of 10 percent or less. The 2060 scenario indicates damage to properties of 3 to 10 percent, except for the El Torito parcel at 600 Cannery Row,[4] which will sustain 20 percent damage in 2060. Property damage of 10 percent or less is not expected to cause closure or affect operations for an extended period. Damage in the amount of 10 percent is indicated for the Spindrift Inn at 652 Cannery Row.[5] The inn will sustain damage to the ground-floor lobby area, but accommodations should not be affected in the 2060 scenario.

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[1] City of Monterey, Consolidated Annual Financial Report [CAFR], Fiscal Year ended June 30, 2017, page 131.
[2] City of Monterey, FY 2017–19 Biennial Budget, page 27.
[3] CAFR.
[4] El Torito and the Spindrift Inn are not Tidelands Trust properties. However, they and several other non-tidelands properties were assessed for potential damage to evaluate the potential impacts to sales tax, TOT, and property tax.

The El Torito restaurant, with damage of 20 percent to its dining area in 2060, could be closed for up to six months for repairs. Since El Torito is not a tidelands property, the City does not collect tidelands rent, and only a small amount of sales tax revenues would be affected.

Fisherman's Wharf (Wharf 1) and Wharf 2 will sustain 20 and 30 percent damage in the 2030 and 2060 scenarios, respectively. With damage of 20 percent, closure of the wharves for up to six months could be expected. Thirty percent damage is expected to result in closure of the wharves for up to one year.

2100 Scenario

The 2100 sea level rise scenario combined with high tides and 100-year storm events will have variable impacts on these revenue streams due to the difference in construction of the properties within the Tidelands Trust area. Well-protected properties will experience only partial disruption, leading to closure for a limited time after a 100-year storm event occurs in the 2100 time horizon. In contrast, Wharf 1 and Wharf 2 will likely experience failures of structural components that would require complete replacement, leading to closure for an extended period, maybe several years.

Tidelands Rents

To a much greater degree than with the 2030 and 2060 scenarios, a 100-year storm event occurring during the 2100 horizon will affect the sales tax revenue and rental income related to sales (a portion of the rent is calculated as a percentage of sales) on all tidelands properties. Cannery Row structures (including transects T31–T34) are projected to sustain at least 30 percent damage in the 2100 SLR horizon. For this risk assessment, it is assumed that 30 percent damage is enough to cause closure for up to one year. The minimum annual rents in these transects from all properties total $295,000, and sales-based (percentage) rents are approximately $415,000. Therefore, assuming both the minimum rents and the percentage rents would not be collected during the period of closure, up to $710,000 in tidelands rental income would be lost from the Cannery Row properties.

Wharf 1 and Wharf 2 (transect T27) (as well as the Coast Guard Pier, from which the City derives no income) are expected to suffer 100 percent damage at some point in the 2100 SLR horizon. This level of damage raises the question of when the wharf infrastructure will be replaced. The downtime for these transects is estimated at five years to allow for planning, design, environmental review and permitting, to secure financing, and for construction and lease-up. As with the Cannery Row transects, the City receives both rents and sales taxes from the businesses on Wharf 1 and Wharf 2. Minimum annual rents from the wharves' vendors total approximately $875,000, percentage rent is $1.10 million, and wharfage fees of $40,000, for a one-year loss of $2.015 million. The five-year loss of these rents and fees is $10,075,000.

Sales Tax

Approximately $1.27 million in sales tax is generated annually in the tidelands: $450,000 on the wharves and $817,000 along Cannery Row. However, the City is not expected to experience this entire amount as a net loss even with the closure of vendors along Cannery Row and on the wharves for an extended period. A substantial portion—up to 90 percent—of the retail and food service demand will shift from the tidelands areas impacted by 100-year storm events to vendors in other areas of the city. The other 10 percent represents expected retail leakage to locations outside the city. The five-year sales tax revenue from the wharves totals $2.25 million ($450,000 x 5), but again, only 10 percent of this amount ($225,000) is expected to be a net loss to the City.

Transient Occupancy Tax

The Cannery Row hotels generate approximately $5.35 million in TOT revenue for the City of Monterey. It is assumed that in the 2100 scenario, the hotels will sustain damage that will require closure for up to one year. However, as with sales tax, only 10 percent of the hotel visitor-days will be a net loss to the City since 90 percent of the visitors would find accommodations elsewhere in the city. A further 8 percent adjustment is made to account for the lack of damage to the Monterey Bay Inn, which would remain open. Therefore, net TOT loss is only $492,000.[5]

7.1.3 Marina and Parking Funds

Separate damage assessments were not conducted for the City-owned marina and the waterfront parking facility. It is assumed the marina docks and support facilities will be able to adjust to the expected SLR and that, after an extreme event in 2100, downtime may only be only a matter of days before operations return to normal. The reduction in activity on Wharf 1 and Wharf 2 may have an impact on the attractiveness of the marina, resulting in potential loss of docking fees. However, the revenue at risk in this case is expected to be incremental and should not be significant relative to the other revenue losses in this assessment.

On the other hand, the loss of revenues to the Parking Fund are expected to be directly related to the loss of activity on Wharf 1 and Wharf 2. Assuming about half of the spaces would not be used during the wharf reconstruction period, the City would lose approximately $4.5 million in parking revenues per year. The annual Parking Fund budget of $8.5 million includes fixed debt service payments, lease payments to the General Fund, transfers and support for other City services, and capital improvements, as well as operations and maintenance, which are not expected to be reduced substantially during the wharves' downtime. Therefore, this assessment assumes a net annual loss of $4.5 million in income from the Parking Fund, or $22.5 million over the five years that the wharves are being rebuilt.[6]

Table 7.1 shows the estimated revenue loss for the year in which a 100-year storm occurs during the SLR scenarios.

[5] The Monterey Bay Inn's 49 rooms represent about 8 percent of the total number of rooms along Cannery Row.
[6] The wharf-loss analysis assumes the wharves will be rebuilt after a total loss event over a five-year period.

Table 7.1: Direct Economic Loss

Tidelands Area	Scenarios		
	2030	2060	2100, including Five-Year Loss [a]
Transient Occupancy Tax	N/A	N/A	$492,000
Sales Tax Revenue Loss [b]			
Aquarium	N/A	N/A	N/A
Hotels [c]	N/A	N/A	N/A
Other Cannery Row [d]	N/A	N/A	$81,700
Wharf 1 and Wharf 2 [e]	$22,500	$45,000	$225,000
Rent Revenue Loss			
Aquarium	N/A	N/A	N/A
Hotels	N/A	N/A	$282,000
Other Cannery Row [d]			$428,000
Wharf 1 and Wharf 2 [e]	$1,007,500	$2,015,000	$10,075,000
Parking Fund			$22,500,000
Total	$1,030,000	$2,060,000	$34,083,700

[a] Extended revenue loss over multiple years will occur for the wharves (Sales Tax: $45,000 x 5 and Rent: $2.015 million x 5) and the Parking Fund ($4.5 million x 5) after a 100-year storm event that occurs during the 2100 scenario. This is due to the time (five years) assumed to be needed to rebuild the wharves, and the resulting reduction in demand for parking at the waterfront lot. Only one year of losses from the other areas is assumed during this period.

[b] Net sales tax loss is only 10 percent of the total sales tax generated in the Tidelands, 90 percent is expected to picked-up elsewhere in the City.

[c] Hotels included in analysis: Monterey Plaza, Intercontinental Clement, and Spindrift; the Monterey Bay Inn (transect 30) is not subject to damage in any scenario. The Spindrift Inn is not a tidelands property but is included in the loss calculations.

[d] "Other Cannery Row" is all properties other than the hotels.

[e] Estimated six months of lost revenue from the wharves in 2030, one year in 2060, and five years total extended loss with 2100 scenario due to 100 percent damage.

Loss of Improvement Values and Property Tax Revenue

Physical damage to properties within the tidelands areas may lead to loss in property tax revenues to the City. State law provides for reassessment of a property's base value after damage to improvements of at least $10,000 by filing a disaster relief claim with the State Board of Equalization.[7] The total value of private improvements for each tidelands area is shown in Table 7.2.

Table 7.2: Property Improvements Summary

Tidelands Area	Improvements Values[a]
Aquarium	$52,500,000
Hotels	$61,400,000
Other Cannery Row	$10,900,000
Wharf 1 and Wharf 2[b]	$31,000,000

[a] County Tax Assessor assessed valuations for improvements.

[b] City-owned real property is not assessed. This estimate is based on the list price per square foot of wharf structures to estimate non-secured property tax from wharf properties.

The improvement values of each of the Tidelands areas are multiplied by the percentage damage estimates for the area for each of the SLR scenarios to arrive at the property value and tax loss in Table 7.3. The table shows the maximum loss in any one year when a 100-year storm occurs during the scenario.

Similarly, with the sales tax and tidelands rental loss, the one-year estimated Wharf 1 and Wharf 2 property tax loss to the City ($310,000 x 1.1526% = $3,573) would be multiplied by five for a total of $17,865 to account for the five-year period to reconstruct the wharves and retail space; the property tax loss for the other properties is $4,424 for one year only.

[7] Revenue and Taxation Code Section 170 provides that if a calamity such as fire, earthquake, or flooding damages or destroys property, the property owner may be eligible for property tax relief if the county has adopted an ordinance that allows property tax relief to owners of damaged or destroyed property, without fault from the assessee. In such cases, the county assessor will immediately reappraise the property to reflect its damaged condition. In addition, when it is rebuilt in a like or similar manner, the property will retain its prior value (Proposition 13) for tax purposes. Monterey County has adopted such an ordinance.

Table 7.3: Property Value and Tax Loss

Tidelands Area	Scenarios		
	2030	**2060**	**2100, including Five-Year Loss [a]**
	Property Value Loss		
Aquarium	$0	$1,575,000	$15,750,000
Hotels	$630,000	$3,809,000	$18,420,000
Other Cannery Row	$182,000	$586,000	$4,210,000
Wharf 1 and Wharf 2	$6,200,000	$9,300,000	$155,000,000
Total	$7,012,000	$15,270,000	$193,380,000
Property tax levy at 1 percent [b]	$70,120	$152,700	$1,933,800
1.1526 percent of countywide tax levy apportioned to the City of Monterey [c]	$808.20	$1,760.02	$22,289

[a] 2100 scenario includes the five-year loss of Wharf property taxes (property value: $31 million x 5)

[b] Prop. 13 rate only; does not include rates for taxpayer-approved special purpose bonds.

[c] The apportionment percentage is variable from year to year. The current percentage is from the Monterey County Auditor's 2018–19 Tax Rate Book.

7.1.4 Loss of Tourism Revenue

Tourism is an important base industry for both Monterey County and the City of Monterey. A base industry is an industry for which nearly all the revenue is generated from outside the region. Table 7.4 presents the estimate of the tourism industry for the county and the city.

Table 7.4: Estimated Direct Income and Taxes Generated in Monterey County and the City of Monterey from Tourism

Industry	County Businesses Income Estimate (millions)	City Businesses Income Estimate (millions)	Taxes to City	
			Type	**Taxes (millions)**
Accommodations	$733.1	$214.5	TOT	$21.5
Other Sales	$2,021.6	$445.8	Sales Tax	$4.3

Source: Dean Runyan Associates, Inc.; Michael Baker International

Tourism generates over $660 million in direct income to the businesses in the City of Monterey annually. This results in the City collecting approximately $26 million annually in taxes from tourists.

7.1.5 Tourism Revenues at Risk Summary

Tourism would be impacted by damages to attractions in the city due to sea level rise and causing a reduction in demand. Two major attractions in the tidelands were identified as possibly sustaining damage according to the scenarios evaluated: the Monterey Bay Aquarium and the wharves (Wharf 1 and Wharf 2).

Table 7.5 shows the estimated annual contribution to the City of Monterey economy from tourists visiting these two attractions.

Table 7.5: Estimated Annual Direct Income and Taxes Generated in the City of Monterey from Visitors by Attraction

Attraction	Sales (millions)	Tax Type	Taxes (millions)
Aquarium			
Accommodations	$130.8	TOT	$13.1
Sales Other Than Accommodations	$130.6	Sales Tax	$1.3
Wharves			
Accommodations	$21.5	TOT	$2.2
Sales Other Than Accommodations	$44.6	Sales Tax	$0.4

2030 Scenario Damage Assessment

The Monterey Aquarium would incur no damage based on the analysis of the 2030 scenario; therefore, there would be no loss of value from a reduction of tourism. However, it is estimated that the wharves would suffer approximately 20 percent damage, resulting in a loss of over $13 million in income and over half a million dollars in total taxes.

Table 7.6: Total Sales Income and Taxes Lost to Businesses in the City of Monterey—2030 Scenario

Attraction	Sales (millions)	Tax Type	Taxes (millions)
Aquarium			
Accommodations	NA	TOT	NA
Sales Other Than Accommodations	NA	Sales Tax	NA
Wharves			
Accommodations	$4.3	TOT	$0.43
Sales Other Than Accommodations	$8.9	Sales Tax	$0.089
Total			
Accommodations	$4.3	TOT	$0.4
Sales Other Than Accommodations	$8.9	Sales Tax	$0.089
Grand Totals	**$13.2**		**$0.519**

2060 Scenario Damage Assessment

The Monterey Aquarium would sustain minor damage based on the analysis of the 2060 scenario. It is estimated that this damage would be easily repaired with little loss of attractiveness; therefore, there would be no loss of value from a reduction of tourism. However, it is estimated that the wharves would incur approximately 30 percent damage, resulting in a loss of almost $20 million in income and nearly three-quarters of a million dollars in taxes.

Table 7.7: Total Sales Income and Taxes Lost to Businesses in the City of Monterey—2060 Scenario

Attraction	Sales (millions)	Tax Type	Taxes (millions)
Aquarium			
Accommodations	NA	TOT	NA
Sales Other Than Accommodations	NA	Sales Tax	NA
Wharves			
Accommodations	$6.5	TOT	$0.65
Sales Other Than Accommodations	$13.4	Sales Tax	$0.134
Total			
Accommodations	$6.5	TOT	$0.65
Sales Other Than Accommodations	$13.4	Sales Tax	$0.134
Grand Total	**$19.9**		**$0.784**

2100 Scenario

In the 2100 scenario, it is estimated that the Monterey Aquarium would incur infrastructure damages, resulting in its temporary closure for at least a year for repairs. Additionally, the wharves would be significantly damaged to the point of making them unusable and would require complete demolition and replacement. If the wharves were not replaced, it is assumed that a new attraction would be developed to mitigate the loss of the wharves. The loss of income from the wharves would extend over at least five years for any rebuilding.

Table 7.8: Total Sales Income and Taxes Lost to Businesses in the City of Monterey—2100 Scenario

Attraction	Sales (millions)	Tax Type	Taxes (millions)
Aquarium			
Accommodations [a]	$126.2	TOT	$12.62
Sales Other Than Accommodations	$130.6	Sales Tax	$1.306
Wharves (5 Years of Recovery)			
Accommodations	$103.8	TOT	$10.38
Sales Other Than Accommodations	$223.6	Sales Tax	$2.236
Total			
Accommodations	$230.0	TOT	$23.000
Sales Other Than Accommodations	$354.2	Sales Tax	$3.542
Grand Total	**$584.2**		**$26.542**

a. The accommodations total has been adjusted to account for the Cannery Row hotels that would be closed in the 2100 scenario.

As indicated on Table 7.8, the loss of tourism in this scenario would result in reduction of over $584 million in direct income to the businesses in the city. This reduction would decrease tax revenues to the City by $26.5 million.

7.1.6 Direct and Indirect Economic Loss from Sea Level Rise

In order to fully ascertain the economic impact of the damages caused by sea level rise, indirect impacts must also be analyzed as they percolate through the local economy. This section presents the findings of that analysis. The methodology that was employed is an input/output (I/O) model, which is a quantitative economic technique that represents the interdependencies between different branches of a national or regional economy. The model was developed by Nobel Prize winner Wassily Leontief, who was the first to use a matrix representation of a national (or regional) economy. His model depicts inter-industry relationships within an economy, showing how output from one industrial sector may become an input to another industrial sector.

The specific version of an I/O model used in this analysis was IMPLAN. IMPLAN (IMpact analysis for PLANning) is an input/output model created by MIG, Inc. (formerly Minnesota IMPLAN Group, Inc.) and is based on work done for the US Department of the Interior, Bureau of Land Management in the 1970s and 1980s. It is arguably the foremost I/O economic impact model used by government and industry. The model allows analysis for changes in output in sectors, commodities, household income, and other economic activities.

The results of the model are described in terms of direct, indirect, and induced economic impacts. Direct impacts result from expenditures associated with constructing and operating the development, including labor, materials, and supplies. Indirect impacts result from the suppliers of the builders during construction and the suppliers of the businesses/entities during operation, purchasing goods and services, and hiring workers to meet demand. Induced impacts result from the employees of the builders during construction and of businesses/entities during operation, purchasing goods and services at a household level. The results from IMPLAN are usually presented as changes in output (sales), employment, and income (including employee compensation, proprietors' income, etc.).

In the case of the impact of sea level rise, these impacts are a loss from a reduction in sales (income) to local businesses from a decrease in tourism and governmental income.

Economic Impact from Scenario 2030

The economic impact caused by sea level rise based on the predicted 2030 scenario is an estimated loss of nearly $18 million in output in Monterey County (see Table 7.11). This countywide number includes a loss of output of $13.27 million for the City of Monterey. The following tables present the results of modeling the impacts from losses from tidelands and tourism revenues, separately and combined, caused by sea level rise during the 2030 scenario.

Table 7.9: Economic Impact from Loss of Tidelands Revenues to Monterey County and the City of Monterey—2030 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	10.0	$0.955	$1.084	$1.253
Indirect Effect	0.7	$0.034	$0.056	$0.101
Induced Effect	3.7	$0.174	$0.317	$0.517
Total Effect	**14.4**	**$1.163**	**$1.457**	**$1.871**
Impact to City of Monterey				
Direct Effect	10.0	$0.955	$1.084	$1.253
Indirect Effect	0.2	$0.009	$0.013	$0.024
Induced Effect	0.9	$0.046	$0.077	$0.125
Total Effect	**11.1**	**$1.010**	**$1.174**	**$1.402**

a. Monterey County figures include City of Monterey impacts.

Table 7.10: Economic Impact from Loss of Tourism to Monterey County and the City of Monterey—2030 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	112.5	$4.489	$6.472	$10.516
Indirect Effect	19.3	$0.920	$1.579	$2.757
Induced Effect	20.3	$0.951	$1.731	$2.817
Total Effect	**152.1**	**$6.360**	**$9.782**	**$16.090**
Impact to City of Monterey				
Direct Effect	112.5	$4.489	$6.472	$10.516
Indirect Effect	4.9	$0.244	$0.382	$0.667
Induced Effect	5.1	$0.252	$0.419	$0.681
Total Effect	**122.5**	**$4.985**	**$7.273**	**$11.864**

a. Monterey County figures include City of Monterey impacts.

Table 7.11: Total Economic Impact from Sea Level Rise to Monterey County and the City of Monterey—2030 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	122.6	$5.444	$7.557	$11.769
Indirect Effect	20.0	$0.954	$1.634	$2.857
Induced Effect	24.1	$1.125	$2.049	$3.333
Total Effect	**166.7**	**$7.523**	**$11.240**	**$17.959**
Impact to City of Monterey				
Direct Effect	122.6	$5.444	$7.557	$11.769
Indirect Effect	5.1	$0.253	$0.395	$0.691
Induced Effect	6.0	$0.298	$0.495	$0.806
Total Effect	**133.7**	**$5.995**	**$8.447**	**$13.266**

a. Monterey County figures include City of Monterey impacts.

Economic Impact from Scenario 2060

The greater damage assessment of the 2060 scenario from sea level rise results in an increased loss of over $28 million in the county and nearly $21 million in the city (see Table 7.14). This represents an estimated loss of 268 jobs in the county including 216 in the city. The results of the analysis on the 2060 scenario are presented on the following tables.

Table 7.12: Economic Impact from Loss of Tidelands Revenues to Monterey County and the City of Monterey—2060 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	18.1	$1.722	$1.956	$2.261
Indirect Effect	1.2	$0.061	$0.100	$0.182
Induced Effect	6.7	$0.315	$0.573	$0.932
Total Effect	**26.0**	**$2.098**	**$2.629**	**$3.375**
Impact to City of Monterey				
Direct Effect	18.1	$1.722	$1.956	$2.261
Indirect Effect	0.3	$0.016	$0.024	$0.044
Induced Effect	1.7	$0.083	$0.138	$0.225
Total Effect	**20.1**	**$1.821**	**$2.118**	**$2.530**

[a.] Monterey County figures include City of Monterey impacts.

Table 7.13: Economic Impact from Loss of Tourism to Monterey County and the City of Monterey—2060 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	180.5	$7.134	$10.037	$16.308
Indirect Effect	29.6	$1.415	$2.429	$4.237
Induced Effect	32.1	$1.502	$2.735	$4.450
Total Effect	**242.2**	**$10.051**	**$15.201**	**$24.995**
Impact to City of Monterey				
Direct Effect	180.5	$7.134	$10.037	$16.308
Indirect Effect	7.5	$0.375	$0.587	$1.025
Induced Effect	8.1	$0.398	$0.661	$1.076
Total Effect	**196.1**	**$7.907**	**$11.285**	**$18.409**

[a.] Monterey County figures include City of Monterey impacts.

Table 7.14: Total Economic Impact from Sea Level Rise in Monterey County and the City of Monterey—2060 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	198.6	$8.856	$11.993	$18.569
Indirect Effect	30.9	$1.476	$2.529	$4.418
Induced Effect	38.8	$1.817	$3.308	$5.382
Total Effect	**268.3**	**$12.149**	**$17.830**	**$28.369**
Impact to City of Monterey				
Direct Effect	198.6	$8.856	$11.993	$18.569
Indirect Effect	7.8	$0.391	$0.612	$1.069
Induced Effect	9.8	$0.482	$0.800	$1.302
Total Effect	**216.2**	**$9.729**	**$13.405**	**$20.940**

a. Monterey County figures include City of Monterey impacts.

Economic Impact from Scenario 2100

The year 2100 scenario has a substantial increase in economic impact, as the direct losses from tourism reduction are considerably greater in this scenario. The loss in sales to county businesses is over $654 million. This includes a loss of nearly $485 million in sales (output) to businesses in the City of Monterey (see Table 7.17). The loss of employment would be 6,367 jobs in the county, which includes 5,181 jobs lost in the City of Monterey.

Table 7.15: Economic Impact from Loss of Tidelands Revenues to Monterey County and the City of Monterey—2100 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	402.2	$38.314	$43.512	$50.285
Indirect Effect	27.3	$1.349	$2.229	$4.045
Induced Effect	149.6	$6.996	$12.738	$20.725
Total Effect	**579.1**	**$46.659**	**$58.479**	**$75.055**
Impact to City of Monterey				
Direct Effect	402.2	$38.314	$43.512	$50.285
Indirect Effect	6.9	$0.358	$0.539	$0.978
Induced Effect	37.8	$1.855	$3.081	$5.012
Total Effect	**446.9**	**$40.527**	**$47.132**	**$56.275**

a. Monterey County figures include City of Monterey impacts.

Table 7.16: Economic Impact from Loss of Tourism to Monterey County and the City of Monterey—2100 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County[a]				
Direct Effect	4,377.3	$163.520	$235.503	$380.183
Indirect Effect	674.0	$32.596	$55.667	$97.116
Induced Effect	736.7	$34.448	$62.725	$102.050
Total Effect	**5,788.0**	**$230.564**	**$353.895**	**$579.349**
Impact to City of Monterey				
Direct Effect	4,377.3	$163.520	$235.503	$380.183
Indirect Effect	170.5	$8.642	$13.463	$23.487
Induced Effect	186.4	$9.133	$15.170	$24.681
Total Effect	**4,734.2**	**$181.295**	**$264.136**	**$428.351**

a. Monterey County figures include City of Monterey impacts.

Table 7.17: Total Economic Impact from Sea Level Rise in Monterey County and the City of Monterey—2100 Scenario

Impact Type	Employment	Labor Income (millions)	Total Value Added (millions)	Output (millions)
Impact to Monterey County (1)				
Direct Effect	4,779.5	$201.833	$279.016	$430.468
Indirect Effect	701.3	$33.944	$57.897	$101.160
Induced Effect	886.3	$41.444	$75.463	$122.776
Total Effect	**6,367.1**	**$277.221**	**$412.376**	**$654.404**
Impact to City of Monterey				
Direct Effect	4,779.5	$201.833	$279.016	$430.468
Indirect Effect	177.4	$9.000	$14.002	$24.465
Induced Effect	224.2	$10.988	$18.250	$29.693
Total Effect	**5,181.1**	**$221.821**	**$311.268**	**$484.626**

a. Monterey County figures include City of Monterey impacts.

7.2 Non-Market Valuation

Non-market valuation is the measure of public values not measured through the normal methods of market analysis, which measure transactions or potential transactions in terms of monetary amounts. In order to determine the value of a non-market good (such as spending a day at the beach), the consumer surplus, which is the value consumers are willing to pay above the price of a good, is calculated. An industry-accepted value is provided in the California Coastal Commission study, "Improved Valuation of Impacts to Recreation, Public Access, and Beach Ecology from Shoreline Armoring." The study determined that for Monterey County the value of a day's use of a beach was $39.49 per person (in 2015 dollars) and that the average density (people per square foot per year) was 1.26. These figures result in an annual value of beach land of $52.50 per square foot (in 2018 dollars, assuming 1.8 percent annual increase).

7.2.1 Non-Market Loss

2030 Scenario Assessment

As would be expected, the beaches in Monterey are especially vulnerable to sea level rise. By the 2030 scenario, over 3,500 square feet of beach could be lost, resulting in an annual loss of $185,000 in consumer surplus.

Table 7.18: Value of Beach Loss—2030 Scenario

Beach	Per Sq. Ft. Value	Sq. Ft.	Value
San Carlos Beach	$52.50	2,658	$140,000
Plaza Hotel Beach	$52.50	367	$19,000
McAbee Beach	$52.50	491	$26,000
Total		3,516	$185,000

2060 Scenario Assessment

By 2060, the loss of beach land could increase nearly fivefold and result in a loss of consumer surplus of over $1.0 million. San Carlos Beach alone could sustain a loss of public value of $712,000.

Table 7.19: Value of Beach Loss—2060 Scenario

Beach	Per Sq. Ft. Value	Sq. Ft.	Value
San Carlos Beach	$52.50	13,553	$712,000
Plaza Hotel Beach	$52.50	967	$51,000
McAbee Beach	$52.50	4,909	$258,000
Total		19,429	$1,021,000

2100 Scenario

In the 2100 scenario, the nearly 30,000 square feet of beach land lost would result in an over $1.5 million reduction in public value annually. San Carlos Beach and McAbee Beach account for the majority of consumer surplus lost per year.

Table 7.20: Value of Beach Loss—2100 Scenario

Beach	Per Sq. Ft. Value	Sq. Ft.	Value
San Carlos Beach	$52.50	19,400	$1,019,000
Plaza Hotel Beach	$52.50	1,667	$88,000
McAbee Beach	$52.50	8,591	$451,000
Total		29,658	$1,558,000

7.3 Summary of Losses During Scenarios

Table 7.21 presents a summary of all direct revenue losses to City government in the Tidelands Trust area and citywide during each of the three scenarios. The table also shows the direct and indirect economic output and job losses due to the loss of visitor-days and sales caused by closure of one or both major attractions in Monterey—the aquarium and the wharves—due to damage associated with SLR. Finally, the closure of one or more of the three beaches would result in the non-market value losses indicated.

Table 7.21: Summary of Market and Non-Market Valuation

Economic Loss Type	2030	2060	2100[a]
Market Valuation			
Direct Revenue Loss to City Government (Tidelands Rent, TOT, Sales Tax, and Property Tax)	$1,030,808	$2,061,760	$34,105,989
Citywide Tourism Revenue Loss (due to loss of attractions)			
TOT	$430,000	$650,000	$23,000,000
Sales Taxes	$89,000	$134,000	$3,542,000
Total Direct Revenue Losses to City Government (Tidelands and Citywide)	**$1,549,808**	**$2,845,760**	**$60,647,989**
Direct and Indirect Economic Output Loss (in the City of Monterey)	$13,266,000	$20,940,000	$484,626,000
Jobs Loss in the City of Monterey	134	216	5,181
Non-Market Valuation (beach loss)	$185,000	$1,021,000	$1,558,000

[a] Includes the five-year extended loss for impacts to wharves in the 2100 scenario.

8. Adaptation Strategies

Sea level rise is unique among other hazard because it's a slow moving disaster that will develop over the span of decades. The vulnerabilities identified for sea level rise projections at the end of the century are overwhelming but the slow moving nature of climate change and sea level rise allows for time to plan, fund and mitigate these impacts. This section presents strategies for protecting and preserving resources impacted by sea level rise. The strategies are organized by asset and relevant time horizon for each strategy. Short-term strategies focus on addressing vulnerabilities identified for ~1-2 feet of SLR, which capture all but the most extreme sea level rise projections through mid-century (2050). Long-term strategies focus on addressing the vulnerabilities identified for ~5 feet of SLR, which has a 2% probability of exceedance by the end of the century (OPC, 2018).

8.1 Cannery Row Waterfront

The natural topography along Cannery Row provides a vertical buffer against permanent or pro-longed inundation of waterfront structures, even when considering a 5 foot SLR scenario. With most finish floor elevations of ~20 ft NAVD 88 or higher, these structures will remain 8 feet above still water levels, even during the highest tides of the year. However, extreme storm conditions combined with sea level rise could pose a threat to some waterfront structures within the short term planning horizon (2050).

The threshold for damage to a particular structure is dependent on building characteristics including foundation type, age and condition of the structure. For example, an older timber pile supported structure with horizontal bracing below deck and corroded connections would have a lower threshold for coastal storm damage and SLR than a new reinforced concrete pile supported structure.

Resilience, the ability to endure and recover from extreme events, will be important to preserve the cultural, historical and economic value of the waterfront structures along Cannery Row. Strategies for increasing resilience over short-term and long-term planning horizons are discussed below.

8.1.1 Short-term Strategies

8.1.1.1 Regular Inspection & Repair

Waterfront structures along Cannery Row are exposed to physical, chemical and biological deterioration from the marine environment. The structures are subject to constantly changing water levels, wave action, corrosion from saltwater and damage from marine borers. Regular inspection, maintenance and repair are vital to the resilience of these waterfront structures and will grow more important as existing structures continue to deteriorate while being exposed increased coastal hazards due to sea level rise. Significant degradation of the building structure and envelope increases the building's vulnerability to damage from natural hazards (FEMA, 2011).

Periodic inspections should be conducted and supplemented with post-storm event inspections. The schedule for maintenance should be established based on an engineer's recommendation and will likely vary depending on the type, age and condition of each waterfront structure. Any significant structural repair should include an analysis of the existing structure to estimate the capacity of the foundation and other structural elements that may be affected by the proposed repair. Guidelines for this type of analysis are provided in *FEMA P-259 Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures (Third Edition)* published January 2012.

Salt spray and moisture effects are hazards commonly overlooked or underestimated by designers and may lead to improper selection or installation of building materials. Metal connectors, straps, and clips used to improve a buildings resistance to lateral loads often show signed of corrosion (FEMA, 2011). Any repairs to these waterfront structural elements should consider use of more durable building materials. *FEMA P-499 Fact Sheet 1.7, Coastal Building Materials* (FEMA, 2010), has information on the use of materials to resist corrosion, moisture and decay.

8.1.1.2 Dry Floodproofing

Most anecdotal evidence of coastal damage along Cannery Row is related to damage from wave uprush which can result in broken windows and flooding of the first floor. Wave uprush can launch loose rocks and debris resulting in damage the building envelope. Temporary dry floodproofing measures deployed in advance of an impending storm could be an effective measure to reduce the potential for damage from wave uprush. Deploying plywood shields over doors and windows is an example of this technique. This type of floodproofing is usually only effective for short duration flooding associated with wave uprush during coincident high water level and wave events. Dry floodproofing is not recommended for pro-longed exposure to coastal flooding (i.e. low lying areas subject to standing water or persistent wave attack).

8.1.2 Long-term Strategies

Sea level rise will increase the frequency and size of waves impacting waterfront structures along Cannery Row. Based on the OPC (2018) projections, there is an 11% chance sea level rise will exceed 2 feet by the year 2070. Therefore, the impacts from a significant rise in sea level will likely occur beyond the design life of most waterfront structures that exist today.

In order to accommodate the hydrodynamic forces associated with SLR in excess of 2 feet and over 50 years into the future many of the historic structures will require major retrofits or new construction to remain in their current location. Building design and construction techniques for waterfront structures should follow recommendations of the most recent publication of the *FEMA P-55 Coastal Construction Manual* (FEMA, 2011) or other document that provides guidelines and design practices for structures in a coastal environment. Some of the features that will improve a structures resilience to extreme events include the following:

8.1.2.1 Design for Future Wave Impacts

Since many of the existing structures are elevated above today’s coastal hazards they were probably not designed for the horizontal or uplift forces that would result from an extreme wave event in combination with ~5 feet of sea level rise. A breaking wave striking a vertical wall, pile, or deck of a waterfront structure exerts both horizontal and vertical loads on a structure. The magnitude of these forces depends on the assumptions for water level and wave height which are uncertain for longer planning horizons. Design of these important foundational elements should follow the guidance from OPC (2018) and the CCC SLR Policy Guidance (2018) in selecting the design life and SLR scenarios for new waterfront construction.

8.1.2.2 Secondary Flood Protection Measures

Secondary protection measures such as a wave-return wall or dry floodproofing (described in 8.1.1.2) can be implemented to address uncertainties associated with water levels and wave heights of the future. These elements can supplement the primary coastal defense systems and improve resilience in the event a design threshold is exceeded.

A wave-return wall is one element that can be used to reduce impacts from wave runup and overtopping. Figure 8-1 is an example of a new wave-return wall installed on an older building foundation at the Monterey Bay Aquarium. The curved feature is designed to deflect wave uprush back seaward and away from the structure. These features are most effective in reducing overtopping when the relative freeboard (distance from still water level to structure crest) is equal to or greater than the design wave height. In low freeboard conditions, this feature is less effective and simply becomes submerged in the overtopping water (EurOtop, 2018).

Figure 8-1: Re-curved Wall at Monterey Bay Aquarium

8.2 Old Fisherman's Wharf (Wharf 1) and Municipal Wharf II (Wharf 2)

Wharf's 1 and 2 were identified as the most vulnerable waterfront structures in this assessment due to the structure type, age and condition. Wharf 1 dates back to the 1800s and Wharf 2 was constructed in 1926 (COWI, 2017). Both structures have undergone many repairs and modifications over the years and are in a poor state of repair based on the 2017 inspection by COWI. As the coastal environment continues to degrade these structures they will also be subject to higher water levels and wave impacts with each increment of sea level rise. A short term strategy focused on repairs and a long-term strategy focused on replacement are discussed below.

8.2.1 Long-term Replacement Strategy: Old Fisherman's Wharf (Wharf 1)

In addition to rising cost of repairs the trigger for when to shift toward a replacement strategy may depend on other factors such as the frequency or magnitude of storm damage, rate of sea level rise, or a change in the programming of businesses and activities on Wharf 1.

If significant damage forces closure of a concession due to safety reasons that could be a trigger for upgrading that portion of the wharf by replacing with a structure that has more adaptive capacity for sea level rise. Another trigger for replacement could be a tenant change, lease expiration, or major re-development of a restaurant. Before making a long-term investment in an above deck concession building, a focused study should be performed of the wharf structure to determine if it has the capacity to support the buildings over the duration of the lease or building life span. If determined that the wharf structure is not adequate to support the building over the lease term then a comparison of the repair versus replacement costs and benefits should be performed to determine the best course of action.

The base of Wharf 1 meets land at an elevation of about 20 feet, NAVD88 which provides a significant amount of adaptive capacity to accommodate even an extreme sea level rise scenario. Therefore, the existing functionality of the wharf could be maintained through a phased replacement program without a major overhaul of the landside access and utility infrastructure.

8.2.2 Short-term Strategy: Repair

Regular inspection and repairs are essential to maintain structural stability and allow for normal use and activities to continue on each wharf. The question is: How long will these repairs be able to withstand increasing water levels and wave action associated with sea level rise?

This vulnerability assessment indicated both wharves could accommodate ~1-2 feet of sea level rise with little impact to their current operations under non-storm conditions. However, each increment of sea level rise increases the potential for damage during an extreme event. Even if regular maintenance and repairs are implemented, the existing wharf structure may still suffer significant damage during an extreme storm event combined with ~1-2 feet of sea level rise. At some point the cost of repairs combined with a higher probability of storm damage will outweigh the benefits of continuing the repair strategy.

The COWI Condition Survey Report (2017) organizes recommended repairs into categories of immediate, critical, non-critical and preventative. Immediate repairs are needed to reduce a threat to public safety or the structure and were identified at eight concessions on Wharf 1 and multiple locations on Wharf 2, including some areas where access is restricted until repairs are made. Given the amount of non-immediate repairs identified, the cost of future repair phases may only increase as critical repairs become immediate, non-critical repairs become critical and so forth.

Once the costs of this programmatic repair strategy begin to outweigh the benefits and longevity of these repairs it would be worthwhile to compare against the cost and benefits of wharf replacement. Some considerations for replacement of Wharf 1 and 2 are provided in the following sections.

8.2.3 Long-term Replacement Strategy: Municipal Wharf 2

Wharf 2 faces similar vulnerabilities as Wharf 1 except the shift toward a replacement strategy would also be driven by its function as a key component of the local commercial fishing industry. The City of Monterey Fishing Community Sustainability Plan (Lisa Wise Consulting, 2013) describes the many commercial fishing activities on the wharf which include offloading, gear transfer, processing, gear repair and storage, ice production among others. The plan also notes the importance of the wharf as a community gathering place that connects residents and visitors with the marine eco-system and economy.

Some of the infrastructure that supports the commercial fishing industry includes two pump houses which require truck access for offloading wetfish, a hoist, an aquaculture facility and a warehouse. The CSP recommended several improvements to physical facilities including improved truck access and potentially a “turn-around” on the wharf, improved safety features, evaluating underutilized sites and other potential uses for these sites.

Given the overall poor state of repair (COWI, 2017) any significant long-term investment on Wharf 2 such as a truck turn-around or new warehouse building should include a focused study to determine if the wharf is able to support the proposed improvements over the desired life span. The focused study should include a comparison of the repair versus replacement costs and benefits to determine the best course of action.

Sea level rise impacts on adjacent beaches and transportation infrastructure could also impact operations and access to Wharf 2. The existing elevation of Del Monte Avenue is roughly 11 feet, NAVD 88 and was identified as a key vulnerability of the City wide sea level rise study (Revell Coastal, 2016). This transportation corridor provides the only vehicular access to Wharf 2 and therefore any long-term adaptation strategies for the Del Monte Avenue corridor also need to consider vehicular and truck access to Wharf 2.

8.3 Beaches and Coastal Access

Higher water levels from SLR and erosion associated with storm events would result in the loss of dry beach area impacting recreational beach users, swimmers, kayakers, and paddle boarders. Formal beach access points within the study area include McAbee Beach, Monterey Plaza Hotel Beach, San Carlos Beach, and Monterey Harbor Beach. A 2 foot sea level rise would result in loss of ~70% of the San Carlos Beach which would limit the opportunities for divers who use the beach as a staging and launch area. Beach loss at the Plaza Hotel Beach and McAbee Beach could also impact access to the water for swimming, diving, kayaking and paddling. Below are a few adaptation strategies for maintaining these pocket beaches and preserving access to the ocean.

8.3.1 Short-term Strategy: Opportunistic Beach Nourishment

The pocket beaches within the study area are confined by rocky outcroppings, small headlands, or breakwaters which act as barriers to sediment movement in the longshore direction. These beaches are also limited from landward migration and further cliff erosion by existing development. Therefore, the natural sources of sediment from cliff erosion or fluvial discharge are no longer providing a significant amount of sediment to these beaches which prohibits their ability to naturally adapt to sea level rise.

An opportunistic beach nourishment program could be an effective measure to supply sediment to these pocket beaches to help adapt to rising sea levels. These types of programs have been implemented in numerous California beach cities and typically involve designated receiver beaches and requirements for sediment compatibility that have been subject to the environmental review process. Given the relatively small pocket beaches and sheltered wave climate even a small amount of beach quality sediment (i.e. 1,000 to 5,000 cubic yards) could offer significant and lasting benefits.

Potential sources of sediment could be upland construction projects that involve excavation of beach compatible material or sediment removal from flood control facilities. This program could also "partner" with a future large scale beach nourishment program, similar to what has been evaluated for southern Monterey Bay, and involves sourcing and placing much larger sediment quantities (i.e. 0.5 to 2 million cubic yards).

8.3.2 Long-term Strategy: San Carlos Beach Park Improvements

San Carlos Beach is the most popular recreational beach of the study area and is a valuable resource for sunbathing, swimming, diving, kayakers etc. The location, parking availability and relatively wide beach area are key amenities of this beach park (Figure 8-2). The sandy beach is backed by a rock revetment which supports the bluff-top park. The sandy beach will eventually become squeezed between rising sea levels and this revetment resulting in significant loss of beach area under a 2 foot SLR scenario.

Figure 8-2: San Carlos Beach

Opportunistic beach nourishment could be an effective strategy for lower rates of sea level rise but it may not be sufficient to maintain a sandy beach area under high to extreme rates of sea level rise. A re-configuration of the revetment and bluff-top park amenities could improve the opportunities for long-term access to San Carlos Beach. The re-configuration could involve elements of managed retreat combined with a tiered park layout that transitions from the grassy bluff top down to the sandy beach. The re-configured park could offer perched beach areas at varied elevations and access ramps to provide easy entrance and exit from the water for divers, kayakers and other activities.

8.4 Coastal Habitat

Rocky intertidal habitats are prevalent along the Monterey waterfront (Figure 8-3). These transition zones provide important habitat areas for a diverse array of marine invertebrates and plant life. An essential element of what maintains the high levels of biodiversity found in rocky intertidal areas is the dynamic environment provided by tidal cycles, wave action, and sediment movement. SLR has the potential to disrupt this ecological balance, reducing benefits to surrounding ecosystems and diminishing shoreline protection functions. A living shoreline approach that incorporates rocky intertidal habitat restoration could be employed to offset these adverse impacts and provide multiple benefits to natural and built resources of the waterfront.

Figure 8-3: Rocky Intertidal Habitat in Monterey

8.4.1 Living Shorelines

Living shorelines refer to shoreline stabilization techniques that primarily consist of native material, combining vegetation or other living elements along with a structural element to provide stability. The use of native vegetation allows living shorelines to reduce coastal erosion while also providing critical habitat values. Working within existing ecosystems also reduces maintenance needs by employing structures that are compatible with natural coastal processes. A typical living shoreline concept applied in a sheltered coastal environment is illustrated in Figure 8-4.

Living shorelines have been employed in a number of forms including coastal mangroves, salt marshes, oyster reefs, reef balls, dunes, and seagrass or kelp beds, but limited examples exist that aim to replicate or enhance rocky intertidal habitat. Most living shoreline projects have been implemented along sheltered coastlines as opposed to the open coast settings subject to more dynamic water levels, wave energy, and sediment transport. The San Francisco Bay Living Shorelines Project, a pilot study of the effects of eelgrass and oyster reef restoration in the San Rafael region, found evidence of wave attenuation within restored habitats, though there is uncertainty whether these findings would hold under a more extreme wave environment.

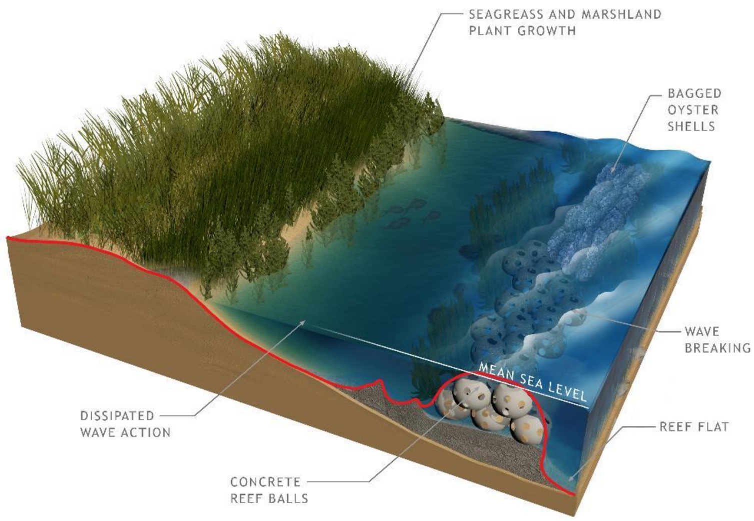

Figure 8-4: Typical living shoreline concept applied in a calm wave environment

8.4.2 Rocky Intertidal Habitat (Artificial Reef)

A living shoreline project based on stable rocky intertidal habitat potentially in combination with restored or enhanced reef structures, would represent a unique approach to living shorelines that, while currently lacking established standards and guidelines, could prove to be an important element of long-term climate resilience. While standards and guidelines are currently limited for such an approach, this strategy could provide additional habitat to keep pace with a rising tidal cycle and offer wave protection to benefit beaches and existing development.

There are also products such as ECOncrete®'s tide pool (Figure 8-5) that are designed to mimic natural rock pools typical to rocky coasts, and increase local biodiversity and biological productivity. The design of these features could also be fine-tuned to provide additional benefits such as sediment retention or potentially improved surfing conditions, and applications could vary to mimic the different nearshore rocky intertidal habitat types along Monterey.

Figure 8-5: ECOncrete Tide Pools (www.econcretetech.com)

8.5 Boating Infrastructure (Marinas and Moorings)

The infrastructure which supports commercial and recreational boating activities in Monterey Harbor include protective structures (breakwater and wave wall), floating docks and piles, utilities, a mooring field, launch ramps and parking. Some adaptation strategies for these facilities are described in this section.

8.5.1 Coast Guard Breakwater - Wave Protection

The Coast Guard Pier breakwater and interior wave wall around the municipal marina provide essential wave protection for commercial and recreational boating activities in Monterey Harbor. A key element of adapting boating infrastructure to future sea level rise is to maintain the condition of these structures. The wave transmission calculations indicate the existing structure will continue to be effective for sea level rise up to 2 feet provided they are maintained in their current condition and repaired if damaged under an extreme wave event.

A sea level rise of 5 feet would be problematic for the existing wave protection infrastructure. The Coast Guard Pier breakwater would need modifications to maintain the same level of protection for the interior harbor. Under this scenario the crest would be submerged at MHHW tide level allowing a significant amount of wave energy to propagate through and over the structure. In order to maintain a level of protection similar to existing conditions the crest of the breakwater would have to increase by about 4 feet. This would involve adding another layer or two of armor stone to the entire structure. For stability reasons the added layer(s) of armor stone would need to cover the entire surface of the trapezoidal structure, not just the crest.

8.5.2 Access and Parking

Vehicular access and parking is an essential element of the boating infrastructure in Monterey Harbor. Del Monte Avenue and portions of the marina parking areas were identified as vulnerable to flooding under 1-2 foot SLR scenarios (Revell Coastal, 2016). This low-lying transportation corridor provides the only vehicular access to the marina parking lots and therefore any long-term adaptation strategies for the Del Monte Avenue corridor should also consider measures to reduce the vulnerability of the marina parking lots. Some adaptation strategies could include improved flood storage or conveyance infrastructure, barriers to prevent flooding of the parking areas, or simply elevating the parking areas.

8.5.3 Floating Docks, Piles and Utilities

The floating docks, guide piles and utility infrastructure of the marinas are perhaps the most adaptive infrastructure in the Harbor since they are designed to function with the ~8 foot tide range. The floating docks are held in place by guide piles which are driven into the seabed and extend up to an elevation of about 13-14 feet NAVD 88. This provides roughly 4-5 feet of freeboard above present day high water level and therefore the docks can accommodate SLR projections for the remainder of their service life.

The typical service life of floating docks is 20-30 years with some newer products designed to last up to 50 years. The service life of the existing docks will likely expire before SLR becomes a major concern. Therefore, SLR adaptation strategies for marina infrastructure can be incorporated into planning and design of future marina upgrades. A key question will be whether the existing piles could remain, or if new (higher) guide piles will be needed to accommodate SLR over the facilities service life. Other marina elements to consider in future project planning include landside utility infrastructure and access gangways which may need to be modified to accommodate higher water levels.

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