FINAL

City of Manhattan Beach Sea Level Rise Adaptation Plan

Prepared for
City of Manhattan Beach

September 2021

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Funded by
California Coastal Commission
City of Manhattan Beach

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The Manhattan Beach Sea Level Rise Adaptation Plan is part of California Climate Investments, a statewide program that puts billions of Cap-and-Trade dollars to work reducing GHG emissions, strengthening the economy, and improving public health and the environment, particularly in disadvantaged communities. The Cap-and-Trade program also creates a financial incentive for industries to invest in clean technologies and develop innovative ways to reduce pollution. California Climate Investments projects include affordable housing, renewable energy, public transportation, zero-emission vehicles, environmental restoration, more sustainable agriculture, recycling, and much more. At least 35 percent of these investments are located within and benefiting residents of disadvantaged communities, low-income communities, and low-income households across California. For more information, visit the California Climate Investments website at: www.caclimateinvestments.ca.gov.

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CHAPTER 1

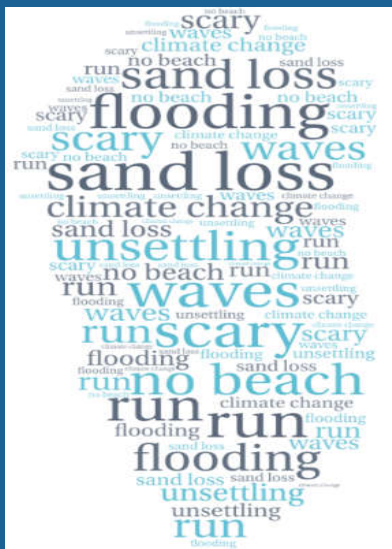
Introduction

1.1 Purpose and Objective

Although Manhattan Beach has experienced only a relatively small amount of sea level rise to date from climate change, the rate of sea level rise in the region is expected to accelerate significantly in upcoming years. Rising sea levels will result in increased hazards, including shoreline erosion and flooding. There is a need for the City and the community to better understand these vulnerabilities, to analyze the physical and economic risks, and to implement actions to prepare and adapt to the impacts of sea level rise.

As a result, the City of Manhattan Beach is updating its Local Coastal Program (LCP), a planning document that regulates development in the City's coastal zone and establishes a long-range vision for the community. The California Coastal Act, passed in 1976, provides for coastal jurisdictions to adopt an LCP to ensure local implementation of Coastal Act priorities. The City of Manhattan Beach's current LCP Land Use Plan (LUP) was certified by the California Coastal Commission (CCC) in 1981 and amended in 1992-1994. This study was commissioned as part of the City's update to its LCP to address anticipated sea

These are the words that come to mind when Manhattan Beach community members are asked about sea level rise.



level rise and its effects on coastal erosion and flooding and is funded by the CCC as part of the LCP Local Assistance Grant Program with California Climate Investment funding.

The first phase of this work included a Sea Level Rise Risk, Hazards, and Vulnerability Assessment (Vulnerability Assessment)[1] that highlighted existing conditions and future vulnerability of the City of Manhattan Beach to projected sea level rise, coastal flooding, and erosion. Based on the results of the Vulnerability Assessment, this document, the *City of Manhattan Beach Sea Level Rise Adaptation Plan*, identifies a variety of adaptation strategies to help Manhattan Beach plan for and address sea level rise, coastal storm flooding, and beach erosion. It provides a framework for the City to plan for sea level rise in phases through monitoring of impacts, tracking of new information, regular evaluations of options, and implementation of adaptation strategies once specified thresholds for action are reached.

The next phase of work will include development of policies that the City will ultimately include in the Climate Action and Adaptation Plan (CAAP), Local Hazards Mitigation Plan, and LCP-LUP update. The LCP-LUP update will require approval by City Council and certification by the CCC.

1.2 State Planning Guidance

The CCC updated their *Sea Level Rise Policy Guidance* in 2018 (CCC 2018). The guidance recommends using the California Ocean Protection Council's (CA OPC) *State of California Sea Level Rise Guidance* (CA OPC 2018) sea level rise projections at various planning horizons to assess vulnerability and conduct adaptation planning. The guidance provides a step-by-step process for addressing sea level rise and adaptation planning in updated LCPs (CCC 2018).

In accordance with the *California Coastal Commission Sea Level Rise Policy Guidance* (CCC 2018) and State of California Sea Level Rise Guidance (CA OPC 2018), this Adaptation Plan:

- Is based on the best science and adaptation practices available today.
- Acknowledges that sea level rise science and practices are evolving and that the City will evaluate future decisions and take action based on the best available science and technology at the time.
- Includes a range of sea level rise adaptation strategies within the three general categories of adaptation: Protect, Accommodate, and Retreat.

Additionally, Senate Bill 379 requires that Cities update the safety elements of their general plans to include climate adaptation and resiliency strategies. According to California's Office of Planning and Research (OPR) General Plan Guidelines, jurisdictions must identify a set of adaptation and resilience goals, policies, and objectives, based on the information analyzed

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[1] Available at https://www.manhattanbeach.gov/ClimateReadyMB

in the vulnerability assessment. The requirements of Senate Bill 379 have five distinct steps, including reviewing existing plans, conducting a vulnerability assessment, developing adaptation goals, creating implementation measures, and updating the safety element with adaptation and resilience considerations.

This Adaptation Plan and the CAAP will also be useful for the housing element update, evacuation route planning, and the environmental justice requirements for the City's General Plan.

1.3 Plan Organization

The Adaptation Plan is organized as follows:

- Chapter 1 identifies the purpose and objective of this Adaptation Plan, discusses State planning guidance, and defines key terms.
- Chapter 2 provides a framework for planning for sea level rise.
  - Section 2.1 provides the results of community input on community values and preferred adaptation strategies.
  - Section 2.2 outlines physical parameters that should be monitored over time, including sea levels, sea level rise projections, beach widths, and flood damages and frequency.
  - Section 2.3 and 2.4 discuss implementation and reevaluation.
- Chapter 3 provides a brief overview of the different adaptation strategies that could be considered for Manhattan Beach.
- Chapter 4 evaluates the key considerations associated with implementing city-wide strategies described in Section 3. This section focuses on strategies that are not asset-specific and could provide protection for many assets.
- Chapter 5 evaluates the key considerations associated with implementing strategies described in Section 3 for specific assets in the city.
- Chapter 6 provides a comparison of the potential hazards associated with a "no action scenario" presented in the Vulnerability Assessment with an adaptation scenario. The economic and fiscal impacts of the no action scenario are compared with the relative costs and benefits of the adaptation scenario.
- Chapter 7 presents tools for implementation of adaptation strategies such as policies, programs, regulatory mechanisms, education and outreach programs, agency resources, and potential funding options.

1.4 Key Terms and Definitions

The following terms are used throughout the document based on the definitions included in this section:

Coastal flooding refers to flooding due to waves and high water levels originating from the ocean.

Coastal storm events impact the shoreline through higher water levels due to storm surge, large waves, and/or elevated river flows, all of which are commonly associated with low-pressure weather systems. Planning and analysis often occurs for the "100-year storm," which is the storm estimated to have a 1% chance of occurring in any given year.

Coastal storm flooding refers to coastal flooding that occurs during coastal storm events.

Tidal inundation refers to coastal flooding during high tides under non-storm conditions.

Coastal erosion refers to loss of sandy beaches, beach dunes, and the low-lying backshore along the shoreline through processes such as waves, wind, or tides.

Rainfall events impact the City through flooding originating from precipitation.

CHAPTER 2

Adaptation Planning Framework

Successful adaptation planning is an ongoing, collaborative process that requires alternatives analysis, implementation, monitoring, and evaluation. This section establishes principles to guide the prioritization, selection, and implementation of adaptation strategies. It also identifies thresholds that should be regularly monitored to inform the timing for implementation of adaptation strategies, which will require revisions to existing City policy, regulatory, and procedural tools; creation of new tools and programs; identification of funding sources; and project-level planning, design, and construction. Changes in best available science, best practices, laws, case law, and community priorities will require regular reevaluation of this Adaptation Plan.

2.1 Community Values

These are the words that come to mind when Manhattan Beach community members are asked about their city.

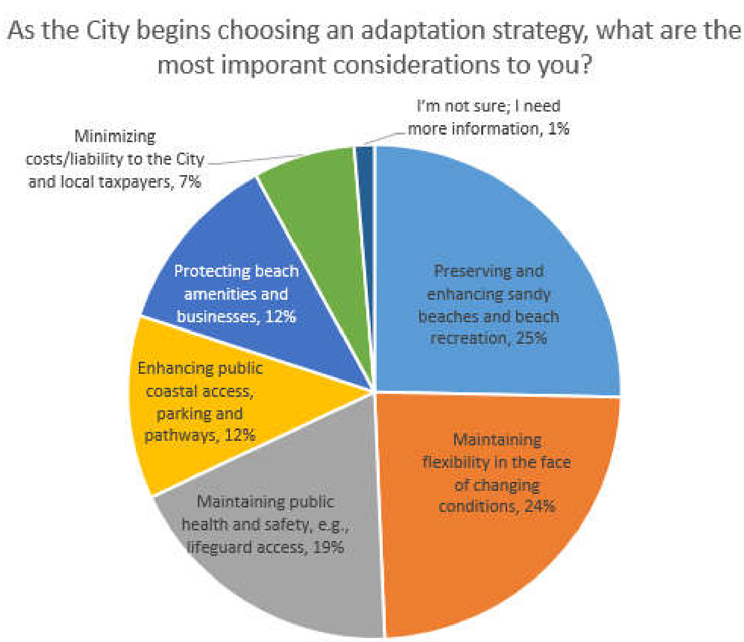
Two public workshops and two focus group meetings were held to inform the development of this plan in February and March 2021 with a total of 77 participants.

2.1.1 Workshops and Focus Groups

The first workshop was held on February 4, 2021, attended by approximately 45 community members, and the objectives for the workshop included:

- Providing an overview of the project,
- Providing scientific context for climate change and sea level rise hazards,
- Providing opportunities for people to ask questions and get answers,
- Gathering input on the community values for Manhattan Beach residents and visitors,
- Sharing next steps and future opportunities for public engagement.

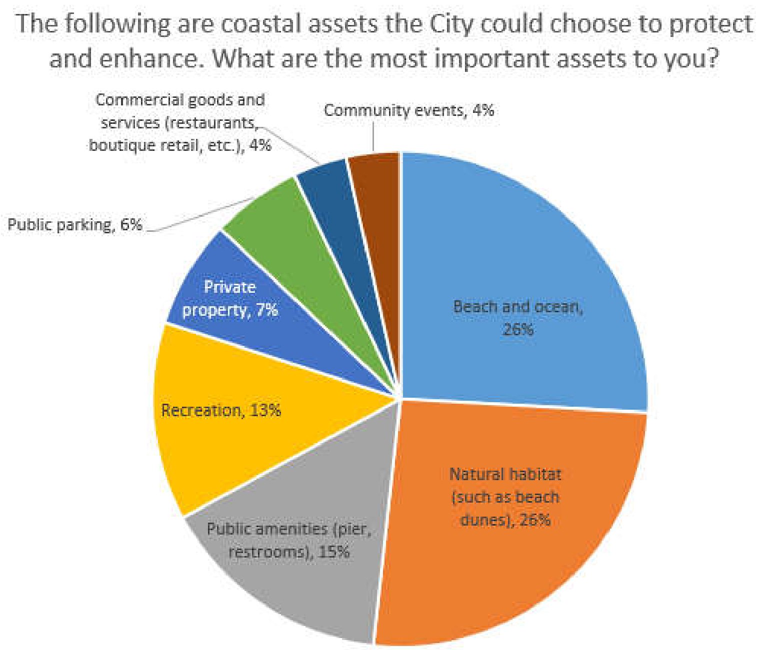
When asked about their priorities when choosing an adaptation strategy, attendees were most concerned with protecting and enhancing sandy beaches and beach recreation and maintaining flexibility in the face of changing conditions, as shown in Figure 1.



Based on 23 participant responses.

Figure 1: Considerations for Adaptation Planning in Manhattan Beach

When asked about the most important coastal assets the City should choose to protect and enhance, participants identified the beach and ocean, natural habitats (such as beach dunes), public amenities (such as the Pier and restrooms), and recreation as their priorities (Figure 2).



Based on 24 participant responses.

Figure 2: Priority Assets to Protect and Enhance

After the first workshop, a series of two focus group meetings were held to facilitate small group discussions around adaptation strategies. The first meeting was held on February 17 and had 7 attendees. The second meeting was held on February 23 and had 11 attendees.

Following the focus group meetings, on March 9, 2021 a second public workshop was held with 14 people in attendance. This workshop focused on coastal adaptation strategies with the objectives to:

- Provide an overview of the city's vulnerabilities to sea-level rise and potential adaptation strategies
- Provide opportunities for people to ask questions and get answers
- Gather input from residents and visitors on the preferred adaptation strategy for Manhattan Beach
- Share next steps and future opportunities for public engagement

Data gathered from the focus group meetings and second workshop are included in Sections 4.8, 5.1.6, and 5.2.7.

2.1.2 Demographics

Approximately 45 people attended the first workshop, and of the 14 people who responded to demographic questions, 11 live in Manhattan Beach, two in Los Angeles, and one in Redondo Beach. Figure 3 presents the age demographics of the workshop attendees who responded.

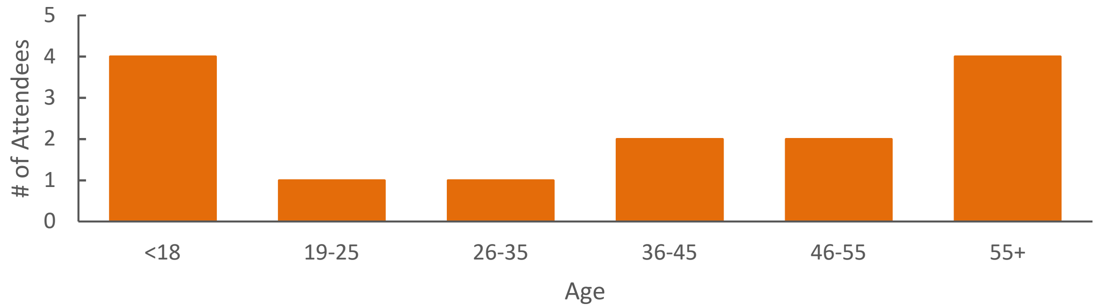


Figure 3: Workshop #1 Attendee Age Demographics

Most attendees at the focus group meetings were from Manhattan Beach with a few from Los Angeles, Long Beach, and beyond. Figure 4 presents the age demographics of the focus group attendees.

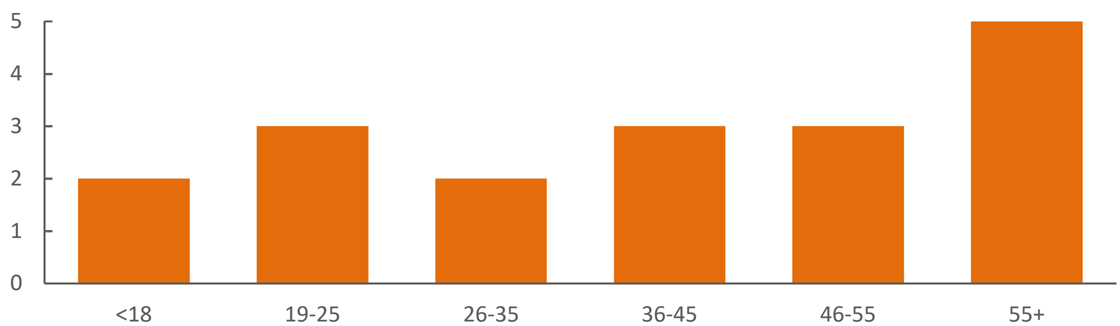


Figure 4: Focus Group Attendee Age Demographics

2.2 Monitoring Change

The Adaptation Plan identifies planning-level thresholds for when decisions on adaptation should be considered to reduce or avoid future risks (see Sections 4 and 5 for examples of thresholds). The City will need to monitor and evaluate the trajectory towards these thresholds to track whether and when these thresholds are met. The City, in consultation with other regional, state, and federal agencies, should create a Shoreline Monitoring Program to track changes in environmental conditions. Table 1 and the sections below identify some parameters that are recommended for monitoring. Additional analysis is needed to determine the exact parameters that should be monitored, given the priorities and goals of the City. The City could partner with other regional agencies or groups, such as Los Angeles County Department of Beaches and Harbors, University of Southern California (USC) Sea Grant, AdaptLA, The Bay Foundation (TBF), or researchers at academic institutions such as Loyola Marymount University Coastal Research Institute (CRI), Cal State Channel Islands or University of California Los Angeles, to assist in tracking thresholds, developing a monitoring program, and conducting regular reporting. The program should be developed in coordination with others to ensure that it is cost effective to maintain over time and that the data can be used by others and/or scaled up to the regional or state level. Additionally, if data could be standardized, it could be used in coordination with existing monitoring programs, such as CRI's regional program monitoring beaches in the Santa Monica Bay area. Quality control checked data or data summaries should be made publicly available to ensure transparency with the public and coordination with other entities.

TABLE 1: SUMMARY OF POTENTIAL MONITORING PARAMETERS TO BE CONSIDERED

PARAMETER	POTENTIAL MONITORING DATA
Sea Level Rise	The monitoring program should track the following resources for science updates: ▪ *California Coastal Commission Sea Level Rise Policy Guidance* ▪ California Natural Resources Agency and OPC *State of California Sea Level Rise Guidance* ▪ California Climate Change Assessment (Fifth Assessment forthcoming) ▪ U.S. Geological Survey Coastal Change Hazards Program, including the Coastal Storm Modeling System (CoSMoS) ▪ National Oceanic and Atmospheric Administration (NOAA) Tides and Currents, Santa Monica Bay station ▪ Coordinate with academic institutions to follow scientific reports they produce on sea level rise in Southern California
Coastal Storm Flooding and Storm Damage Frequency	The monitoring program should record coastal flooding and storm damage events and information: ▪ Photos, videos, reports of event or damage (can coordinate with the Urban Tides program) ▪ Date, type, location, and severity of flooding (e.g., depth, duration, wave height), and damages
Beach Width	The monitoring program should include topographic surveys of the beach (e.g., beach elevation transects) to measure beach width over time. These could be conducted in coordination with Los Angeles County Beaches and Harbors.

2.2.1 Sea Level Rise

Sea levels in Manhattan Beach have increased by 0.51 feet in the last 100 years (NOAA Tides and Currents, Station #9410840). Available sea level rise projections use the year 2000 as a baseline. Over the past 20 years, sea levels are estimated to have increased by 0.11 feet[2] in Manhattan Beach. However, the rate of sea level rise is expected to accelerate in the coming decades with potentially 6.8 feet of sea level rise by 2100[3]. The City should monitor the rate of sea level rise and progress toward thresholds because certain actions will need to be taken when sea levels have risen by specific amounts (e.g., relative to a baseline of the year 2000) to reduce vulnerability to coastal hazards. Currently, the best available sources for this information are found through the NOAA tide gage in Santa Monica Bay and in the following state documents:

- California *Coastal Commission Sea Level Rise Policy Guidance*: initially adopted August 2015, updated November 2018 (https://www.coastal.ca.gov/climate/slrguidance.html)
- California Natural Resources Agency (CNRA) and Ocean Protection Council (OPC) *State of California Sea Level Rise Guidance*: initially released in 2010, updated in 2013, and updated in 2018 (http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/)

2 This estimate is based on applying the rate of historic sea level rise of 1.54 mm/yr published by NOAA Tides and Currents at Station #9410840 over a 21-year period (2000 to 2021).

3 Based on the CNRA and OPC 2018 medium-high risk aversion scenario.

- California Climate Assessment: initially released in 2006, updated in 2009, updated in 2012, and updated in 2018 (http://www.climateassessment.ca.gov/)
- NOAA Tides and Currents for Station ID 9410840 (or others): updated regularly (https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9411340)

2.2.2 Flooding and Coastal Storm Damage Frequency

The City should monitor the frequency of flooding and coastal storm damage. To monitor the frequency of flooding and storm damage, the City should track and keep records of coastal flooding and storm damage events and information, including "king tide events," which are some of the highest and lowest tides of the year. In particular, the City should track storm flooding of and damage to the Marvin Braude Bike Trail; the public restrooms at El Porto beach, the end of Rosecrans Avenue; the maintenance facility at the end of Rosecrans Avenue; the food stand and beach rental buildings at El Porto Beach; the Lower Pier Parking Lot; and the Manhattan Beach Pier.

This effort will require a framework for coordination between multiple departments, such as Community Development, Parks and Recreation, Fire, and Public Works. This effort could also be a collaborative effort between City staff, community groups, other agencies such as Los Angeles County Beaches and Harbors, and community members in which reports, pictures, and videos are collected, such as through the Urban Tides program. This provides a secondary benefit of keeping the community engaged and increasing knowledge of the impacts of sea level rise. It could also assist with obtaining funding to mitigate flood risks. The date, type, location, and severity of flooding (e.g., depth, duration, wave height), and damages can be collated into a database. The intent should be to track the frequency, extent, and severity of flooding to assess if and how the frequency of flooding is increasing. If the tracking shows an increase in the flood and storm damage frequency, implementation of an adaptation measure could be considered.

2.2.3 Beach Width

The City should monitor beach width or participate in a regional program to monitor beach widths. This is in line with recommendations included in the Los Angeles County Coastal Regional Sediment Management Plan (CRSMP; Noble Consultants and Larry Paul Associates 2012). Beaches provide recreational and ecological value, as well as a buffer from erosion and flooding for beachfront development. The City is partnering with Los Angeles County Department of Beaches and Harbors and The Bay Foundation to implement the pilot Manhattan Beach Dune Restoration Project (see Section 4.1 for more information on this project). Post-project monitoring will include beach width and other physical characteristics. Additional data have been collected by CRI as part of a regional beach characterization study. It is recommended that an annual long-term survey for Manhattan Beach be implemented. This data should be analyzed regularly to evaluate beach width trends and to identify the need for adaptation strategies.

2.3 Implementation

This Adaptation Plan provides a structure for decision making and planning for sea level rise. Adaptation strategies are analyzed at a conceptual planning-level of detail for purposes of considering potential benefits and effects of adaptation strategies. Implementation of adaptation strategies will require a broad suite of tools, programs, collaboration, and funding sources to help the City take action (Chapter 7).

As projects are developed, additional detailed project-level planning and design would be required. For adaptation strategies involving construction, the project-level planning and design should consider:

- A feasibility study that includes additional technical analyses, development, and assessment of project alternatives and details, conceptual and preliminary engineering design, and cost estimates.
- Community and stakeholder engagement to solicit input on the project alternatives and design details.
- California Environmental Quality Act (CEQA) and possibly National Environmental Protection Act (NEPA) environmental review and regulatory permitting. Regulatory permitting could require approvals and permits from the U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service, NOAA, California State Lands Commission, CCC, and California Department of Fish and Wildlife (CDFW), as well as other federal and state agencies.
- Final engineering design.

Lead time is required to perform project-level planning, secure funding, and implement or construct an adaptation measure. All adaptation options discussed in this Adaptation Plan require substantial lead time; therefore, thresholds have been developed so that planning for these projects occurs before they are needed (see Sections 4 and 5).

2.4 Evaluation

The Adaptation Plan should be evaluated and regularly updated to capture advances in sea level rise science and best practices, and new or evolving community priorities. The Adaptation Plan should be updated approximately every ten years or as substantive new information is available and as major updates occur to the *State of California Sea Level Rise Guidance*.

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CHAPTER 3

Adaptation Measures

This section identifies adaptation measures based on science, best practices, CCC guidance (see Section 1.2), and input from the community. Section 3 presents a range of strategies. Considering a broad range of sea level rise adaptation measures allows Manhattan Beach to respond to the threat of rising sea levels through adaptive management with a variety of strategies that can work at different places and at different times.

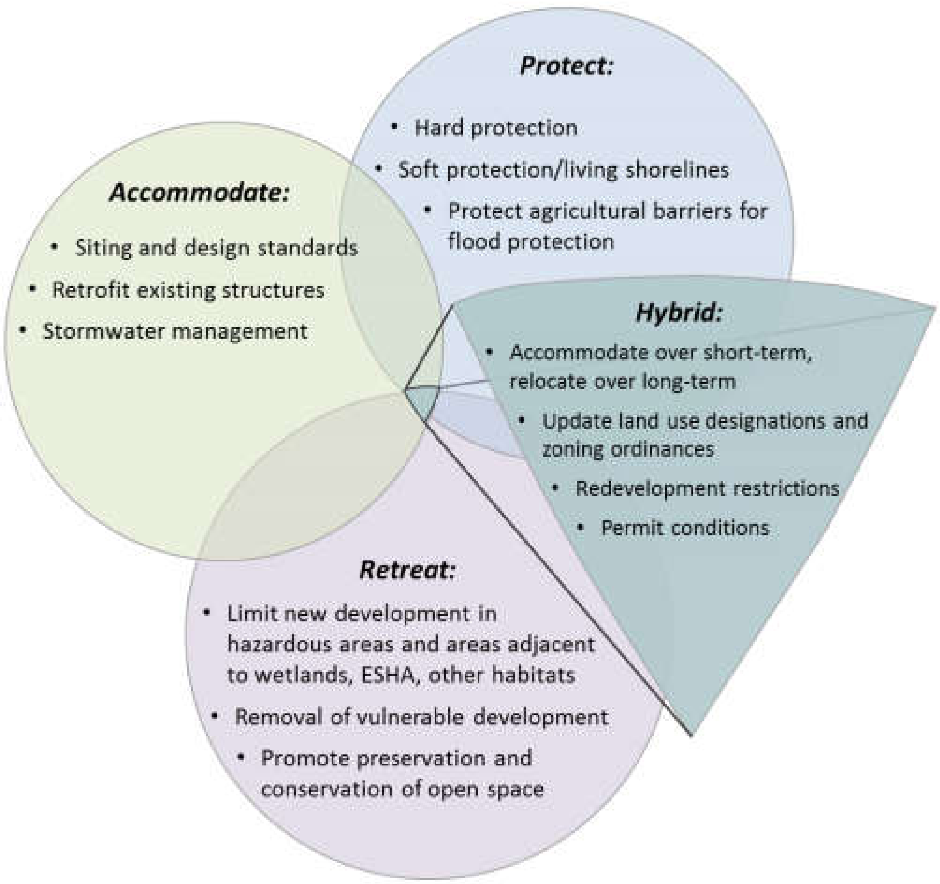
3.1 Categories of Adaptation Strategies

Adaptation strategies, which defend against coastal hazards like wave impacts, erosion, and flooding, are typically organized within the following categories (Figure 5):

- **Protection strategies,** which employ some sort of nature-based method, engineered structure, or other measure to defend development or resources in their current location without changes to the development itself. Examples of protection strategies include beach dunes; beach sand nourishment; engineered shoreline protective devices such as seawalls, revetments, groins, and breakwaters; living shorelines; and hybrid approaches using both artificial and natural infrastructure such as engineered beach dunes.

- **Accommodation strategies,** which modify existing development or design new development in a way that decreases hazard risks and increases the resiliency of development. Examples include elevating and/or retrofitting structures and using materials that increase the strength of development. In Manhattan Beach, this could include floodproofing or raising buildings to accommodate high-water-level events.
- **Retreat strategies,** which relocate existing development, limit substantial redevelopment, and/or limit the construction of new development in vulnerable areas. Development setbacks are an example of a retreat strategy.

Different types of strategies will be appropriate in different locations, and, in some cases, a hybrid approach with strategies from multiple categories may be the best option. Additionally, the suite of strategies chosen may need to change over time as conditions change and previous areas of uncertainty and unknown variables become more certain.



Note: ESHA is defined as Environmentally Sensitive Habitat Area

SOURCE: CCC 2018

Figure 5: Examples of General Adaptation Strategies

3.2 Potential Adaptation Strategies for Manhattan Beach

The Vulnerability Assessment identified the degree of vulnerability the City could face as a result of sea level rise. This Adaptation Plan provides tools for Manhattan Beach to manage risks, plan for, and take actions to build more coastal climate resiliency. The following subsections describe a variety of typical adaptation strategies that are considered in the Adaptation Plan. Sections 4 and 5 then discuss how these, and other more site-specific adaptations, can be applied to the different vulnerable areas of Manhattan Beach.

3.2.1 Coastal Sediment Management – Beach Dune Restoration

Beach dune restoration is recognized as a nature-based way of mitigating backshore erosion, as well as maintaining a wider beach by creating an additional source of sand at the back of the beach, while increasing local sand retention. When beach dunes are allowed to form by natural accretion, they provide a cost-effective buffer of protection from sea level rise and storm erosion. Beach dunes may be allowed to form naturally by restricting grooming and mechanical raking of the beach sand, or through active construction. Seeding or planting native dune plant species to form "living" beach dunes with specialized plants that naturally trap sand as it blows through the system, can create the potential for dunes to grow vertically over time. For example, Santa Monica's beach dune restoration has accreted over a foot of sand, with dune hummocks up to three feet, over about four years with no mechanized sediment movement, just natural accretion (The Bay Foundation 2020). Based on wind data and sediment availability, Manhattan Beach dunes could have similar accretion. Beach dune construction could include placing or moving sand, grading, and planting native plant species (Figure 6). Beach dune restoration can provide aesthetic, ecological, resiliency, and recreational benefits. Native dunes provide habitat for wildlife such as shorebirds, lizards, and specialized invertebrates, including many rare species. When constructing dunes, one hybrid engineered option includes placement of cobble or rock below the constructed sand dune. Cobble and rock are often naturally present below beaches in California (Figure 7). Burying a layer of cobble or rock provides a "backstop" that may be more erosion resistant and dissipates waves to a greater degree.

Restored beach dunes can provide coastal resiliency and storm protection, and have the potential to grow over time to provide increased protection. Both beaches and dune systems are naturally dynamic and can be eroded and washed out during large storm events. However, some of the eroded sand often forms an offshore bar. During the summer and post-storm-events, waves gradually return some of the eroded sand from offshore back to the beach. However, some of the sand can be lost offshore or moved down-coast.

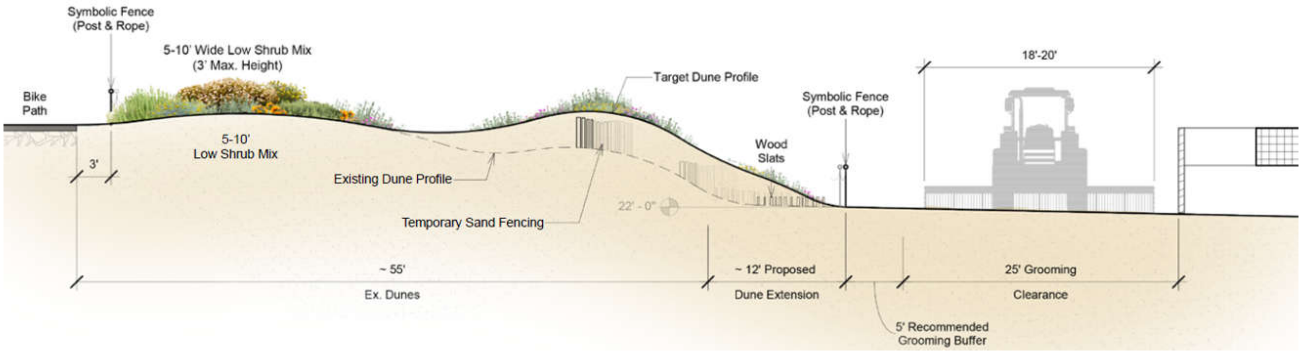


Figure 6: **Cross-section of the planned Manhattan Beach dune restoration project**

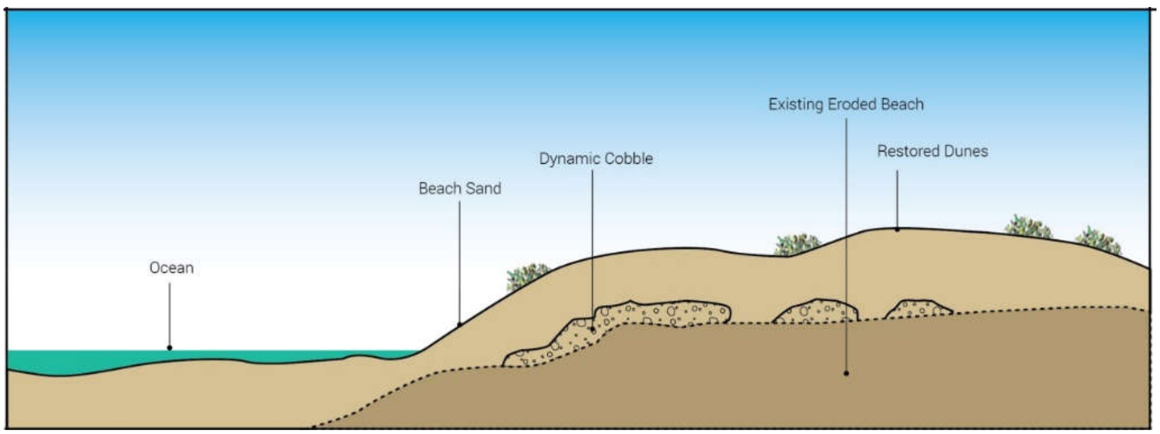


Figure 7: **Cross-section of dune restoration and cobble placement**

3.2.2 Coastal Sediment Management – Winter Berms

Beach sculpting or the creation of winter beach berms is an adaptation strategy that provides protection against coastal storm flooding and waves during the winter coastal storm season. Sand is scraped from the foreshore using bulldozers to construct berms that are generally between 12 to 16 feet high (Figure 8).

Los Angeles County Department of Beaches and Harbors (LACDBH) regularly constructs temporary seasonal sand berms at beaches such as Zuma Beach, Venice Beach, Dockweiler State Beach, and Hermosa Beach to reduce winter flooding of the lifeguard facilities, restrooms, maintenance yards, bike paths, public parking lots and other infrastructure along the coast (LA County 2016). The County considers it to be one of the most cost-effective strategies to protect coastal assets. However, as sea levels rise and beaches erode, the temporary winter berms will become less effective and harder to construct each season. Additionally, winter berms have detrimental impacts on the nearshore ecological community since berm creation can smother species and grading of the beach can lower diversity and abundance of wrack-associated animals.

Source: LA County 2016

Figure 8: Construction of a temporary winter berm at Hermosa Beach

3.2.3 Coastal Sediment Management – Beach Nourishment

Example of beach nourishment in Carlsbad, CA

Source: SANDAG

Beach sand nourishment is an adaptation strategy that refers to placement of sand to widen a beach, which can be accomplished by placing a sediment-water slurry directly on the beach or mechanical placement of sediment with construction equipment (see photo to the left). Beach nourishment is an adaptation strategy that provides protection against coastal storm erosion while increasing the sediment supply and beach width and some dynamic coastal processes, such as the ability of the beach to erode in response to winter coastal storms and build up sand in response to summer wave conditions. However, impacts to nearshore ecology and beach species such as fish, invertebrates, and birds can occur during sand placement and beach construction. Sand can be obtained from inland sources (e.g., construction projects, quarries) or can be dredged from offshore; however, it can be difficult to find sand supplies of the right quality (e.g., grain size, color, non-toxic/clean) and quantity for beach nourishment. There are substantial permitting requirements for beach nourishment including timing the nourishment project to minimize ecological and public access impacts, requirements for sediment (testing requirements, grain size, contaminants, etc.), and monitoring for impacts over time. However, the coastal permitting tends to be more feasible than engineered coastal structure adaptation strategies, such as groins and breakwaters. The City should coordinate on beach nourishment strategies with LACDBH and the California Coastal Sediment Management Work group (CCSMW), which is a collaboration between the CNRA, the U.S. Army Corps of Engineers, and regional entities. USACE and CCSMW developed the CRSMP, which includes recommendations to identify, quantify, and dedicate offshore sand resources in Los Angeles County to restore public beaches.

While beach nourishment initially reduces the risk of flooding and erosion along the beach, beach width is expected to diminish with time, requiring an ongoing cycle of “re-nourishment” to maintain the beach. Additionally, while a wider beach reduces wave energy that reaches the shore, nourishment may not protect against flooding during high water level events, such as those that occur with King Tides and storms. During large coastal storm events, sand can be transported off the beach rapidly, reducing or eliminating the benefit of the sand nourishment.

As sea level rises, the frequency of required nourishment is likely to increase, as seen in other coastal jurisdictions in California. In addition to widening the beach to offset erosion, additional sand will be needed to raise the elevation of the beach up to the increased sea level. The demand for sand sources is likely to increase, and the availability of sand may become increasingly scarce or uncertain. Beach nourishment can be considered in conjunction with sand retention measures to improve the longevity of sand placements such as nature-based methods or construction methods (see Section 3.2.4 below).

3.2.4 Sand Retention Structures – Groins

Groins are engineered perpendicular revetments like jetties that extend perpendicular to the beach and trap sand from drifting downcoast (Figure 9). Where wave conditions are ideal, groins have been successfully used along some parts of the California coast and other locations to maintain a wider beach. In other cases, groins can induce and/or accelerate erosion downcoast of the groin, as shown in Figures 9 and 10. Construction of groins is generally considered along stretches of the coast with high net longshore sediment transport. In application, groins segment the beach and nourishment efforts into compartments, where sand is ideally contained within the compartment.

SOURCE: Google Earth

Figure 9: Aerial of Groins at Will Rogers State Beach in Santa Monica Bay

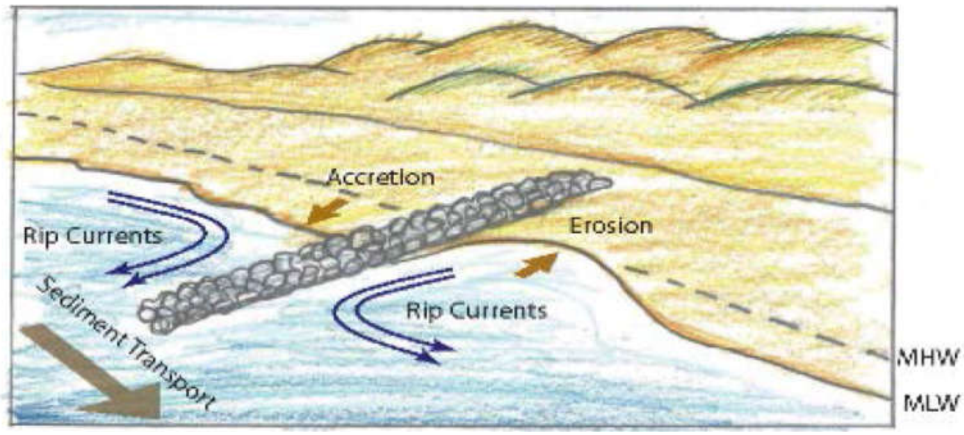


Figure 10: Example of the processes around groins

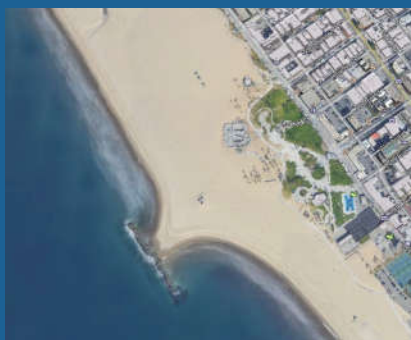
Limited public access over or across groins has the potential to negatively impact horizontal access along the beach, such as seen in South Redondo Beach. Constructing rock groins and other rock structures on the beach and/or in the ocean would alter the character of the natural shoreline and offshore habitats and have biological impacts to beach and nearshore species. Groins can significantly reduce the amount of sand transported down-current to neighboring beach areas as sand is trapped up-current of the groin. This impact may be somewhat mitigated if the area up-current of the groin is partially filled with sand as part of construction. This can require significant amounts of imported sand. A regional plan may be needed to address down-current impacts.

Due to the potential impacts to down-shore beaches and ecological impacts, new groins are challenging to permit. Most groins in Los Angeles County were constructed decades ago under different permitting regulations and before the California Coastal Act. At a minimum, the following would be required for there to be a chance at permitting success with CCC and other agencies with jurisdiction offshore: (1) a robust alternatives analysis showing that no other feasible, less damaging alternatives exist; (2) a clear demonstration of need; and (3) consistency with the goals of the Coastal Act and the Public Trust Doctrine which applies to public trust lands (tide and submerged lands and beds of navigable waters). Permitting conditions could include, among others, habitat mitigation and/or sand mitigation to address any impacts to sand transport downcoast. However, if the groins worked as intended, stabilizing and widening the beaches would add recreational area and provide a buffer for development, which could potentially meet the objectives of the California Coastal Act.[4]

[4] Griggs, G, K. Patsch, C. Lester, and R. Anderson. 2020. Groins, sand retention, and the future of Southern California's beaches. Shore and Beach, Vol 88, No 2. Spring 2020.

3.2.5 Sand Retention Structures – Breakwaters

The Venice Breakwater has slowed sand transport behind it, widening the beach.



Source: Google Earth

Breakwaters are offshore structures constructed parallel to the beach to reduce wave action. Typically built out of rock or concrete, breakwaters extend from the ocean floor to above the ocean level, thereby acting as a wall that blocks waves by causing them to break farther offshore. Breakwaters dissipate incident wave energy shoreward of the breakwater and change the pattern of sand transport in their lee (i.e., wave shadow), thereby reducing the transport of sand. These structures are generally applicable where there is a firm seabed and the need to create a calm area free from wave energy.

Breakwaters have been used to shelter shorelines and harbors, have been built in shorter segments to encourage sand accumulation behind the breakwater segments, and in some instances can provide access and recreation. However, breakwaters significantly change wave patterns and have the potential to change surfing resources. They can also starve down-current areas of sand as sand accumulates in front of the breakwater. Breakwaters can also displace and change ocean habitats.

Due to permitting and mitigation requirements, very few new breakwaters are being considered in California, and the removal of breakwaters has been explored in some cases such as the City of Long Beach's East San Pedro Bay Ecosystem Restoration Feasibility Study to remove the Long Beach Breakwater. However, the repair and enhancement of existing structures has been approved by the CCC in several cases. For example, in Laguna Beach, the CCC permitted the enlargement of a rock ledge to increase its ability to retain sand, and in 2021, the CCC approved the use of small rock groins to help stabilize a living shoreline, shore protective feature at West Trail in Half Moon Bay. In the future, sea level rise may change the way proposed projects are analyzed under the Coastal Act. For example, with future sea level rise, sand retention structures could possibly become more feasible to permit if they are the most protective measure for coastal resources at a particular location. It is therefore uncertain as to whether current permitting trends will continue into the future or not.

Similar to groins, the following would be required for there to be a chance at permitting success with CCC and other agencies with jurisdiction offshore: (1) a robust alternatives analysis showing that no other feasible less damaging alternative exist; (2) a clear demonstration of need, and (3) consistency with the goals of the Public Trust Doctrine and Coastal Act. Permitting conditions could include, among others, habitat mitigation and/or sand mitigation (e.g., beach nourishment) to address any impacts to sand transport downcoast.

3.2.6 Sand Retention Structures – Reefs, Kelp Beds, and Eelgrass Beds

Rocky reefs, kelp beds, and eelgrass beds can provide habitat for native species, sequester carbon through plant life, and accumulate sediment offshore. Restoring or constructing these habitats offshore can potentially provide some protection from coastal hazards as well.

Artificial reefs are underwater, offshore structures constructed of rock or other materials (Figure 11). Multipurpose artificial reefs are intended to encourage sand retention behind the reef, reduce wave energy, provide rocky reef habitat, and provide or enhance surfing resources (Figure 12). Because reefs are usually submerged, they do not completely reduce wave energy or flooding at the shoreline. Artificial reefs installed to act as submerged breakwaters have received increased attention in recent years as a means of shore stabilization and erosion control. This is primarily due to their low aesthetic impact, enhanced water exchange relative to traditional emergent breakwaters (Vicinanza et al. 2009), ecological benefits, and potential to enhance local surfing conditions (Ranasinghe and Turner 2006).

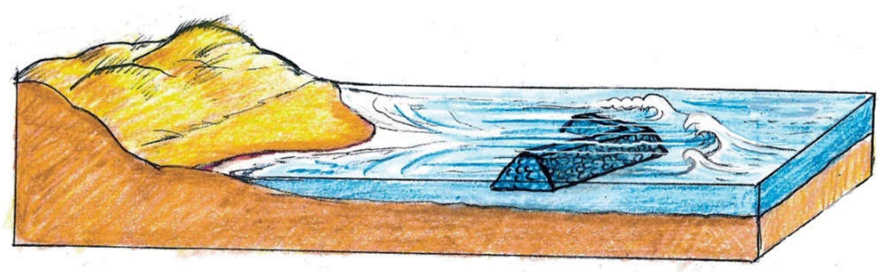


Figure 11 Example illustration of an offshore reef

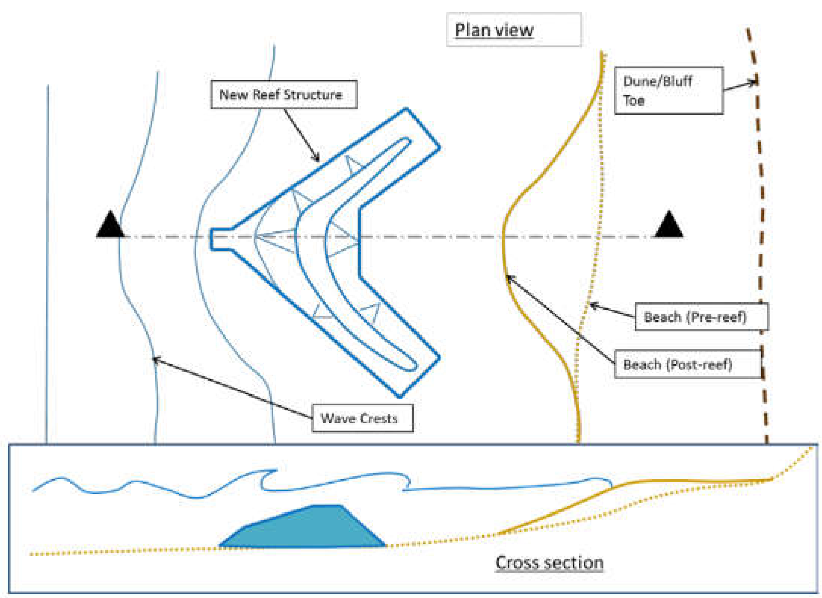


Figure 12 Schematic of multipurpose reef intended to create a surfing break

Use of artificial reefs to retain sand and enhance surfing is still a relatively recent method when compared with groins and breakwaters. Artificial reefs have been investigated, constructed, and monitored as a way to enhance habitat and marine life in various locations, including locally in Palos Verdes and Orange County; however, these projects were not designed for sand retention. Pratt's reef, constructed off the beach of El Segundo in 2000 with the purpose of improving surfing conditions, was considered a failure at providing surf and was removed in 2010[5]. There is not currently enough evidence with successful sand retention associated with artificial reef construction to assess the feasibility of reefs for this purpose. CDFW is currently

[5] https://www.surfrider.org/coastal-blog/entry/asr-removal-in-el-segundo-ca

working to develop a statewide artificial reef management plan, which will help guide strategies for possible future artificial reef construction in California. While reefs may reduce sand transport downcoast less than groins and breakwaters, their purpose from a coastal adaptation standpoint would still be to retain sand, which would have some impact to downcoast sand transport. Artificial reefs can provide underwater habitat for marine species, but they can also displace and change existing ocean habitats at the reef site and shoreward of the reef.

As with any sand retention structure proposed offshore, permitting would be complex. At a minimum, the following would be required for there to be a chance at permitting success with CCC and other agencies with jurisdiction offshore: (1) a robust alternatives analysis showing that no other feasible less damaging alternative exist; (2) a clear demonstration of need, and (3) consistency with the goals of the Public Trust Doctrine and Coastal Act. Permitting conditions could include, among others, habitat mitigation and/or sand mitigation to address any impacts to sand transport downcoast.

Kelp beds combined with artificial reef installation can provide habitat benefits with some reduction in sand movement downcoast as well as wave attenuation benefits. Restoring kelp beds requires a rock substrate and can be accomplished in areas with existing submerged rock or by constructing and placing rock offshore. Scientists at UC Davis and LMU are currently assessing kelp beds for wave attenuation. With a focus on restoration of kelp forest habitat, permitting of this strategy may be less complex than other sand retention structures and strategies.

Eelgrass beds establish in sandy bottom habitat, such as the habitat found along Manhattan Beach's coast. Scientists in California are currently investigating the potential carbon sequestration, sand accretion, and wave energy dissipation from offshore eelgrass beds (*Zostera pacifica*), which could inform Manhattan Beach's adaptation strategies. The Bay Foundation has three eelgrass restoration projects throughout Santa Monica Bay, that can provide additional data on this strategy. With multi-benefits to marine life from eelgrass bed restoration, permitting of this strategy may be less complex than other sand retention structures and strategies, especially if current studies show that eelgrass retains and stabilizes offshore sediment, while providing benefits to marine life and sequestering carbon.

3.2.7 Shoreline Protection Devices

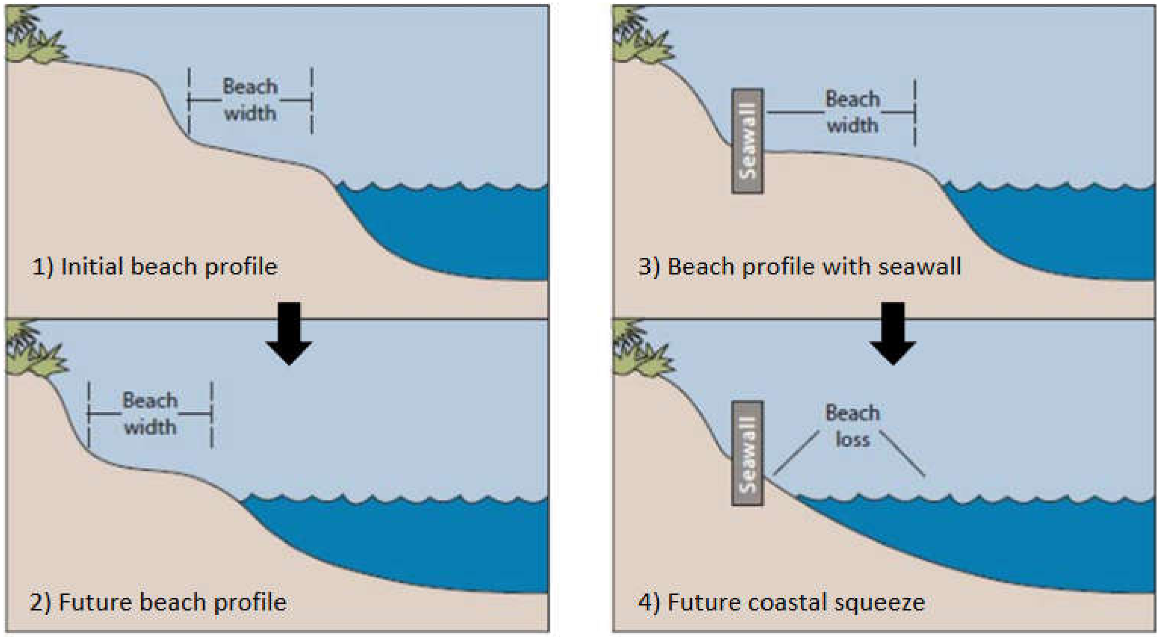
A photo of a seawall in San Diego, CA

Shoreline protection devices, such as seawalls and rock revetments, are structures along the coast that can provide flood and erosion protection for properties by absorbing or dissipating wave energy. Seawalls are vertical structures along a beach used to protect structures and property from wave action (see the photo to the right). They may be either gravity- or pile-supported structures and are normally constructed of stone or concrete.

Revetments provide protection to slopes and are constructed of materials such as stone boulders (Figure 13). Similar in purpose to a seawall, revetments work by absorbing or dissipating wave energy. Revetments are made up of an armor layer (e.g., rock rip-rap piled up or a carefully placed assortment of interlocking material, which forms a geometric pattern), a filter layer (which provides for drainage and retains the soil that lies beneath), and a buried toe (which adds stability at the bottom of the structure).

Figure 13: Photo of waves against a revetment in Pacifica, CA

While seawalls and revetments can provide protection to existing coastal development behind them, these structures can contribute to erosion and accelerate beach loss. The structures fix the shoreline from moving inland, impacting natural coastal dynamics. Normally, waves lose momentum and energy as they run up a gently sloping shoreline, and sand is deposited to form beaches. Many shoreline protection devices make a hard back-stop to the shoreline. Waves hit the devices and reflect backward, rather than dissipating, often causing increased sand erosion in front of the device. They can also increase beach erosion on either side of the device and impact down-shore sand supplies. With ongoing beach erosion and sea level rise and without any other mitigating measures, "fixing" the shoreline location with a seawall or revetment will eventually lead to the loss of the beach seaward of the structure (Figure 14).



SOURCE: CCC 2018

Figure 14: Coastal squeeze process resulting in beach loss

In some cases, seawalls and rock revetments can have significant impacts on lateral acccess along the beach due to their displacement of beach area during construction as well as beach loss that can occur in front of and adjacent to these devices after construction. In some cases they may also impair vertical access to the beach. Paths of access can be provided over and along the top of seawalls and revetments. It is more difficult, however, to climb one of these structures than to simply walk on the beach. Seawalls and rock revetments also can displace and significantly alter beach habitats and ecology.

Additionally, using seawalls or rock revetments to "hold the line" on an eroding shoreline with sea level rise may not be sustainable due to increasing wave action and overtopping associated with the loss of the fronting beach. Sea level rise will require more frequent maintenance or reconstruction of these structures. Over time, the rocks of a revetment can move around and get washed onto the beach, reducing the effectiveness of the revetment and causing increased impacts to beach access.

Note that shoreline protection devices are designed to protect and withstand coastal storm events up to a certain severity, such as the "100-year storm event." Storm events that are more severe than the design events can cause flooding and damage.

Permit applications for shoreline protection devices is a complex and lengthy process. When allowed, seawalls and revetments would need to be designed to eliminate or mitigate adverse impacts on the local shoreline sand supply, habitats, and public access to and along the shoreline. Permitting conditions could include, among others, mitigation projects, in-lieu mitigation fees, and monitoring to address these concerns that can be expensive. If the shoreline protection devices are located on State tidelands, the projects would also have to be consistent with the goals of the State tidelands trust to be permitted.

3.2.8 Elevating or Waterproofing Structures and Infrastructure

Examples of elevated development

Source: SPUR Report, 2011. https://www.spur.org/sites/default/files/2013-09/SPUR_ClimateChangeHitsHome.pdf

Source: Copyright 2002-2016 Kenneth & Gabrielle Adelman, California Coastal Records project, www.californiacoastline.org

Raising structures such as buildings, trails, and utilities is a measure that can shift infrastructure above coastal flooding elevations. Elevating structures can include raising buildings on pile foundations or caissons to allow for some limited migration and persistence of a fronting beach in the near-term (photo to the left). Raising trails and utilities could include replacing at-grade trails with pile-supported boardwalks. Associated utilities such as power, sewer, water, and electrical connections also need to be raised or waterproofed to avoid damage.

Raising buildings to address flooding as a result of more frequent coastal storm events allows use of the buildings in between storm events. However, as sea levels rise and areas become more inundated from regular high tides or more frequent small coastal storm events, raising buildings on piles becomes ineffective as an adaptation strategy by itself because access to the structures would be restricted due to flooding of surrounding areas. Additionally, it could become hard to maintain services (e.g., water, wastewater, and electricity) to the structures. If elevating infrastructure is not paired with protective measures such as beach dune restoration and beach nourishment (Section 3.2.1 and 3.2.2), the shoreline could continue to migrate past structures and potentially damage additional infrastructure.

Building designs can also be modified so that the first floor is durable and resilient to flood damage. Trails could be raised to avoid flood hazards. Infrastructure such as water and wastewater pipelines could be redesigned to be waterproofed.

3.2.9 Elevating Property Grade

Raising buildings or trails could be accomplished by placing fill to rebuild the grades at higher elevations. Utilities such as sewer pipelines and storm drains that are vulnerable to flooding, erosion, or increased groundwater levels can also be raised, so long as gravity flow is maintained or pumps are installed. However, if one area is raised, all connecting roads, trails, and utilities would have to be rebuilt to slope up to the new grade. Elevating grades requires significant amounts of fill and, therefore, may only be feasible for areas of limited size. Additionally, filling an area changes the hydrology of both the area filled and the way rainfall runoff flows to neighboring areas. Stormwater would have to be managed effectively from the filled areas so as to not increase flood risks elsewhere.

3.2.10 Managed Retreat

Managed retreat strategies are those strategies that relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. As buildings, utilities, and other infrastructure are increasingly at risk along beaches, removal or relocation to a less hazardous area is an effective adaptation strategy. Relocation requires sufficient and appropriate space. In some cases, this could require land acquisition. Removal or relocation can also be phased to maintain at least some temporary use of the development or infrastructure as sea levels rise.

Hazard avoidance can also be facilitated through development restrictions that are consistent with state statutes, including the Coastal Act, and the state and federal constitutions. Managed retreat in California has been most typically used for public property and by government agencies, which have applied it in Asilomar State Beach and Surfer's Point.

CHAPTER 4

City-Wide Adaptation Approach

Certain adaptation measures could be implemented city-wide to help provide additional protection to multiple city assets. These strategies could be used to protect the more dynamic and spatially-varying assets as well, such as the beach, events, and beach habitat.

The beach is currently 300-400 feet wide in places; however, Manhattan Beach has not always been so wide. In 1938, Dockweiler Beach was nourished with approximately 1.8 million cubic yards of sand from the construction of the Hyperion Sewage Treatment Plant on sand dunes. Multiple beach nourishments followed in Santa Monica Bay, adding over 30 million cubic yards of sand to upcoast beaches, including Dockweiler Beach, Venice Beach, and El Segundo. Sand nourishment of upcoast beaches combined with a net southward sediment transport caused by waves and currents towards Manhattan Beach deposited enough sand to widen the beach by approximately 250 feet from the 1940s to the 1970s. The construction of numerous breakwaters, groins, and jetties in Santa Monica Bay has reduced sediment transport. Specifically, the groin at El Segundo Marine Terminal reduces sediment transport southward towards Manhattan Beach, limiting deposition on the beach. But King Harbor at Redondo Beach, south of Manhattan Beach, limits sediment transport from leaving Manhattan Beach and Hermosa Beach's shoreline, where it would otherwise be lost to the Redondo Submarine Canyon. This allows Manhattan Beach to retain sand on the beach. However, beach nourishment projects of this scale are not expected to be feasible in the future due to a lack of sand supply and permitting constraints.

If no adaptation measures are taken, sea level rise will cause increased levels of erosion of the beach, as well as increased flooding risk to coastal infrastructure, resulting in increased risk to vulnerable assets. Table 2 presents projected average beach widths over time if no adaptation measures are implemented based on erosion modeling results presented in the Vulnerability Assessment. Because the beach width is fairly constant across the city, the values in Table 2 are spatially representative of the city. However, it is important to note that beach widths vary temporally, with beaches eroding in the winter in response to storm events and building up in the summer in response to wave conditions. Table 2 presents the *average* beach width; typical seasonal oscillations of the shoreline are around 30 feet in Southern California but large coastal storm events can cause larger oscillations with the beach eroding by as much as 100 feet.

TABLE 2: BEACH WIDTH EVOLUTION

YEAR	AMOUNT OF SEA LEVEL RISE (FT)	TOTAL BEACH WIDTH RELATIVE TO MEAN HIGH WATER (FT)	% LOSS
2020	0.5	370	0%
2030	0.8	360	2%
2040	1.2	350	5%
2050	1.9	330	11%
2060	2.6	310	16%
2070	3.4	290	22%
2080	4.4	260	29%
2090	5.5	230	37%
2100	6.8	200	47%

Beaches, which are dynamic ecosystems already subject to dramatic cycles of erosion and accretion, tend to be resilient to coastal storm events. However, sea level rise will lead to long-term erosive trends, which could lead to impacts to biodiversity, community composition, ecological function, and wildlife populations. Additionally, the narrower beach could lead to impacts to sand accumulation, wrack retention, and nutrient cycling. A smaller beach would also reduce the area for mobile intertidal animals that spend most of their time in the lower intertidal zone, but move during high waves and storm conditions.

The beach is also a major recreational asset of Manhattan Beach and the region, including hosting large beach events such as beach volleyball tournaments. Access to sandy beach will become more limited with rising sea levels, affecting not only beach activities, but also beach access, safety logistics (lifeguards, fire), recreational and mobility infrastructure such as the bike trail, and management practices (trash removal, grooming, etc.).

Additionally, visitors from surrounding areas may increase in the future as other beaches are lost. Los Angeles County estimates that Redondo Beach and Torrance Beach may be completely eroded by 2100 (LA County 2016). This will likely increase the demand for beach access at Dockweiler State Beach, Manhattan Beach, and Hermosa Beach, which may maintain around 200-foot wide beaches by the end of the century (LA County 2016, Table 2). While the City of Manhattan Beach does not contain any disadvantaged or low-income communities as defined by SB 535 and AB1550, there are both disadvantaged and low-income communities north and east of the city, who may rely on the coastal resources and amenities within Manhattan Beach. This may increase the consequences of coastal hazard impacts to certain assets, like parking lots and restrooms, since these assets allow visitors to access the coastal resources. Therefore, it will be important for the City to prioritize maintaining and improving coastal access resources, such as trails (Section 5.1), visitor-serving amenities (Sections 5.2 and 5.4), public parking (Section 5.3), EV charging stations, bike racks, and other mixed-modal facilities for non-residents.

The threshold criteria to be monitored for the beach area includes sea level rise, flood impacts (to access points, assets, etc.), and approximate beach widths. A specific trigger distance should be developed for the beach based on the projections in Table 2 and an acceptable level of risk as determined by the City.

Adaptation options that could be used for the beach include (in recommended order):

1. Beach dune restoration
2. Winter sand berms
3. Offshore reefs, kelp beds, and eelgrass beds
4. Managed retreat – accepting a narrower beach
5. Beach nourishment
6. Groins

Section 3.2 describes these different adaptation strategies in detail. The following sections analyze whether these strategies would be feasible and effective to implement along the beach and summarizes tradeoffs associated with each strategy.

4.1 Beach Dune Restoration

The Manhattan Beach Dune Restoration Project[6], led by The Bay Foundation in partnership with LACDBH, City of Manhattan Beach, and California State Coastal Conservancy, is currently finalizing the permitting and planning stage for restoring dunes along 0.6 miles of the coast up and downcoast of Bruce's Beach (as of May 2021). The project, expected to be implemented beginning in fall 2021, will enhance and expand approximately three acres of existing beach backdunes from 36th Street to 23rd Street. The goal of this dune restoration project is to increase the resiliency of the beach through the restoration of sandy beach and backdune habitat, implement nature-based protection measures against sea level rise and coastal storms, and increase engagement of the community through enhanced beach experiences. The restoration project will include removing non-native plants and seeding and planting native vegetation, which will increase sand retention while building dunes over time. The project will also include strategic installation of various types of fencing and installation of educational features like interpretive signage. This demonstration site will serve as a model for the region, showing that heavy recreational use of beaches and meaningful habitat restoration are not incompatible goals.

Additional beach dune restoration could be pursued in other areas of the city or across more of the beach width as an adaptation strategy to maintain the beach and provide flood protection, while also providing valuable habitat (Section 3.2.1). While the pilot project is focused in the backdunes, the City could consider implementing restoration of foredune habitat to

[6] https://www.santamonicabay.org/explore/beaches-dunes-bluffs/beach-restoration/manhattan-beach-dune-restoration-project/manhattan-beach-dune-restoration-project-faq/

provide additional protection to the beach. However, foredune habitat is expected to experience more erosion during extreme storm events compared to backdune habitat.

4.2 Winter Sand Berms

Temporary winter berms could be constructed to provide flood protection, although the berms would create disturbances to existing habitat (Section 3.2.2). Los Angeles County currently builds winter sand berms on other beaches in Santa Monica Bay and is considering expanding the program to Manhattan Beach in the future, when their beach assets, such as the restrooms, become exposed to flooding. The County could potentially include the low-lying areas of the Marvin Braude Trail in their winter berm construction. The County estimates that winter berms built to a height of 12 to 16 feet above the existing wetted beach provide wave runup protection from a 50-year storm event. Approximately 200 feet of sandy beach width would be required to implement the winter berm program. (LA County 2016).

4.3 Reefs, Kelp Beds, and Eelgrass Beds

Restoration of kelp and eelgrass beds offshore of Manhattan Beach could provide habitat benefits with some reduction in sand movement downcoast (Section 3.2.6). However, while offshore kelp and eelgrass beds may dissipate waves to some extent, they may not be very effective at maintaining sand on the beach. Note that hard substrate is required to establish kelp beds. Areas offshore of Manhattan Beach have predominantly sandy substrates and rock or other hard substrate would likely need to be placed to establish kelp beds. Additionally, eelgrass beds could be established on sandy bottom habitat closer to the shore.

The effectiveness and feasibility of reefs, kelp beds, and eelgrass beds in conditions similar to those in Manhattan Beach have not been established; however, they are currently being studied. They remain, to date, experimental pilot adaptation strategies for sand retention and coastal flood reduction. More studies are necessary to prove feasibility, but it is possible reefs, kelp bed, and eelgrass bed restoration could be pursued further based on results of pilot projects in similar locations. While not recommended solely as a sea level rise adaptation strategy for Manhattan Beach, restoration of kelp beds, eelgrass beds, and offshore reefs can provide other benefits to the community by providing habitat and carbon sequestration as well as some attenuation of wave energy.

4.4 Managed Retreat – Accepting a Narrower Beach

Because Manhattan Beach has such a wide beach, some narrowing of the beach may be considered acceptable (Section 3.2.10). As presented in Table 2, the beach would still be 200 feet wide, on average, with 6.8 feet of sea level rise. Accepting a narrower beach would be a cost-effective strategy compared to other adaptation measures, but may require changes to the layout of beach events. This means beach events should also be timed to not co-occur during King Tides or when large waves are expected/predicted. Some amount of beach is still expected to be dry with 6.8 feet of sea level rise except during storm events (e.g., 1-year event or larger).

Accepting a narrower beach could also be part of a hybrid strategy where no action is taken in the near- to mid-term but additional measures are implemented in the long-term.

4.5 Beach Nourishment

Manhattan Beach has a history of benefitting from beach nourishment efforts by being downcoast of such projects (Section 3.2.3). The City could pursue additional sand sources such as opportunistic beach nourishment (surplus sand from various sources, including inland construction or development projects), additional offshore dredging, or regional nourishment programs. It is important to note, however, that it can be difficult to find sand supplies of the right quality (e.g., grain size, color, non-toxic/clean) and quality for beach nourishment.

4.6 Groins

The previous construction of numerous breakwaters, groins, and jetties in Santa Monica Bay has reduced sediment transport in and around Manhattan Beach. Specifically, the groin at El Segundo Marine Terminal reduces sediment transport southward towards Manhattan Beach, limiting deposition on the beach. But King Harbor at Redondo Beach, south of Manhattan Beach, limits sediment transport from leaving the city's shoreline, where it would otherwise be lost to the Redondo Submarine Canyon. This allows Manhattan Beach to retain sand on the beach.

One or more groins could be placed along the beach to maintain a wider beach (Section 3.2.4), which could be implemented in conjunction with beach and dune nourishment (Section 3.2.3) to improve the effectiveness of nourishment. Groins would decrease sand transport downcoast of the city, which could impact downcoast areas. However, groins in conjunction with beach nourishment could possibly partially mitigate potential downcoast impacts.

Compared to beach dune restoration, managed retreat, and beach nourishment, groins have a higher implementation cost. Additionally, constructing groins would require navigating complex permitting requirements from state and federal agencies, with unknown success.

4.7 Other Strategies

The following strategies are not recommended for Manhattan Beach at this time.

4.7.1 Breakwaters

Breakwaters often destroy surfing resources and permitting in California for new breakwaters has become rare, so building a new breakwater may be infeasible (Section 3.2.5). Due to very low likelihood of success in permitting, construction of new breakwaters is not currently recommended at this time.

4.7.2 City-Wide Shoreline Protection Devices

As discussed in Section 3.2.7, seawalls and revetments can contribute to erosion, accelerate beach loss, and impact lateral and vertical beach access. Since The Strand and development to the east is not expected to be impacted by coastal hazards before the end of the century, city-wide shoreline protection devices are not necessary at this time. As discussed in Sections 5.1.2, 5.2.2, and 5.3.2, certain coastal assets may benefit from short lengths of seawalls, but a city-wide structure is not recommended.

4.7.3 Elevating Structures or Property Grade

Elevating structures or property grade can be very costly and can impact the hydrology of surrounding areas. Since The Strand and development to the east is not expected to be impacted by coastal storm events nor erosion before the end of the century, elevating structures or property grade is not necessary at this time. As discussed in Sections 5.1.3, 5.2.3, 5.2.4, and 5.4, certain coastal assets may benefit from raising structures or grades, but expanding this strategy city-wide is not recommended.

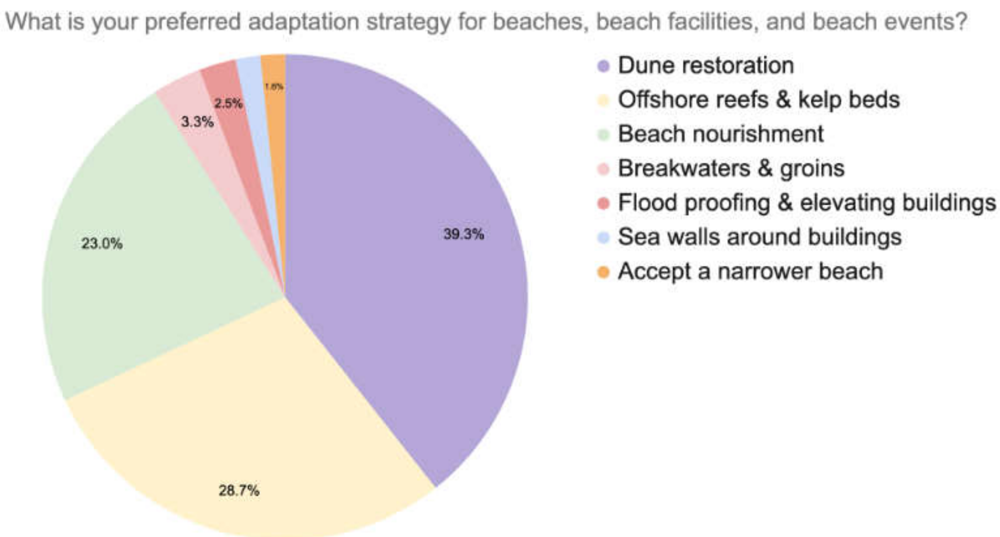
4.7.4 Managed Retreat

Since The Strand and development to the east is not expected to be impacted by coastal hazards before the end of the century, managed retreat is not necessary at this time. As discussed in Sections 5.1.4 and 5.2.5, certain coastal assets could be removed and/or relocated, but expanding this strategy city-wide is not recommended.

4.8 Community Input

During the community focus group meetings (Section 2.1), the groups were asked to rank their first, second, and third priority adaptation strategy for the beach, beach facilities, and beach events. Figure 15 provides the weighted[7] results of this survey. The results were very focused on green solutions, with beach dune restoration as the favored strategy.

[7] Each adaptation strategy received 3 points for a “first priority” response, 2 points for a “second priority” response, and 1 point for a “third priority” response. The totals for each strategy were then adjusted by the total number of points awarded to come up with a percentage.



Based on 26 participants.

Figure 15: Public Input on Adaptation Strategies for the Beach, Beach Facilities, and Beach Events

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CHAPTER 5

Asset-Specific Adaptations

This section revisits the assets analyzed in the Vulnerability Assessment and provides recommendations for adaptation measures that would be appropriate for each asset. Each section below summarizes the key vulnerabilities identified in the Vulnerability Assessment as a result of sea level rise if no action is taken to mitigate the hazards. The sections then describe the thresholds for determining when adaptation is needed for the asset. Lastly, the sections consider the feasibility, effectiveness, and the tradeoffs associated with implementing the applicable adaptation strategies presented in Section 3.2 to the different assets in Manhattan Beach.

5.1 Marvin Braude Bike Trail

The Marvin Braude Bike Trail is expected to be vulnerable to wave runup during a 100-year storm event with 4.9 feet of sea level rise. Some locations through the El Porto beach area could be exposed to more extensive storm inundation with 4.9 feet of sea level rise, but the trail is not expected to experience daily tidal inundation with up to 9.8 feet of sea level rise (the highest amount of sea level rise analyzed in the Sea Level Rise Vulnerability Assessment).

The threshold criteria that should be monitored for the Marvin Braude Trail is the frequency of flooding and coastal storm damage. Once monitoring shows the trail is experiencing flooding once a year or more, which would be expected sometime after 5.7 feet of sea level rise, planning for implementation of an adaptation measure would begin.

Adaptation options that could be used for the trail include:

1. Beach dune restoration
2. Temporary winter berms
3. Shoreline protection devices
4. Building a boardwalk or elevating the trail
5. Managed retreat

Section 3.2 describes these different adaptation strategies in detail. The following sections analyze whether these strategies would be feasible and effective to implement along the Marvin Braude Trail and summarizes tradeoffs associated with each strategy.

5.1.1 Beach Dune Restoration

Permanent, restored beach dunes could be constructed along the low sections of the Marvin Braude Trail to reduce the likelihood of flooding during extreme storm events, as discussed in Section 3.2.1. Section 4.1 discusses the Manhattan Beach Dune Restoration Project, which will enhance and expand approximately three acres of existing beach dunes from 36th Street to 23rd Street. A similar project could be conducted along other parts of the trail.

5.1.2 Winter Sand Berms

Temporary winter sand berms could be constructed along the low sections of the Marvin Braude Trail to reduce the likelihood of flooding during extreme storm events, as discussed in Section 3.2.2. See Section 4.2 for additional discussion on this strategy.

5.1.3 Shoreline Protection Devices

Seawalls and revetments could be used along the Marvin Braude Trail to mitigate the threat of flooding, as discussed in detail in Section 3.2.7. Part of the trail along north El Porto Beach is protected by a revetment and a seawall protects the trail near the Pier. Flood protection could be accomplished with new shoreline protection devices at select threatened areas. In order to function properly and effectively mitigate inland flooding hazards, any seawalls would have to be combined with access points in the walls that would be blocked during storm events but could allow drainage when flood waters recede. Figure 16 shows an example from Del Mar of how access could be blocked during a high water level event.

SOURCE: Robin Crabtree, March 8, 2016

Figure 16: Seawall with Access Closed During High Water Event in City of Del Mar

5.1.4 Building a Boardwalk or Elevating the Trail Grade

In areas of the trail that are expected to flood with sea level rise, the trail could be turned into a boardwalk or the grade under the trail could be raised (Sections 3.2.8 and 3.2.9) to protect them from flooding. Surrounding pedestrian connections and infrastructure would need to be raised as well. Turning portions of the trail into a boardwalk may require additional safety measures as well, such as railings.

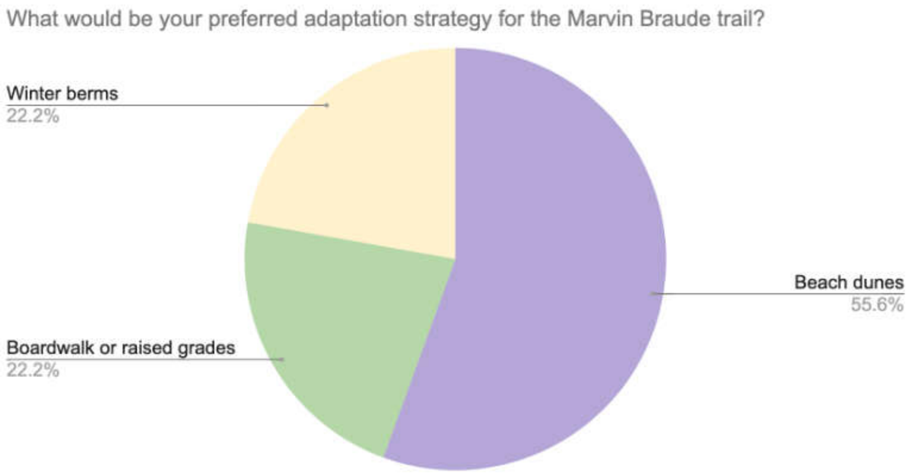
As discussed in detail in Section 3.2.9, raising grades can change runoff patterns and the hydrology of an area, and can cause increases in flooding in adjacent lower areas if stormwater flows are not managed effectively.

5.1.5 Managed Retreat

Removal and relocation of threatened trail sections could occur in phases as sea level rise progresses (Section 3.2.10). Removal, relocation, or rerouting of public trails must be done with close consideration of temporary and permanent impacts to public services, transportation, and public access and recreation.

5.1.6 Community Input

During the second community workshop (Section 2.1), the groups were asked about their priority adaptation strategy for the Marvin Braude Bike Trail. Figure 17 provides the results of this survey. The results varied, but the majority of participants favored beach dune restoration.



Based on 9 participants.

Figure 17: Public Input on Adaptation Strategies for the Marvin Braude Bike Trail

5.2 Buildings along the Beach

Although there are no residential structures on the beach, there are three public restrooms located along the shoreline of Manhattan Beach: El Porto beach restrooms between 43rd and 42nd Streets, restrooms and maintenance building at the end of Rosecrans Avenue, and the restrooms at the Pier. There is also a food stand and beach rental building at El Porto Beach.

The restrooms and maintenance building at Rosecrans Avenue are the most vulnerable of the three restroom buildings and are already vulnerable to wave runup during a 100-year storm event, whereas the restrooms at the Pier would not be vulnerable until 1.6 feet of sea level rise and the El Porto restrooms would not be vulnerable until 4.9 feet of sea level rise. The Rosecrans Avenue building could be exposed to more extensive storm inundation with 3.3 feet of sea level rise, and daily tidal inundation between 6.6 and 9.8 feet of sea level rise. The Pier and El Porto restrooms could experience storm inundation with 3.3 feet and 4.9 feet of sea level rise, respectively, but neither would be expected to experience daily tidal inundation with up to 9.8 feet of sea level rise (the highest amount of sea level rise analyzed in the Sea Level Rise Vulnerability Assessment).

The El Porto food stand and beach rental building is already vulnerable to wave runup during a 100-year storm event. The building could be exposed to more extensive storm inundation with 3.3 feet of sea level rise and daily inundation with 6.6 feet of sea level rise.

The threshold criteria that should be monitored for the buildings on the beach is the frequency of flooding and coastal storm damage. Once monitoring shows that the buildings are experiencing flooding once every ten years or more frequently, which would be expected sometime after 4.1 feet of sea level rise, planning for implementation of an adaptation measure would begin.

Adaptation options that could be used for the restrooms include:

4. Beach dune restoration

5. Temporary winter berms
6. Shoreline protection devices
6. Elevating or waterproofing the buildings
7. Elevating property grade
8. Managed retreat

Section 3.2 describes these different adaptation strategies in detail. The following sections analyze whether these strategies would be feasible and effective to implement for the buildings and summarizes tradeoffs associated with each strategy.

5.2.1 Beach Dune Restoration

Permanent, restored beach dunes or a hybrid engineered cobble approach could be constructed in front of the buildings along the beach to reduce the likelihood of flooding during extreme storm events, as discussed in Section 3.2.1. See Section 5.1.1 for additional discussion on this strategy.

5.2.2 Winter Sand Berms

Temporary winter sand berms could be constructed in front of the buildings along the beach to reduce the likelihood of flooding during extreme storm events, as discussed in Section 3.2.2. See Section 4.2 for additional discussion on this strategy. Keeping the buildings in place with winter sand berms in front of them could result in the loss of lateral beach access in front of the buildings, recreational space, and beach habitat while the berms are in place. However, the loss of lateral access is not likely to occur until after 6.6 feet of sea level rise.

5.2.3 Shoreline Protection Devices

A seawall could be constructed around the restrooms at El Porto beach and Rosecrans Avenue and the food stand and beach rentals building at El Porto beach, all of which are at grade with the beach (Figure 18). As discussed in Section 3.2.7, in order to function properly and effectively mitigate inland flooding hazards, the seawalls would have to be combined with breaks in the walls that would be blocked during storm events but could allow drainage when flood waters recede.

At the Pier restrooms, a seawall could be added in the location of the existing railing (Figure 19) to provide some additional protection against waves.

SOURCE: Google Street View

Figure 18: Public Restrooms at El Porto Beach

SOURCE: Google Street View

Figure 19: Public Restrooms at the Pier

Keeping the buildings in place with shoreline protection devices in front of them could result in the loss of lateral beach access in front of the buildings. However, the loss of lateral access is not likely to occur until after 6.6 feet of sea level rise.

5.2.4 Elevating or Waterproofing the Buildings

The beach buildings could be elevated on piers or rebuilt to be waterproofed (Section 3.2.8). The restrooms at Rosecrans Avenue are built above the maintenance portion of the building (Figure 20), removing them from the flood zone. However, the maintenance portion of the building may need to be floodproofed, with utilities and key infrastructure moved to the second floor.

SOURCE: Google Street View

Figure 20: Public Restrooms at Rosecrans Avenue

Keeping the buildings in place and floodproofing them could result in the loss of lateral beach access in front of the buildings. However, the loss of lateral access is not likely to occur until after 6.6 feet of sea level rise.

5.2.5 Elevating Property Grade

The grades under the beach buildings could be raised (Section 3.2.9) to protect them from flooding. Surrounding pedestrian connections and infrastructure would need to be raised as well. As discussed in detail in Section 3.2.9, raising grades can change runoff patterns and the hydrology of an area, and can cause increases in flooding in adjacent lower areas if stormwater flows are not managed effectively. Additionally, raising the grades would likely require a full rebuild of the structures themselves. With 6.6 feet of sea level rise, keeping the buildings in place could result in the loss of lateral beach access.

5.2.6 Managed Retreat

Removal and relocation of the beach buildings could occur as sea level rise progresses (Section 3.2.10). If the buildings were removed, they could be replaced with more mobile facilities, such as food trucks or portable toilets, that could be removed before predicted storm events.

5.2.7 Community Input

During the community focus group meetings (Section 2.1), the groups were asked to rank their first, second, and third priority adaptation strategy for the El Porto food stand and rentals building. Figure 21 provides the weighted[8] results of this survey. The results varied, but the majority of participants favored green solutions, such as beach dune restoration, offshore reefs and kelp beds, and beach nourishment.

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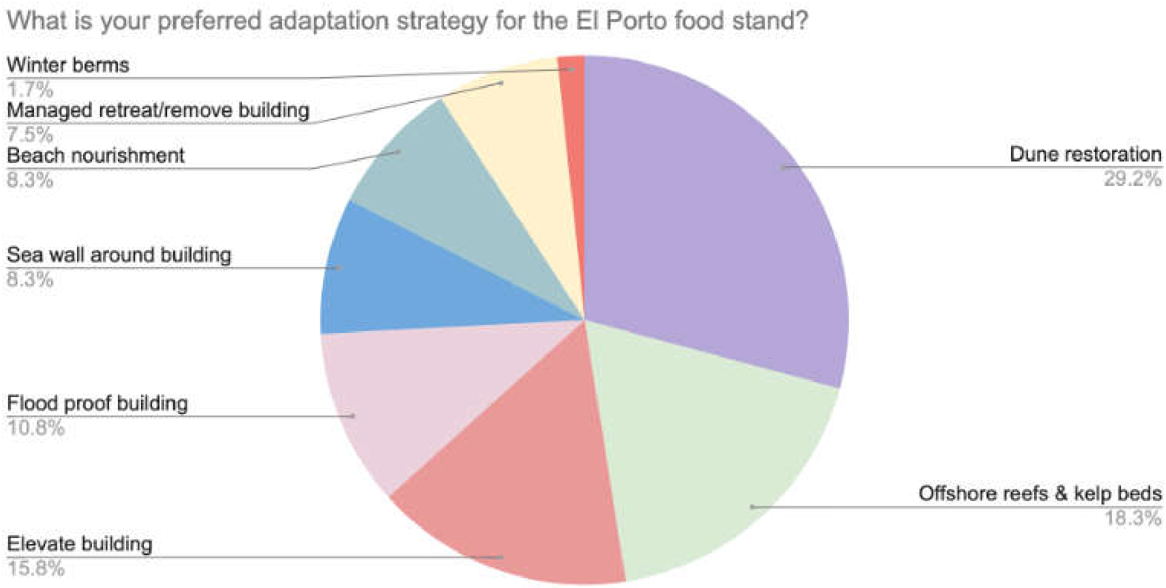
[8] Each adaptation strategy received 3 points for a "first priority" response, 2 points for a "second priority" response, and 1 point for a "third priority" response. The totals for each strategy were then adjusted by the total number of points awarded to come up with a percentage.



Based on 26 participants.

Figure 21: Public Input on Adaptation Strategies for the El Porto Food Stand and Rentals Building

5.3 Lower Pier Parking Lot

The Lower Pier parking lot is expected to be vulnerable to wave runup during a 100-year storm event with 4.9 feet of sea level rise. The parking lot is not expected to experience more extensive storm inundation until after more than 9.8 feet of sea level rise.

The threshold criteria that should be monitored for the Lower Pier parking lot is the frequency of flooding and coastal storm damage. Once monitoring shows the parking lot is experiencing flooding once a year or more, which would be expected sometime after 9.8 feet of sea level rise (per the Sea Level Rise Vulnerability Assessment), planning for implementation of an adaptation measure would begin.

Adaptation options that could be used for the Lower Pier parking lot include:

1. Beach dune restoration
2. Temporary winter berms
3. Shoreline protection devices

5.3.1 Beach Dune Restoration

Permanent, restored beach dunes could be constructed in front of the Lower Pier parking lot to reduce the likelihood of flooding during extreme storm events, as discussed in Section 3.2.1. See Section 5.1.1 for additional discussion on this strategy.

5.3.2 Winter Sand Berms

Temporary winter berms could be constructed in front of the Lower Pier parking lot to reduce the likelihood of flooding during extreme storm events, as discussed in Section 3.2.2. See Section 4.2 for additional discussion on this strategy.

5.3.3 Shoreline Protection Devices

A seawall could be added in the location of the existing railing (Figure 22) around the Lower Pier parking lot to provide additional protection against waves, as discussed in Section 3.2.7. A short seawall could be constructed to address coastal storm events with height added to it over time as needed.

SOURCE: Google Street View

Figure 22: Lower Pier Parking Lot

5.4 Municipal Pier

The Manhattan Beach Municipal Pier is specifically designed and intentionally located to be in the potential hazard zones. However, over time, the exposure of the structure to waves and large storm events will increase. Additionally, the assets at the pier (e.g., Roundhouse Aquarium) will experience more frequent wave overtopping with sea level rise.

The threshold criteria that should be monitored for the Pier is the frequency of wave overtopping and coastal storm damage. Once monitoring shows the Pier is experiencing overtopping or damage once every 10 years or more frequently, planning for implementation of an adaptation measure would begin.

Adaptation of the Pier could consist of reconstructing the Pier with a higher deck and deck structural supports (Section 3.2.9). Raising the Pier would require reconstruction of buildings and infrastructure on the Pier and the access up to it.

Over time as sea level rise rates begin to accelerate, costs and risks associated with replacement of the Pier could potentially begin to outweigh economic, public access, visitor-serving, and social benefits of maintaining the Pier. However, more detailed cost-benefit analysis for the Pier would need to be conducted to make that determination.

5.5 Storm Drain Outfalls

The City's storm drain outfalls are expected to be vulnerable to beach erosion and sand blockage with sea level rise. This may lead to more frequent maintenance to remove sand from the outfall before anticipated rainfall events. The City is currently implementing projects to improve the stormwater system, such as the 28th Street Storm Drain Infiltration project.

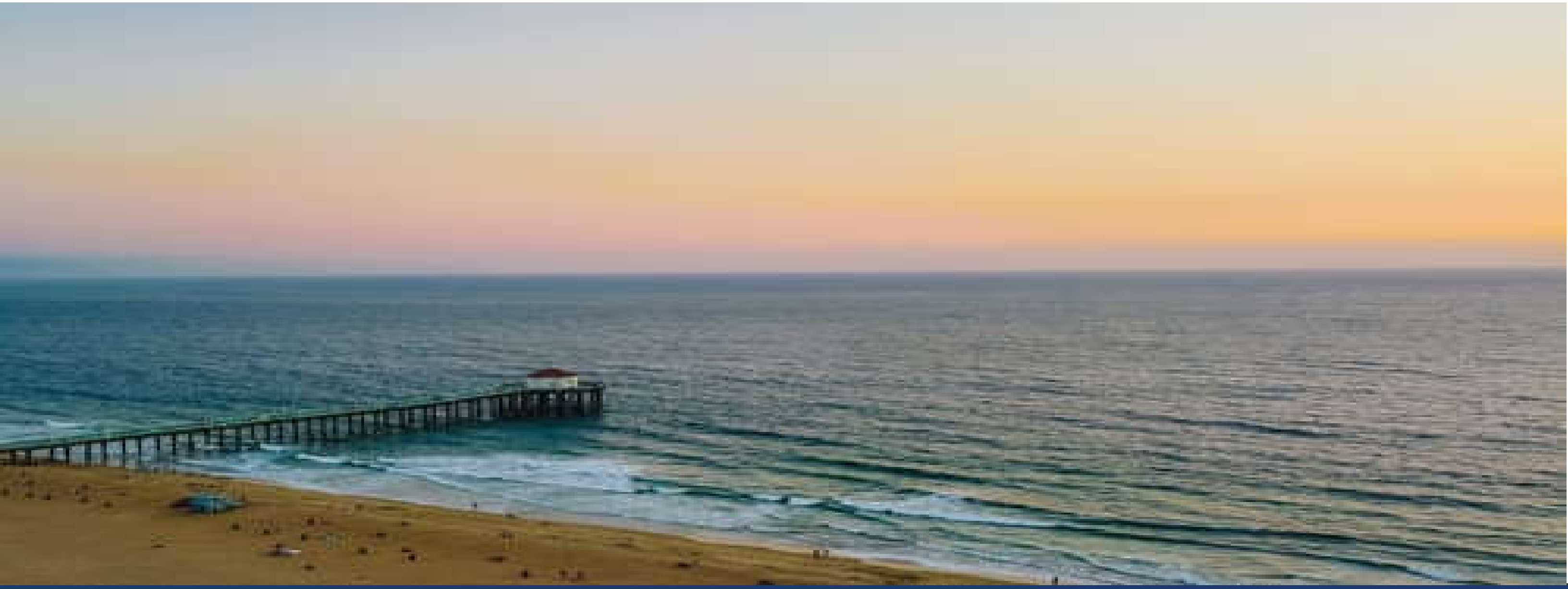
The threshold criteria that should be monitored for the outfalls is the frequency of maintenance required. Once monitoring shows that any outfall is requiring maintenance more frequently than City staff find desirable, planning for implementation of an adaptation measure would begin.

Adaptation for the stormwater outfalls could include shortening the outfalls. However, depending on the location of the pipes (i.e., slope and depth below ground), shortening the pipes may require additional changes to the infrastructure (e.g., reconstructing a section of a pipe or adding a pump to the system) and would need to be analyzed further. Future projects, such as stormwater infiltration projects along the backshore, should consider sea level rise during feasibility assessments.

5.6 South Bay Cities' Main Sewer Trunk Line

Beach erosion is not expected to reach the sewer line under 6.6 feet of sea level rise, but water levels during a 100-year storm could extend to the sewer line between 27th and 32nd Streets and around Marine Avenue. Higher water levels could limit access to the line for maintenance and operation or inundate maintenance holes and increase flows in the system that the treatment plant would then have to process. These storm impacts would be temporary.

While no adaptation is expected to be needed before the end of the century, monitoring of the sewer line during major storm events could be done to track the impacts to access and increased flows in the system. If monitoring shows that access is impacted more frequently than County staff find desirable or if storm flows are impacting the operation of the system, planning for implementation of an adaptation measure would begin.



CHAPTER 6

Potential Adaptation Scenario Analysis

The Vulnerability Assessment presents the potential impacts of sea level rise through 2100 if no action is taken to mitigate the additional hazards posed by sea level rise. This section compares this “no action scenario” with a potential adaptation scenario designed to mitigate future coastal hazard risks. This section also includes a summary of the results of a cost-benefit analysis (Appendix A) that compares the economic and fiscal impacts of the no action scenario with the relative costs and benefits of the adaptation scenario.

This Adaptation Plan identifies a range of adaptation strategies that the City could take in the future to reduce risks associated with sea level rise. The City will then have the flexibility to select and implement different adaptation strategies as the effects of sea level rise reach certain thresholds over time. The scenario presented in this section is not intended to reflect the City’s exact proposed or preferred approach to adaptation in the future. The purpose of this section is to bracket a range of possible actions the City could take to get a high-level understanding as to what is at risk economically and fiscally and the relative costs and benefits associated with actively planning for and adapting to sea level rise.

The quantitative analysis conducted for the economic and fiscal impacts study employs many large-scale assumptions that may or may not be realized in the future. Detailed cost-benefit analysis for each adaptation action is outside the scope of this initial city-wide, planning-level document, but can be conducted in the future as part of project specific studies.

6.1 Adaptation Scenario

The cost-benefit analysis compares the "no action scenario" represented in the Vulnerability Assessment (ESA 2021) to the adaptation scenario described below. The "no action scenario" represents the property and infrastructure damages and associated economic impacts that could occur if no action is taken. The theoretical adaptation scenario used for the cost-benefit analysis includes multiple adaptation strategies at multiple timeframes:

- 2030: City-wide beach dune restoration
- 2060: City-wide beach nourishment

This analysis uses the same sea level rise projections as the rest of this Adaptation Plan: the CNRA and OPC (2018) medium-high risk sea-level rise scenario, which projects 6.8 feet of sea level rise by 2100. While the timing of individual adaptation measures in the adaptation scenario is based on this sea level rise projection, the actual timing of adaptation actions in the future will depend on monitoring of sea level rise and erosion that occurs in the future, as described in Section 2.2.

6.2 Economic Analysis Methods

6.2.1 Valuing Beach Recreation

The beach is a major recreational asset of Manhattan Beach and the region, therefore, determining the value of the beach is a fundamental component of any analysis of coastal adaptation. In California, all beach areas below the mean high tide line are public trust lands and, under the California Coastal Act, cannot be bought or sold (unless the state retains a permanent property interest in the land adequate to provide public access to or along the sea). As a result, a market price for beaches cannot be established or used as a proxy for their value. In addition, with mandated public access, there is no price for admission, although many beaches (including Manhattan Beach) do charge for parking in official beach parking lots. Even though beaches' recreational amenities are free to use, they still have value to the public. Economists measure the value of these "non-market" resources using estimates of consumer willingness to pay (WTP) for these services. These methods are generally referred to as "non-market valuations" and are discussed in more detail in Appendix A.

To evaluate adaptation strategies, this study derived an average use value of $42 per day from numerous past studies of beachgoers' willingness to pay (Pendleton and Kildow, 2006), adjusted for inflation. This approach is consistent with a recent case before the CCC in Solana Beach (CCC, 2017) as well as a study commissioned by the CCC and funded by NOAA (CCC 2015). To estimate the total value of beach recreation, the day use value ($42) is multiplied by the number of people attending the beach. For example, if 100,000 people attend a beach in 2025, the value of beach recreation would be $42*100,000, or $4.2 million. This approach was applied to the no action and adaptation scenarios based on the expected attendance, allowing for comparison between the two.

6.2.2 Carrying Capacity and Turnover Rate

The standard approximation for the value of a beach trip allows city planners and researchers to understand the value of existing patterns of beach recreation and attendance. Attendance depends in large part on *carrying capacity*. The "carrying capacity" of a beach is the number of visitors that can visit a beach at one time, or essentially the maximum occupancy of a beach. While visitors do not think in terms of explicit carrying capacity, people do make decisions and alter their visiting behavior based on how crowded a beach appears. When a beach becomes too crowded, and people choose to go elsewhere or not to visit the beach as a result, the carrying capacity has been exceeded. A standard assumption is that beachgoers generally require about 100 square feet of "towel space" (City of Newport Beach 2018).

Importantly, most beachgoers do not spend an entire day at the beach. Thus, the turnover rate (the rate at which visitors leave the beach and are replaced) needs to be accounted for. While the turnover rate may vary from site to site, past estimates use a rate of 1.6 persons per day (King and McGregor 2012). The carrying capacity, therefore, is determined by dividing the area of the beach by required towel space (100 square feet) and multiplying the result by the turnover rate (1.6). An alternate turnover rate of 2.5 is also considered in this analysis, based on studies in Los Angeles County.

Daily attendance, however, is rarely equivalent to carrying capacity, except for at the more popular beaches in high season (summer). Therefore, models of recreation value must adjust for the average utilization rate at a given beach, or how close daily visitation is to the maximum occupancy (carrying capacity) of the beach. Additionally, many beaches are highly seasonal, with more than half of all visits taking place in the summer high season (Dwight 2007). At some of these highly seasonal beaches, the beach may be nearly at capacity for much of the summer (high utilization), and nearly empty in the winter (low utilization).

Applying this methodology to the future of California's beaches shows the impact of sea level rise on beach recreational value as a function of lost area. As sea levels rise, beaches will lose area, and this loss in area will lead to a loss in attendance. The relationship between lost area and lost attendance can be modeled based on the reduction of the carrying capacity of a given beach. Additionally, understanding seasonality is important, as a loss of beach area during the summer would impact the attendance far more than a loss of beach during the winter.

6.2.3 Spending and Tax Revenue

When fewer people are able to visit the beach, spending at local beach establishments is reduced, as is the tax revenue collected on that spending. Data for estimated daily spending at California beaches was collected from a 2004 study (King 2004) and adjusted for inflation according to the Consumer Price Index (CPI). Los Angeles County collects a 3.5% county tax on all categories, except parking and lodging. For food from stores and take out, only 25% of the total spent is taxed at the 3.5% rate. Lodging is also subject to a transient tax of 12.5%. Table 3 below shows that for each person turned away from Manhattan Beach, an estimated $88.60 is lost in total daily spending at local businesses, $1.49 is lost in county tax revenue, and $4.07 is lost in transient occupancy taxes.

TABLE 3: DAILY SPENDING (PER INDIVIDUAL) AT CALIFORNIA BEACHES

	GAS & AUTO	FOOD FROM STORES AND TAKE OUT	BEER, WINE AND LIQUOR	SIT-DOWN RESTAURANTS	PARKING	SUNDRIES	LODGING	TOTAL DAILY SPENDING PER PERSON
Daily Spending								
2002 values (King 2004)	$7.60	$9.16	$4.25	$11.19	$1.90	$2.22	$21.06	**$57.38**
Adjusted to 2021 CPI	$11.74	$14.14	$6.56	$17.28	$2.93	$3.43	$32.52	**$88.60**
County Tax	$0.41	$0.12	$0.23	$0.60	$0.00	$0.12	$0.00	**$1.49**
Transient Tax	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$4.07	**$4.07**

6.2.4 Economic Analysis and the Future

The economic analysis in this study projects the impacts of sea level rise upon non-market values in Manhattan Beach over the period 2020 to 2100, and the value of those impacts are presented in 2021 dollars. This analysis also includes sales tax revenues to the City of Manhattan Beach and transient occupancy taxes, all of which go to the City.

As is standard in any economic cost-benefit analysis, future costs and benefits must be discounted, i.e., future benefits/costs are worth less than the same benefit/cost today. The choice of discount rate is critical in any cost-benefit analysis. Currently, there is no consensus among economists as to what the proper discount rate should be. When considering capital investments (e.g., financing a seawall) the cost of capital should be considered, i.e., what it actually costs to borrow the necessary funds to finance a project. Currently, short- and long-term interest rates are relatively low, and the cost of financing a project through Federal, State, or local bonds is in the 3% to 5% range. However, even a relatively low discount rate can imply that benefits and costs for future generations are valued far less than current benefits, and many economists have argued that the social discount rate should be lower than the market cost of capital. Table 4 below shows the discounted value of a $100 benefit in future time horizons. When projecting out to 2100, even a relatively low discount rate, such as 3%, implies that a $100 benefit in 2100 is worth less than one-tenth of what it would be worth today: $9.68 (see Table 4 below). Effectively, a higher discount rate values benefits to future generations much lower than benefits to today's generation. However, following common practice, this study employs a 3% discount rate in all benefits and costs projected out to the future.[9]

TABLE 4: VALUE OF $100 OVER TIME AT VARIOUS DISCOUNT RATES

DISCOUNT RATE	0%	1%	3%	4%	5%
2030	$ 100.00	$ 91.43	$ 76.64	$ 70.26	$ 64.46
2060	$ 100.00	$ 67.84	$ 31.58	$ 21.66	$ 14.91
2100	$ 100.00	$ 45.56	$ 9.68	$ 4.51	$ 2.12

[9] A full discussion of the issue of discounting is beyond the scope of this study. However, see Weitzman (2001) and Arrow et al. for more discussion.

6.3 Adaptation Cost-Benefit Analysis Results

6.3.1 Beach Attendance

This analysis collected beach attendance data for three beach areas (El Porto, Marine, and Manhattan Pier) from the past five years (correspondence with D. Murphy, Los Angeles County Fire Department, March 28, 2021) to estimate average daily beach attendance over the study period, assuming that beach demand remains the same through 2100. Demand was assumed to remain constant based on the California Department of Finance's estimates that population in Los Angeles County will essentially remain flat through 2100, with a slight decrease beginning in 2033. The analysis does not account for potential changes in visitorship from outside Los Angeles County nor how changes in accessibility and carrying capacity at other beaches may impact demand at Manhattan Beach. It is possible that if nearby beaches erode, visitors will flock to Manhattan Beach (e.g., see Pendleton et al. 2008).

Based on the lifeguard beach estimates[10], an average day at Manhattan Beach sees approximately 15,000 visitors. Most of the year, less than 20,000 people visit the beach in a given day, and for 30% of the year, less than 5,000 people visit the beach per day. Figure 23 presents the breakdown of average beach visitors per day, per site during the calendar year. Overall, Manhattan Pier experiences the greatest number of beach visitors per day of the three beaches. For the purposes of this study, adaptation and non-market losses are evaluated for these three sites combined.

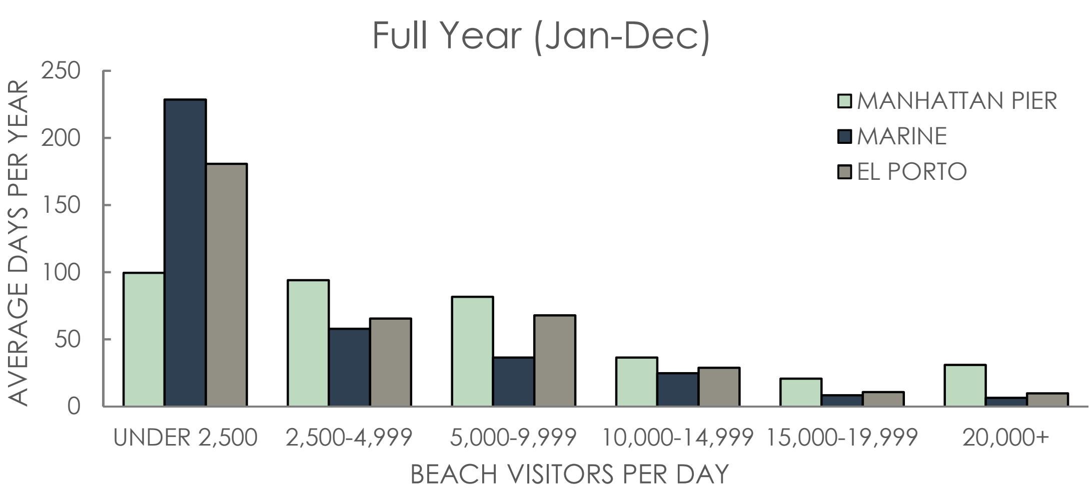


Figure 23: Beach Visitors Per Day, Per Beach

[10] King and McGregor (2012) found that "official" lifeguard counts are very inaccurate and often overestimate attendance, especially at less attended beaches (which Manhattan Beach is not). Our analysis assumes that these estimates are accurate, though many people from LA County were concerned about these estimates. If Manhattan Beach's estimates are too high, which is quite likely, that would delay the onset of a capacity constraint and delay the need for nourishment or dune restoration.

During the summer months from June to August (high season), beach attendance increases drastically. An average of approximately 31,000 people visit Manhattan Beach per day during the high season, compared to roughly 9,100 people during low season. Some days during high season see an excess of 100,000 visitors. For example, in 2016 on the Fourth of July, an estimated 145,000 people visited Manhattan Beach. Figures 24 and 25 below present the average beach visitors in high season compared to low season.

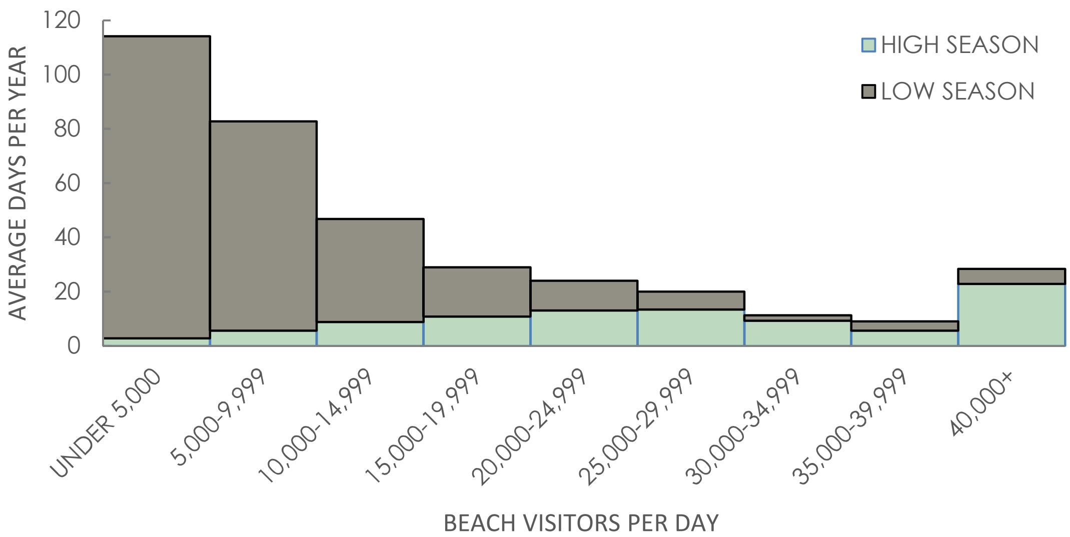


Figure 24: Average Beach Visitors Per Day in High and Low Season

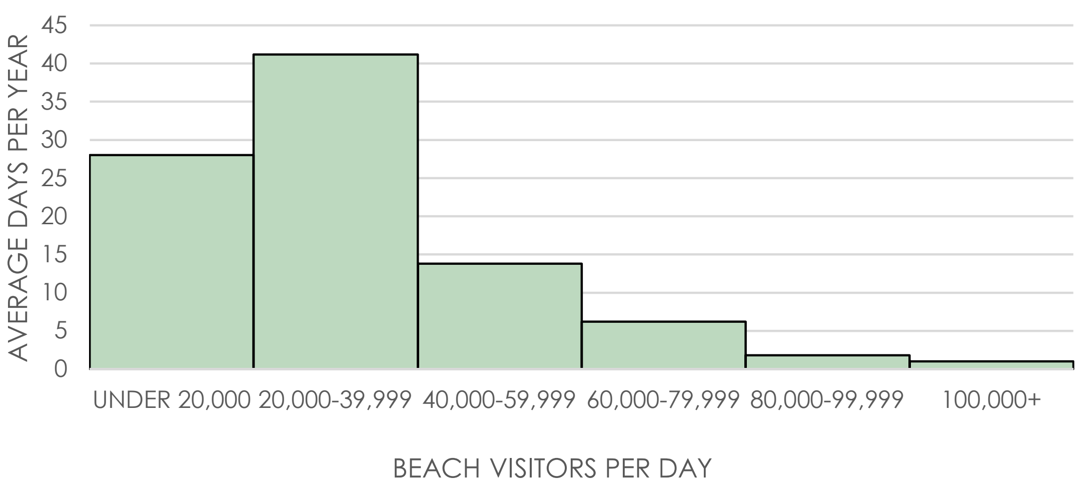


Figure 25: Average Beach Visitors Per Day in High Season

Sea level rise and associated coastal storms and erosion are expected to reduce the width of Manhattan Beach and severely impact beach attendance. Table 5 below shows the predicted progression of beach loss over time without adaptation and the resulting expected changes to attendance. Manhattan Beach is approximately 11,000 linear feet (2.1 miles) long. This analysis included two possible turnover rate scenarios to calculate the carrying capacity of the beach: 1.6 persons per day, and 2.5

persons per day, per 100 square feet. In both scenarios, beach erosion will severely limit beach attendance over time. By 2100, nearly half the beach will be inaccessible due to sea-level rise.

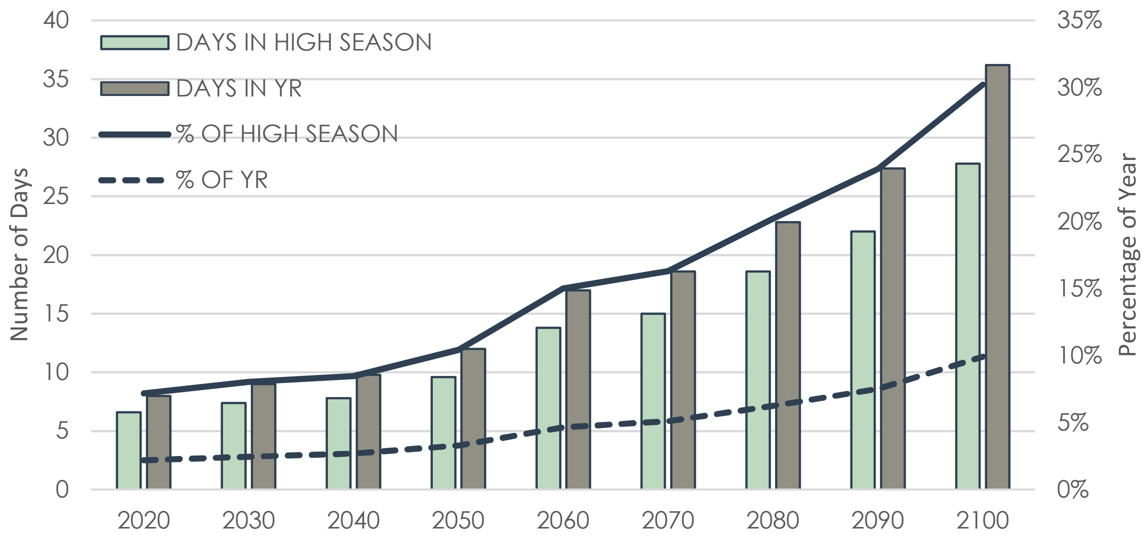
TABLE 5: ESTIMATED REDUCTION IN BEACH CAPACITY

YEAR	BEACH WIDTH (FT)	TOTAL SQUARE FEET	CAPACITY (PEOPLE/DAY) 1.6 TURNOVER RATE	CAPACITY (PEOPLE/DAY) 2.5 TURNOVER RATE
2020	370	4,070,000	65,120	101,750
2030	360	3,960,000	63,360	99,000
2040	350	3,850,000	61,600	96,250
2050	330	3,630,000	58,080	90,750
2060	310	3,410,000	54,560	85,250
2070	290	3,190,000	51,040	79,750
2080	260	2,860,000	45,760	71,500
2090	230	2,530,000	40,480	63,250
2100	200	2,200,000	35,200	55,000

6.3.2 Non-Market Loss

No Adaptation Scenario

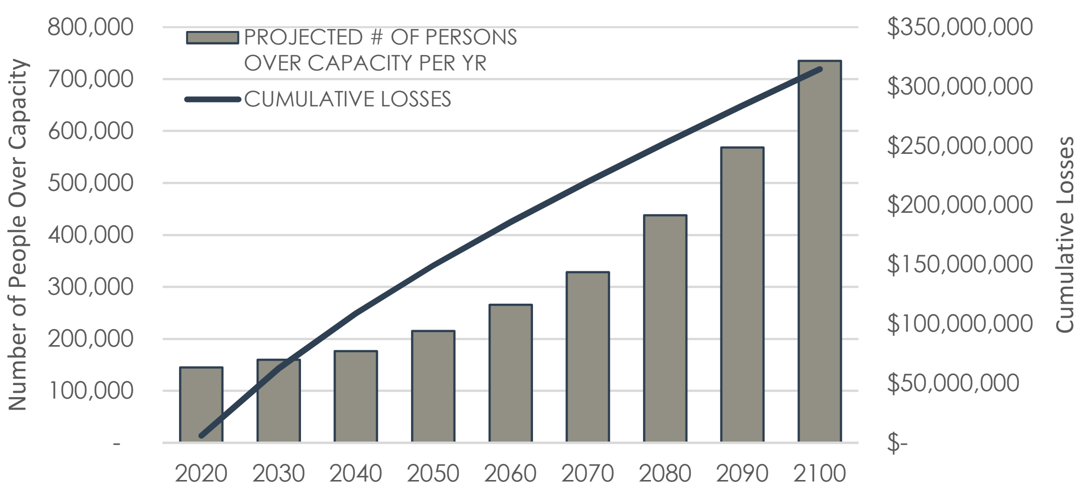
With no adaptation, Manhattan Beach will continue to erode. As the beach's carrying capacity decreases, the number of people who are unable to attend the beach will increase over time. Figure 26 shows the number and the percent of days in a year expected to exceed carrying capacity over time, assuming a turnover rate of 1.6 persons per year per 100 square feet. Note that by 2100, approximately 31% of days during the high season and 10% of days in the year exceed beach carrying capacity.



Note: Assumes a turnover rate of 1.6 persons/day/100 square feet

Figure 26: Count and Percent of Days Per Year Exceeding Beach Carrying Capacity

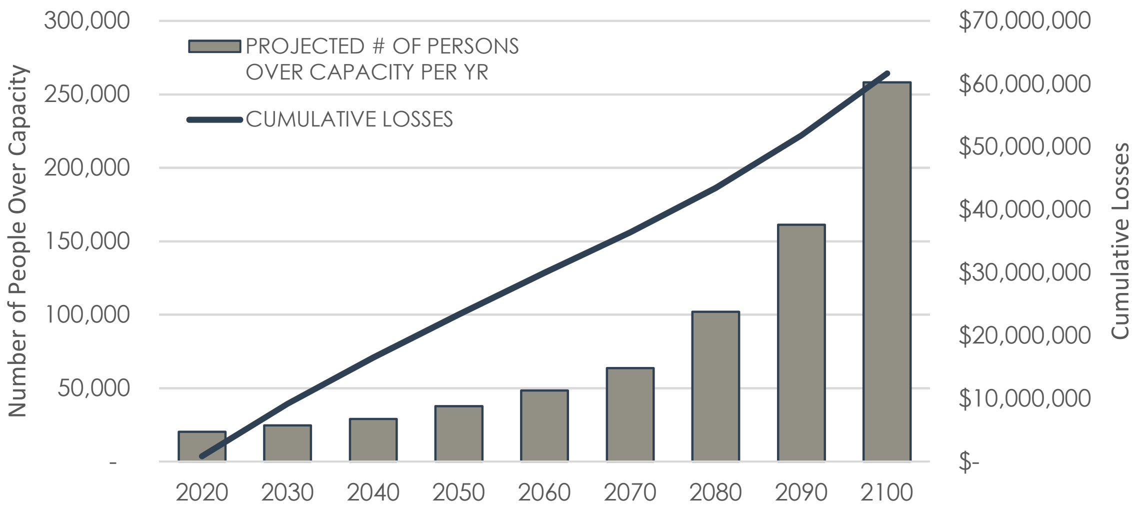
Figure 27 presents the number of persons exceeding the beach's carrying capacity per year along with the cumulative non-market losses (adjusted for present value) using a turnover rate of 1.6. Note that by 2100, more than 730,000 people are no longer able to visit Manhattan Beach annually, and non-market losses exceed $300 million.



Note: Assumes a turnover rate of 1.6 persons/day/100 square feet

Figure 27: Projected Number of Persons Over Capacity Per Year and Expected Cumulative Losses – 1.6 Persons Per Day Turnover Rate

Figure 28 displays an alternate turnover rate of 2.5 based on studies in Los Angeles County. If people visit Manhattan Beach for shorter periods of time, thus allowing for more people to visit in a single day, carrying capacity significantly increases and recreational value losses decrease. Even still, cumulative non-market losses exceed $60 million by 2100, and more than 250,000 people per year are unable to visit the beach.



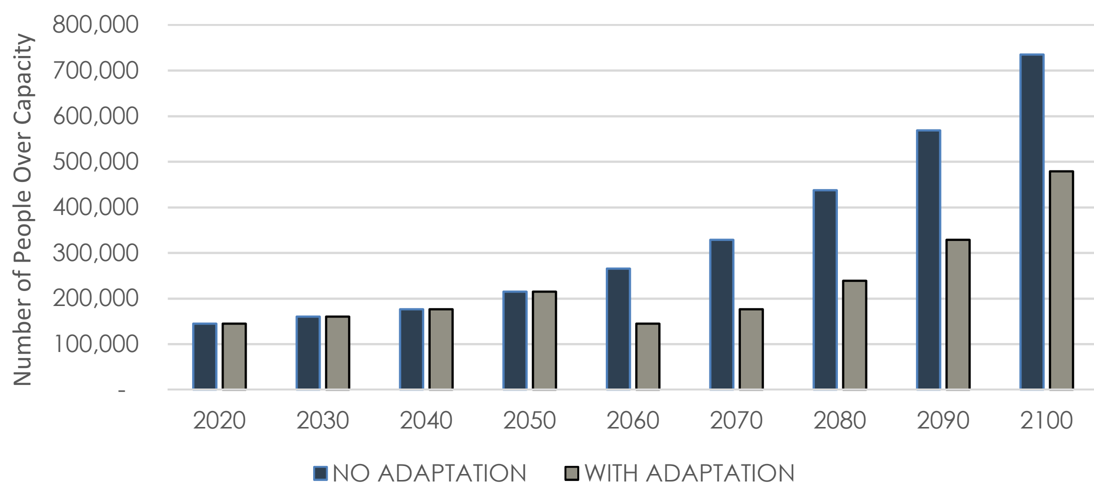
Note: Assumes a turnover rate of 2.5 persons/day/100 square feet

Figure 28: Projected Number of Persons Over Capacity Per Year and Expected Cumulative Losses – 2.5 Persons Per Day Turnover Rate

Adaptation Scenario

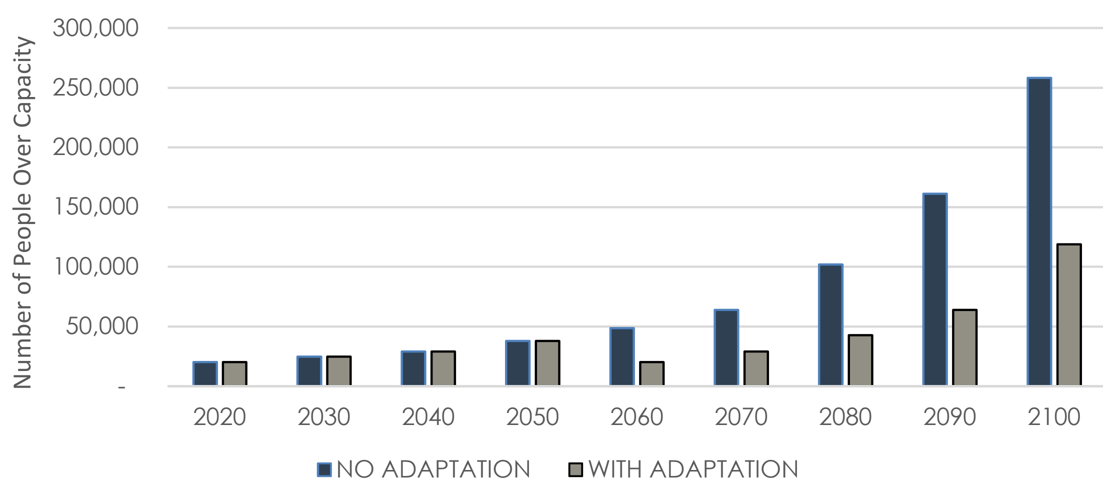
As discussed in Section 6.1, the adaptation scenario considers a dune restoration project in 2030, and a beach nourishment project in 2060. Since the existing dunes that would be restored are at the back of the beach, these restored dunes likely will not contribute significantly to the width of the beach until water levels rise to a point where they are interacting with the dunes. Therefore, this analysis assumes that the dune restoration project will not impact the beach width but would provide flood protection for assets behind the dunes. Foredune restoration could be effective at retaining sand on and supplying sand to the beach earlier, but is not included in this scenario.

As shown in Figures 29 and 30, the nourishment project will increase beach width in 2060, allowing more people to visit the beach. The beach nourishment essentially restores the beach to the 2020 width. However, one-time beach nourishment is not a permanent solution. Note that the number of people unable to visit Manhattan Beach begins increasing again after 2060 in both the 1.6 and 2.5 turnover rate assumptions, since the beach continues to erode.



Note: Assumes a turnover rate of 1.6 persons/day/100 square feet

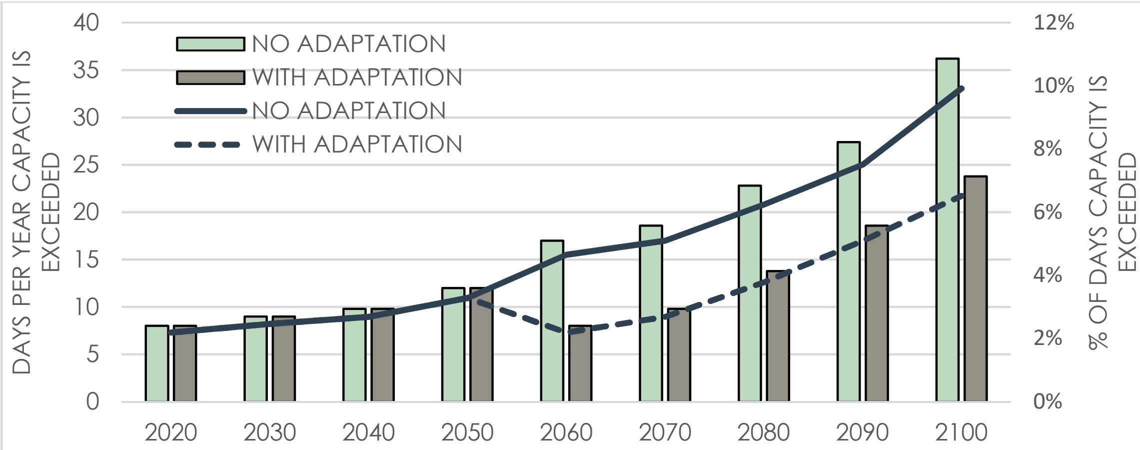
Figure 29: Projected Number of Persons Over Capacity Per Year with and without Adaptation – 1.6 Persons Per Day Turnover Rate



Note: Assumes a turnover rate of 2.5 persons/day/100 square feet

Figure 30: Projected Number of Persons Over Capacity Per Year with and without Adaptation – 2.5 Persons Per Day Turnover Rate

Modeled with a turnover rate of 1.6, the beach nourishment project will reduce the percentage of days carrying capacity is exceeded from 10 percent to 7 percent (Figure 31).



Note: Assumes a turnover rate of 1.6 persons/day/100 square feet

Figure 31: Count and Percent of Days Per Year Exceeding Beach Capacity, With and Without Adaptation

Table 6 presents the cumulative non-market losses at ten-year periods through 2100, with and without adaptation, under the 1.6 turnover rate. By 2050, the loss in non-market recreational value will be approximately $149 million in 2021 dollars, or $224 million without discounting. By 2060, with the beach nourishment project, we begin to see a difference between the adaptation and no adaptation scenarios. Adaptation saves approximately $10 million in non-market losses in 2060, and nearly $75 million by 2100 (in 2021 dollars). Cumulatively, adaptation saves over $1 billion in recreational value (without adjusting to present value).

TABLE 6: CUMULATIVE NON-MARKET LOSSES – 1.6 PEOPLE PER DAY TURNOVER RATE

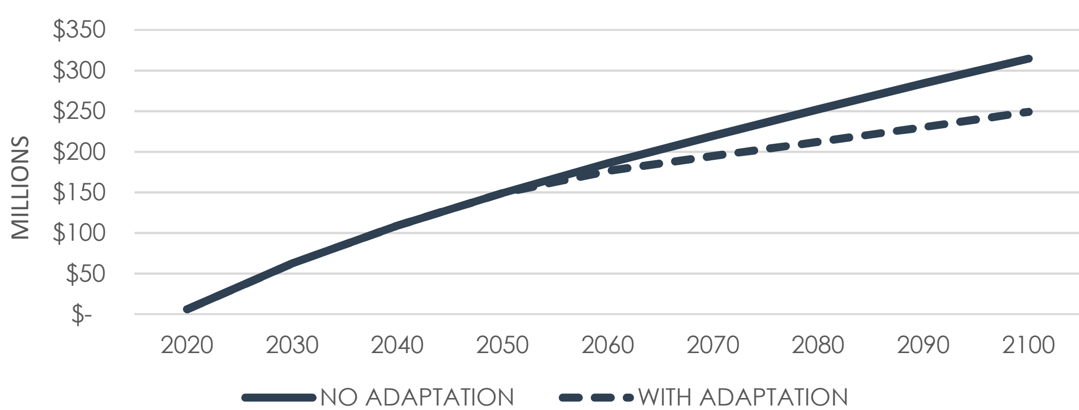
	NO ADAPTATION			WITH ADAPTATION		
YEAR	PROJECTED # OF PERSONS OVER CAPACITY	CUMULATIVE NON-MARKET LOSSES (NOT DISCOUNTED)	CUMULATIVE NON-MARKET LOSSES (NPV)	PROJECTED # OF PERSONS OVER CAPACITY	CUMULATIVE NON-MARKET LOSSES (NOT DISCOUNTED)	CUMULATIVE NON-MARKET LOSSES (NPV)
2020	145,240	$ 6,100,080	$ 6,100,080	145,240	$ 6,100,080	$ 6,100,080
2030	160,160	$ 70,547,400	$ 62,590,132	160,160	$ 70,547,400	$ 62,590,132
2040	176,720	$ 141,639,960	$ 108,957,522	176,720	$ 41,639,960	$ 108,957,522
2050	215,340	$ 224,783,580	$ 149,211,889	215,340	$ 24,783,580	$ 149,211,889
2060	265,780	$ 326,878,020	$ 185,980,905	145,240	$ 99,033,280	$ 176,348,010
2070	328,556	$ 453,006,876	$ 219,780,055	176,720	$ 67,305,960	$ 194,650,144
2080	437,772	$ 616,229,292	$ 252,268,803	238,684	$ 55,842,044	$ 212,267,306
2090	568,548	$ 830,302,788	$ 283,993,988	328,556	$ 76,849,756	$ 230,176,037
2100	734,960	$1,107,534,120	$ 314,568,451	478,800	$749,549,640	$ 249,169,387

As we see in Table 7, if we assume a higher 2.5 person per day per 100 square feet turnover rate, cumulative losses are drastically reduced, and savings from the adaptation project are also diminished. Adaptation saves approximately $3 million in non-market losses in 2060, and $20 million by 2100 with this assumption. Without discounting to 2021 dollars, adaptation saves $125 million cumulatively.

Table 7: Cumulative Non-Market Losses – 2.5 People per Day Turnover Rate

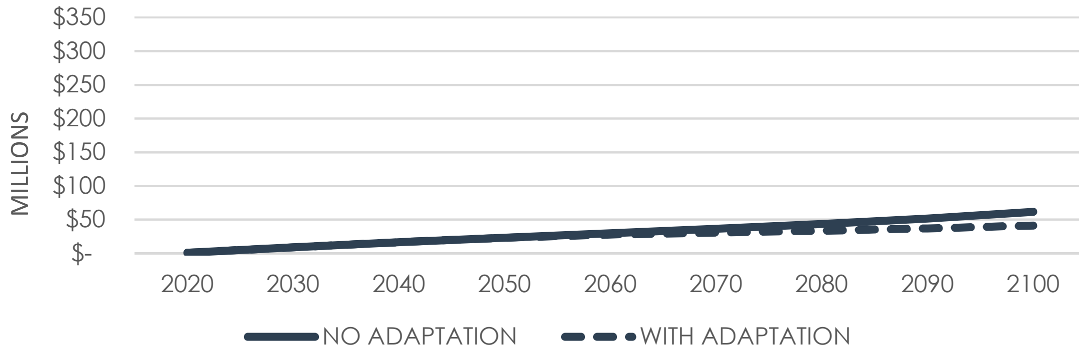
	NO ADAPTATION			WITH ADAPTATION		
YEAR	PROJECTED # OF PERSONS OVER CAPACITY	CUMULATIVE NON-MARKET LOSSES (NOT DISCOUNTED)	CUMULATIVE NON-MARKET LOSSES (NPV)	PROJECTED # OF PERSONS OVER CAPACITY	CUMULATIVE NON-MARKET LOSSES (NOT DISCOUNTED)	CUMULATIVE NON-MARKET LOSSES (NPV)
2020	20,200	$ 848,400	$ 848,400	20,200	$ 848,400	$ 848,400
2030	24,600	$ 10,348,800	$ 9,156,018	24,600	$ 10,348,800	$ 9,156,018
2040	29,000	$ 21,697,200	$ 16,545,831	29,000	$ 21,697,200	$ 16,545,831
2050	37,800	$ 35,910,000	$ 23,416,088	37,800	$ 35,910,000	$ 23,416,088
2060	48,450	$ 54,246,150	$ 30,013,909	20,200	$ 47,720,400	$ 27,756,324
2070	63,750	$ 78,129,450	$ 36,404,591	29,000	$ 58,237,200	$ 30,564,723
2080	101,900	$ 113,717,100	$ 43,458,779	42,600	$ 73,558,800	$ 33,607,562
2090	161,150	$ 170,201,850	$ 51,791,947	63,750	$ 96,336,450	$ 36,972,120
2100	258,300	$ 260,326,500	$ 61,682,488	118,700	$135,804,900	$ 41,289,425

Figures 32 and 33 present the same cumulative non-market losses over time as Tables 6 and 7, with and without adaptation. In both turnover rate assumptions, beach nourishment provides benefits when implemented in 2060 in the form of decreased non-market losses. Under the higher turnover rate, we see approximately $62 million in cumulative losses by 2100 with no adaptation, and $41 million with adaptation. Again, significant non-market recreational losses are still realized under both turnover rate assumptions, even after the beach nourishment project.



Note: Assumes a turnover rate of 1.6 persons/day/100 square feet

Figure 32: Cumulative Non-Market Losses – 1.6 Persons Per Day Turnover Rate

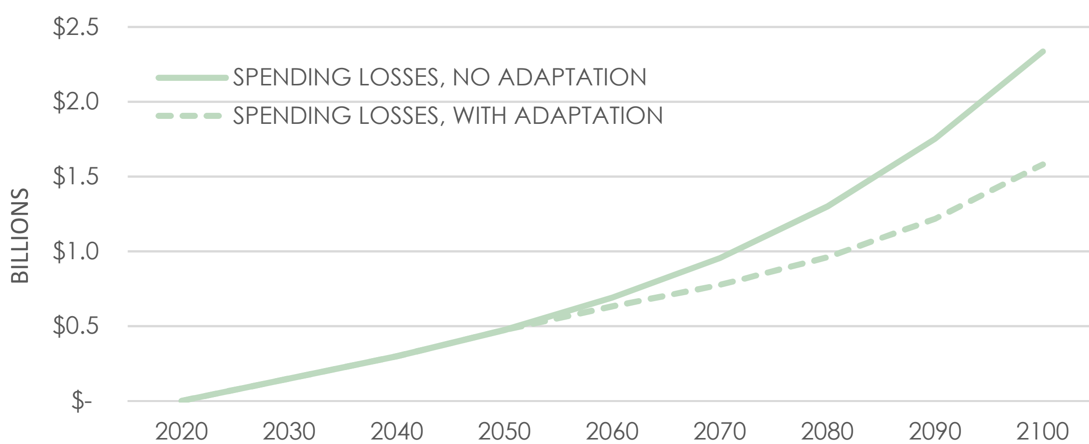


Note: Assumes a turnover rate of 2.5 persons/day/100 square feet

Figure 33: Cumulative Non-Market Losses – 2.5 Persons Per Day Turnover Rate

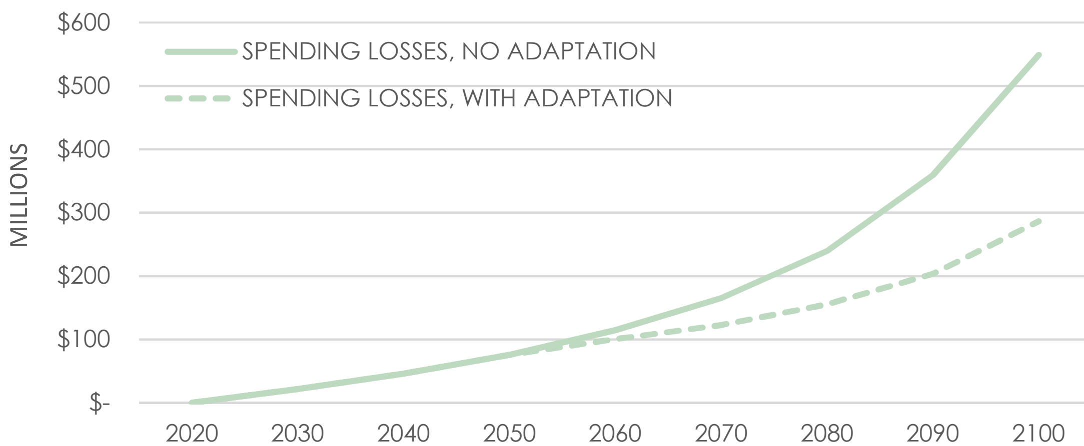
6.3.3 Losses in Spending and Tax Revenues

When fewer people visit the beach, spending and taxes at visitor serving businesses declines. With no adaptation, losses in cumulative spending reach nearly half a billion dollars by 2050, and exceed $2.3 billion by 2100, assuming a 1.6 turnover rate and no discount (Figure 34). Beach nourishment curbs these losses by approximately $750 million by 2100. Alternatively, assuming a 2.5 person per day per 100 square feet turnover rate, cumulative spending losses are in the *millions* rather than the *billions*. Figure 35 shows that nearly $100 million in spending losses can be expected by 2050. Adaptation saves about $260 million by 2100.



Note: Assumes a turnover rate of 1.6 persons/day/100 square feet

Figure 34: Losses in Spending, With and Without Adaptation – 1.6 Persons Per Day Turnover Rate



Note: Assumes a turnover rate of 2.5 persons/day/100 square feet

Figure 35: Losses in Spending, With and Without Adaptation – 2.5 Persons Per Day Turnover Rate

Tax revenue is also impacted when fewer people are able to visit the beach. Lower spending means fewer dollars are collected in county and transient taxes. Tables 8 and 9 show losses in sales and transient tax revenue with and without adaptation, alongside cumulative losses in spending, for both turnover rates. Without adaptation, the data shows that the County of Los Angeles will lose out on $39.3 million in sales taxes under the 1.6 turnover scenario by 2100, or $9.2 million under the 2.5 turnover assumption. In the latter scenario, transient tax losses are likely to exceed at least $25 million, and could exceed $100 million. Beginning in 2060, beach nourishment reduces cumulative losses in spending, sales taxes, and transient occupancy taxes, though significant losses are still expected, even with adaptation.

TABLE 8: **CUMULATIVE LOSSES IN SPENDING AND TAX REVENUE – 1.6 PERSONS PER DAY TURNOVER RATE**

	CUMULATIVE LOSSES					
	NO ADAPTATION			WITH ADAPTATION		
	SPENDING	SALES TAXES	TRANSIENT TAXES	SPENDING	SALES TAXES	TRANSIENT TAXES
2020	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ 148,828,527	$ 2,501,009	$ 6,828,008	$ 148,828,527	$ 2,501,009	$ 6,828,008
2040	$ 298,807,136	$ 5,021,345	$ 13,708,780	$ 298,807,136	$ 5,021,345	$ 13,708,780
2050	$ 474,208,957	$ 7,968,909	$ 21,755,927	$ 474,208,957	$ 7,968,909	$ 21,755,927
2060	$ 689,589,894	$ 11,588,307	$ 31,637,250	$ 630,847,947	$ 10,601,170	$ 28,942,266
2070	$ 955,674,424	$ 16,059,761	$ 43,844,770	$ 774,877,668	$ 13,021,537	$ 35,550,113
2080	$ 1,300,012,439	$ 21,846,236	$ 59,642,432	$ 961,655,564	$ 16,160,271	$ 44,119,175
2090	$ 1,751,627,140	$ 29,435,456	$ 80,361,771	$ 1,216,936,403	$ 20,450,173	$ 55,831,040
2100	$ 2,336,481,163	$ 39,263,715	$ 107,193,912	$ 1,581,268,317	$ 26,572,638	$ 72,545,989

TABLE 9: CUMULATIVE LOSSES IN SPENDING AND TAX REVENUE – 2.5 PERSONS PER DAY TURNOVER RATE

	CUMULATIVE LOSSES					
	NO ADAPTATION			WITH ADAPTATION		
	SPENDING	SALES TAXES	TRANSIENT TAXES	SPENDING	SALES TAXES	TRANSIENT TAXES
2020	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ 21,832,082	$ 366,880	$ 1,001,620	$ 21,832,082	$ 366,880	$ 1,001,620
2040	$ 45,772,946	$ 769,198	$ 2,099,987	$ 45,772,946	$ 769,198	$ 2,099,987
2050	$ 75,756,617	$ 1,273,062	$ 3,475,589	$ 75,756,617	$ 1,273,062	$ 3,475,589
2060	$ 114,439,009	$ 1,923,106	$ 5,250,273	$ 100,672,127	$ 1,691,758	$ 4,618,672
2070	$ 164,823,805	$ 2,769,804	$ 7,561,845	$ 122,858,626	$ 2,064,594	$ 5,636,552
2080	$ 239,900,385	$ 4,031,439	$ 11,006,235	$ 155,181,450	$ 2,607,768	$ 7,119,470
2090	$ 359,062,000	$ 6,033,906	$ 16,473,174	$ 203,233,739	$ 3,415,269	$ 9,324,030
2100	$ 549,191,174	$ 9,228,958	$ 25,195,988	$ 286,497,350	$ 4,814,484	$ 13,144,027

Sales taxes are collected by the County of Los Angeles, and transient taxes are collected by the City of Manhattan Beach. Tables 10 and 11 present the total combined tax losses avoided for both revenue streams with adaptation. There are no tax losses avoided until 2060 when the beach nourishment project is implemented. By 2100, total tax losses avoided by the beach nourishment project exceed $47 million under the 1.6 persons per day turnover rate, or nearly $16.5 million under the 2.5 turnover rate assumption.

TABLE 10: CUMULATIVE LOSSES IN TAX REVENUE – 1.6 PERSONS PER DAY TURNOVER RATE

	CUMULATIVE TAX LOSSES AVOIDED WITH ADAPTATION		
	SALES TAXES	TRANSIENT TAXES	TOTAL
2020	$ -	$ -	**$ -**
2030	$ -	$ -	**$ -**
2040	$ -	$ -	**$ -**
2050	$ -	$ -	**$ -**
2060	$ 987,137	$ 2,694,984	**$ 3,682,121**
2070	$ 3,038,224	$ 8,294,658	**$ 11,332,881**
2080	$ 5,685,964	$ 15,523,257	**$ 21,209,221**
2090	$ 8,985,283	$ 24,530,731	**$ 33,516,014**
2100	$ 12,691,077	$ 34,647,923	**$ 47,339,000**

TABLE 11: CUMULATIVE LOSSES IN TAX REVENUE – 2.5 PERSONS PER DAY TURNOVER RATE

	CUMULATIVE TAX LOSSES AVOIDED WITH ADAPTATION		
	SALES TAXES	TRANSIENT TAXES	TOTAL
2020	$ -	$ -	**$ -**
2030	$ -	$ -	**$ -**
2040	$ -	$ -	**$ -**
2050	$ -	$ -	**$ -**
2060	$ 231,347	$ 631,602	**$ 862,949**
2070	$ 705,210	$ 1,925,293	**$ 2,630,503**
2080	$ 1,423,671	$ 3,886,765	**$ 5,310,436**
2090	$ 2,618,637	$ 7,149,144	**$ 9,767,781**
2100	$ 4,414,474	$ 12,051,960	**$ 16,466,434**

6.3.4 Impacts to Restrooms

To estimate flooding damages to public restrooms, this study used a standard method of applying US Army Corps of Engineers as well as the Federal Emergency Management Agency (FEMA) Flood Depth Damage Curves. The "curves" are expressed as a proportion or percentage of the total value of a structure and the depth of flooding. Table 12 below displays the total market loss determined by one 100-year flood event and 6.6 feet of sea level rise. The Manhattan Pier restroom is the largest physical structure and, therefore, valued the highest. The El Porto restroom is more vulnerable to higher flood depths. The total market loss from one 100-year flood with 6.6 feet of sea level rise is nearly $1 million. The city-wide dune restoration proposed in 2030 protects all three bathrooms from flooding, and saves $923,900 in replacement costs.

TABLE 12: MARKET LOSS OF PUBLIC RESTROOMS (100-YEAR FLOOD EVENT WITH 6.6 FT OF SEA LEVEL RISE, NOT DISCOUNTED)

RESTROOM LOCATION	ESTIMATED MARKET VALUE	FLOOD DEPTH	MARKET LOSS
Rosecrans Ave	$ 750,000	0.5 ft	$ 298,800
Manhattan Pier	$1,000,000	0.5 ft	$ 398,400
El Porto	$ 500,000	1.5 ft	$ 226,700
TOTAL			**$ 923,900**

6.3.5 Conclusions and Discussion

The analysis indicates that sea level rise and the resulting beach erosion may negatively impact the City of Manhattan Beach's ability to provide visitors with adequate recreational capacity by mid-century. The losses in recreational value occur during peak times, when predicted "carrying capacity" is exceeded by current attendance patterns, mostly in July and August. A summary of cumulative total losses expected by 2100 is presented below in Table 13. Adding to beach capacity through dune restoration or nourishment would preserve $65 million in non-market value through 2100,[11] depending upon the assumed turnover rate. The analysis also indicates that Manhattan Beach and Los Angeles County will lose significant tax revenues without adaptation. With no adaptation, the City would lose between $25 and $107 million in transient Occupancy Taxes (TOTs) and between $9 and $39 million in County (sales) taxes. Adapting would lower these losses significantly, possibly enough to finance the restoration projects proposed. Given these values, it is likely that nourishment or dune restoration would be a cost-effective adaptation strategy in the future.

[11] These estimates are present values applying a 3% discount rate. With no discounting (i.e., discount rate is zero) the losses are $260 million; see Table 6-5 above.

TABLE 13: SUMMARY OF CUMULATIVE TOTAL LOSSES BY 2100

	NO ADAPTATION		WITH ADAPTATION	
	1.6 TURNOVER	2.5 TURNOVER	1.6 TURNOVER	2.5 TURNOVER
Recreational	$ 315,000,000	$ 62,000,000	$ 249,000,000	$ 41,000,000
Spending	$ 2,336,000,000	$ 549,000,000	$ 1,581,000,000	$ 286,000,000
Sales Tax	$ 39,000,000	$ 9,000,000	$ 27,000,000	$ 5,000,000
Transient Tax	$ 107,000,000	$ 25,000,000	$ 73,000,000	$ 13,000,000
Bathrooms	$ 1,000,000		$ 0	
Total	**$ 2,798,000,000**	**$ 646,000,000**	**$ 1,930,000,000**	**$ 346,000,000**

Table 14 below presents a brief benefit/cost assessment of the proposed adaptation scenario (nourishment with dunes) versus the baseline (doing nothing to maintain beach width or dunes). All costs and benefits were discounted using a 3% discount rate, assuming that dune restoration is implemented in 2030 and beach nourishment is implemented in 2060.

In Table 6-12 below, the net benefit of adaptation is measured in terms of increased carrying capacity. Without adaptation, the beach will erode to the point where the beach does not have adequate carrying capacity by the middle of the 21st century. One crucial assumption in the analysis is the turnover rate. If the average turnover rate for southern California beaches of 1.6 is used, the benefits of nourishment/dune restoration increase. With the 1.6 turnover rate assumption, net benefits are positive for the entire range of costs estimated for adaptation. A 2.5 turnover rate, which may be more appropriate in Los Angeles County, results in a higher carrying capacity for a given area of beach, so the benefits of adaptation are lower, indicating the City could delay or possibly not implement adaptation because the loss of recreational value would be lower.

Table 6-12 also contains a low and high estimate of the **costs** of adaptation, specifically for beach nourishment. These differences are primarily due to *uncertainty about the future cost and availability of sand,* as well as the costs of moving this sand to the beach. Using the 2.5 turnover rate assumption, net benefits are low ($3.6 million), but still positive, if the costs of adaptation are on the low end of the range (i.e., assuming $24/cy of sand). However, the net benefits are negative (a $12.5 million loss) if the cost of adaptation reach the high end of the range (i.e., assuming $54/cy of sand). Note that only non-market savings from adaptation are included in the net benefits calculation; savings in spending losses, transient taxes, and sales taxes are excluded, which is standard in a benefit-cost analysis.

TABLE 14: SUMMARY OF NET BENEFITS WITH ADAPTATION (MILLIONS, 2021 DOLLARS)

	COSTS	NON-MARKET SAVINGS FROM ADAPTATION		NET BENEFITS	
		1.6 TURNOVER	2.5 TURNOVER	1.6 TURNOVER	2.5 TURNOVER
Low Cost Estimate of Adaptation	$9.1	$65.3	$12.7	$56.2	$3.6
High Cost Estimate of Adaptation	$25.2			$40.1	($12.5)

6.3.6 Access for All

One important consideration beyond the scope of the economic analysis is consideration of access for underserved groups. The analysis assumes that current attendance patterns will continue. However, coastal policymakers are increasingly concerned with the inequality of access to California's coastal resources (e.g., see Christensen and King, 2017). Manhattan Beach is only a few miles directly west of some districts, including underserved communities. The analysis indicates that Manhattan Beach has adequate capacity for more visitors from underserved communities, except for peak days (mostly in July and August) when some visitors may not find space on the beach, presenting access challenges for all demographic groups.

6.3.7 Sensitivity Analysis

Table 15 below provides a general discussion and sensitivity analysis of the critical parameters used in this study and how changing these parameters could influence the study results. The results presented above explicitly account for some uncertainty in turnover and adaptation costs; the two parameters which are the most uncertain. However, the impacts of other parameters on adaptation were also examined in a qualitative fashion.

In many cost-benefit analyses, the discount rate is crucial. However, in this analysis since both costs and benefits are spread over time, varying the discount rate from 3% to a lower rate (e.g., 0%) or a higher rate (e.g., 6%) makes little difference in the analysis. Attendance, on the other hand, is a critical variable in the analysis. King and MacGregor (2012) found that official attendance estimates were generally much higher than actual measured attendance. If this is the case at Manhattan Beach, then the need for adaptation from an economic perspective may be delayed or avoided. However, another critical factor to consider is that as other beaches in the area erode and possibly lose carrying capacity, beach visitors may be more likely to visit Manhattan Beach, which will still have adequate beach width/area. Pendleton (2011) found that as smaller beaches in Orange and Los Angeles County erode with sea level rise, visitors will be more likely to attend beaches with adequate capacity. The analysis here did not explicitly factor in this possibility. If Manhattan Beach becomes a more popular destination as other beaches erode, then nourishment/adaptation will increase net benefits.

Of course, if the City increases the carrying capacity of its beaches, then it may also need to consider parking and other related capacity issues. Increasing the value of a beach day from $42 (2021 dollars) would also increase the benefits of adaptation, although since Manhattan Beach has adequate carrying capacity for most days, the impact here will be modest. Nelsen (2012) showed that the inability to survey niche recreational activities such as surfing, diving, and paddle boarding may underestimate the value of a beach day, which could be as high as $138 in Southern California.

Finally, this analysis only accounts for two ecosystem services provided by beaches—recreation and storm buffering. Defeo (2009) lists 14 distinct ecosystem services provided by beaches/dunes. King (2018) proposes valuing these services at replacement cost. If such an approach were applied here, the benefits of dune restoration would be considerably higher, and adaptation would have higher net benefits.

TABLE 15: SENSITIVITY ANALYSIS

PARAMETER	IMPACT ON ADAPTATION
Turnover	Higher turnover increases "carrying capacity" and delays/abates the economic need for adaptation.
Discount Rate	Changing discount rate has little impact.
Nourishment (Sand) Cost	Higher nourishment costs delay/abate the economic need for adaptation
Attendance	Lower attendance estimates would delay/abate the economic need for adaptation
Value of a Beach Day	Higher day use values would increase benefits of adaptation.
Dune Ecosystem Services (DES)	Accounting for DES would increase benefits of adaptation.
Access for All	Encouraging underserved communities would increase benefits of adaptation.

If beach erosion continues, the City may find other ways to adapt. This analysis did not explicitly include impacts to volleyball tournaments, which are popular at Manhattan Beach. However, a partial analysis of scheduled volleyball tournaments at Manhattan Beach in 2016 revealed that the number of average beach attendees on a tournament day is higher than an average day in the calendar year. One event-specific adaptation strategy may be to spread out games to reduce crowds on busy days, or to schedule tournaments during non-peak days. However, this strategy may also lower spending, tax revenues, and other beneficial economic impacts.

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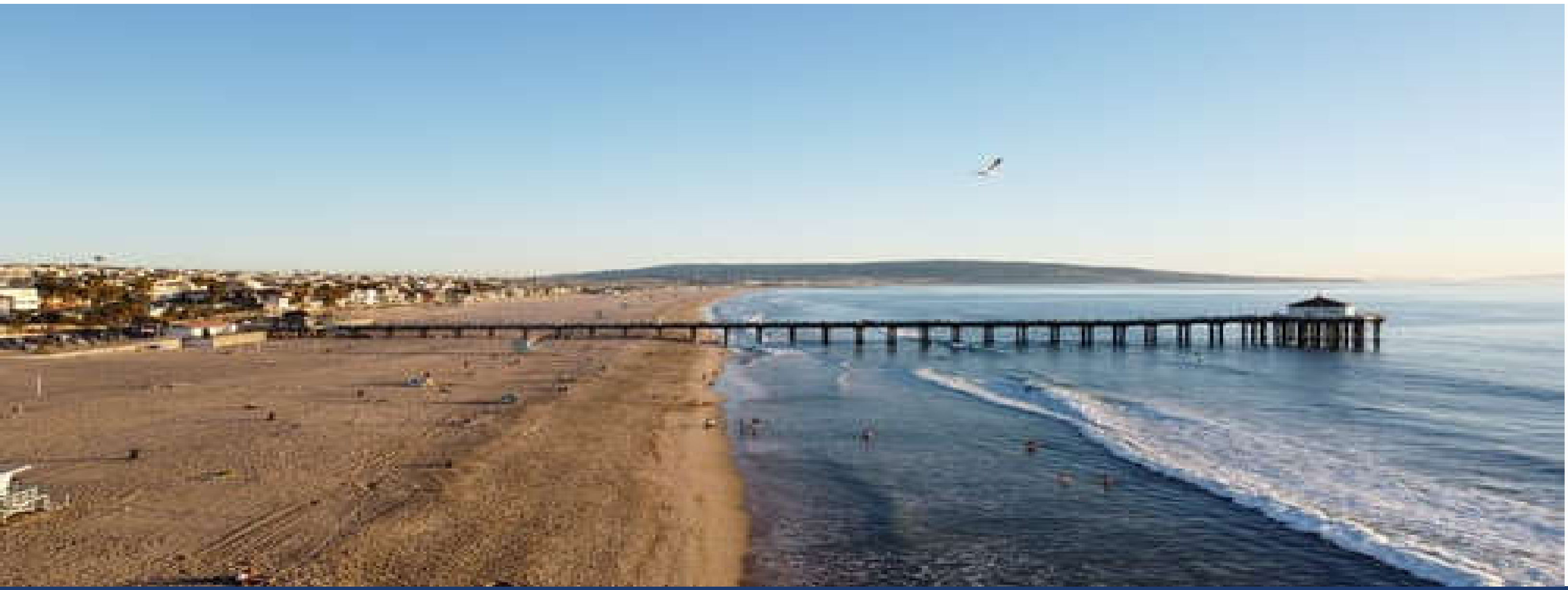

CHAPTER 7

Implementation Tools

This section describes the tools, programs and policies, and potential funding sources that can help the City take action and implement the adaptation strategies identified in this Adaptation Plan.

7.1 City Tools to Facilitate Implementation

The City can choose from a variety of existing policy, regulatory, and procedural tools to facilitate the implementation of the adaptation strategies identified in this Adaptation Plan. Amendments to plans and programs can help to establish a policy and regulatory framework for implementation and improve the City's ability to seek funding from state and federal agencies. Possible implementation tools could include:

1. **General Plan** – The goals, objectives, policies, and implementation measures that relate to sea level rise in the General Plan, particularly the Safety Element, could be reviewed for consistency with this Adaptation Plan and revised as appropriate.

2. **Local Coastal Program (LCP) –** The City will be reviewing the LCP and amending policies and regulations as needed to incorporate adaptation strategies from this Adaptation Plan.

3. **Local Hazards Mitigation Plan –** The City will be reviewing the vulnerabilities and mitigation measures that relate to sea level rise in the Local Hazards Mitigation Plan for consistency with this Adaptation Plan. The City will consider incorporating new mitigation measures as part of the update to the Local Hazards Mitigation Plan to facilitate federal funding for adaptation projects.

4. **Capital Improvement Program –** For adaptation strategies that require capital expenditures, the capital improvement program is an appropriate place to address priorities, funding, and scheduling of implementing adaptation strategies.

5. **Administrative policies, procedures, and initiatives –** The City could amend or create administrative policies, procedures, and initiatives that would direct City staff efforts toward implementation of certain adaptation planning actions, such as:

    a. Establishing a process and responsibility for monitoring the trajectory toward planning-level adaptation threshold criteria (identified in Section 2.2).

    b. Participating in regional coordination efforts.

    c. Engaging state and federal agencies and the state legislature in planning, funding, and assistance with adaptation.

    d. Facilitating public education, outreach, and assistance efforts.

    e. Tracking current information on sea level rise, adaptation measures, legal context, and planning by other jurisdictions.

    f. Ensuring consistency in approach and methodologies for addressing sea level rise citywide.

6. **Climate Action and Adaptation Plan –** The City is creating a Climate Action and Adaptation Plan and including adaptation strategies from this Sea Level Rise Adaptation Plan.

7.2 Implementation Programs and Policies

The following are programs, policies, and standards that would serve to implement the adaptation strategies identified in this Adaptation Plan.

7.2.1 Local, Regional, State, and Federal Coordination

There are several key agencies and stakeholders that the City should coordinate with as it moves forward with adaptation planning. These include:

- California Ocean Protection Council (OPC), Governor's Office of Planning and Research (OPR), California Coastal Commission, California State Lands Commission, Coastal Conservancy, and other state agencies – In an effort to stay ahead of major changes, the City should coordinate with OPC and OPR as they seek to update the best available science on sea level rise projections and adaptation approaches for California. The City should continue to coordinate with the CCC on updates to the LCP and permitting issues related to sea level rise.

- Regional and State Climate Collaboratives – The City should continue participating in the Los Angeles Regional Collaborative for Climate Action to share best practices and information with other local and regional agencies.
- Neighboring Jurisdictions – The City could stay in regular communication with neighboring jurisdictions to share best practices and information on adaptation planning, to jointly conduct needed monitoring, and to coordinate on issues that cross jurisdictional boundaries (e.g., sand nourishment).
- Local Community Groups – Local community and interest groups play key roles in implementation of adaptation. The City could establish mechanisms for regular updates and input from these groups.

7.2.2 Education and Outreach Programs

Engaging and communicating with the community on an ongoing basis is essential to ensuring that adaptation strategies can be successfully and efficiently implemented. Public engagement offers the opportunity to educate and build commitment and consensus among decision-makers and community members. The following are outreach materials and programs the City could implement:

1. Alert community members of the hazards expected as a result of sea level rise by distributing information regarding hazards through a variety of communication tools (e.g., social media, City website, emails to City listservs, presentations to community groups and other stakeholders, pop-up booths at community events, signage on the beach).
2. Continue to pursue funding and partnerships to formalize a sea level rise public education program.
3. Continue support of programs such as the University of Southern California (USC) Sea Grant[12] Urban Tides Beach Walk events, The California King Tides Project[13], and dune restoration with The Bay Foundation[14].

7.3 Funding Sources and Mechanisms

Adaptation planning is a challenging undertaking, and substantial funding could be needed to design, permit, implement, and maintain adaptation strategies in the long-term. There are state and federal grant programs currently available to support adaptation planning. Additional funding programs are likely to emerge in coming years as more and more communities face the impacts of sea level rise. This section identifies some of the grant funding opportunities available as well as some local funding strategies. The list below is not comprehensive, but highlights some key funding sources currently available to local communities.

[12] Learn about USC Sea Grant at https://dornsife.usc.edu/uscseagrant/directors-welcome/

[13] Learn about the California King Tides Project at https://www.coastal.ca.gov/kingtides/learn.html

[14] Learn about The Bay Foundation at www.santamonicabay.org

7.3.1 State and Federal Funding Sources

National Oceanic Atmospheric Administration – Coastal Resilience Grants

This highly competitive grant program funds projects that are helping coastal communities and ecosystems prepare for and recover from extreme weather events, climate hazards, and changing ocean conditions.

California Department of Fish and Wildlife, California State Coastal Conservancy, and California State Parks – 2019 Proposition 1 & Proposition 68 Grant Opportunities

Proposition 1 (Water Quality, Supply, and Infrastructure Improvement Act of 2014) and Proposition 68 (California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access for All Act of 2018) are new funding opportunities available to support multi-benefit ecosystem restoration and protection projects. Proposition 1 funds ecosystems and watershed protection and restoration, and water supply infrastructure projects. Funds are distributed via grant programs by multiple state and regional agencies. Proposition 68 funds environmental protection and restoration projects, water infrastructure projects, and flood protection projects. Projects eligible for funding under these grants include: planning activities that lead to specific on-the-ground implementation projects, funds for implementation activities (e.g., construction and monitoring) of restoration and enhancement projects, and funds for acquisition or purchases of interests in land or water.

California Coastal Commission and California Coastal Conservancy – Local Coastal Program Local Assistant Grant Program and Climate Ready Grants

The LCP Local Assistance Grant Program provides funds to support local governments in completing or updating their local coastal programs consistent with the California Coastal Act, with special emphasis on planning for sea level rise and climate change. The Climate Ready Grant Program generally funds planning and implementation of managed retreat, natural shoreline infrastructure, living shorelines, and habitat enhancement projects.

7.3.2 Potential Funding Mechanisms

Infrastructure Financing Districts

Enhanced infrastructure financing districts allow for incremental property tax revenues to be devoted to a specific purpose. In 2014, the passage of Assembly Bill 313 and Senate Bill 628 both: (1) further defined enhanced infrastructure financing districts to include brownfield restoration and other environmental mitigation, transit priority projects, and projects to implement a sustainable communities' strategy, and (2) streamlined the requirements for the establishment of these districts. Once an infrastructure financing district is established and priority projects have been identified as part of the business plan, funds can be drawn from changes in local tax revenues occurring as part of a redevelopment or rezone, or can be used to apply for grant funds.

Establishment of a Shoreline Account

A "Shoreline Account" could be established to serve as the primary account where funds generated for future adaptation programs would be kept in reserve. Funds, subject to the restrictions of any terms of the funding sources, may be used to pay for adaptation-related projects identified in this Adaptation Plan, including repair and maintenance costs, and to pay for conducting surveys and monitoring programs.

Bonds

Bonds allow municipalities and other entities to borrow money from investors, which is then repaid to the investor over an established period at a certain rate. Often, interest earned on government-issued bonds is tax exempt, and they are a common mechanism for financing public infrastructure and government programs. Green bonds are a new market that has emerged to specifically fund green adaptation infrastructure.

Taxes

The City may impose a special tax with two-thirds majority voter approval to fund adaptation strategies. The taxing agency must publish an annual report including: (1) the tax rate, (2) the amounts of revenues collected and expended, and (3) the status of any project funded by the special tax (Institute for Local Government 2016).

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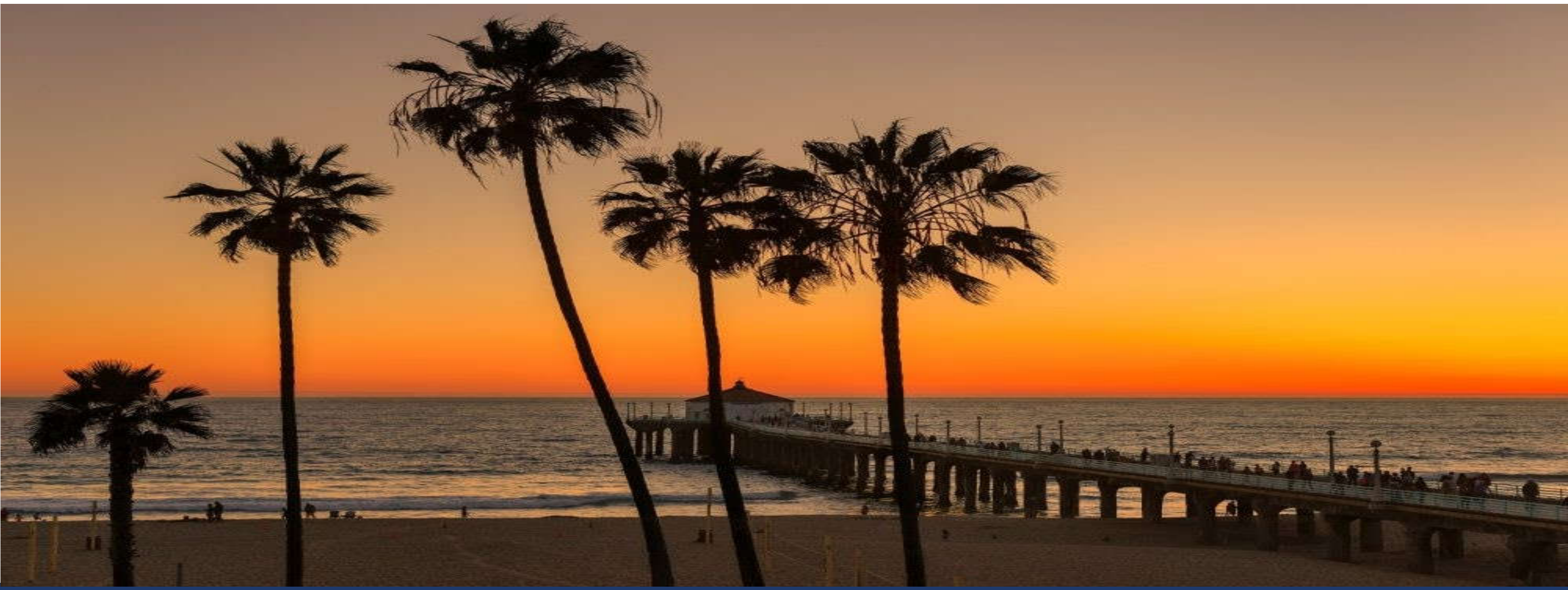

CHAPTER 8

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The City thanks the individuals and groups who gave up their personal time to participate in the Sea Level Adaptation Plan process. The City appreciates the civic investment these individuals and groups have made in the future of Manhattan Beach's shoreline.

Appendix A

Determining Day Use Values

A.1 How to Determine the Value of Ecosystem Services

Although we know that ecological functions goods and services (EFGS) have tremendous value, placing a (reasonably) precise dollar value on the EFGS is fraught with controversy, and the sub-field within economics of non-market valuation is still in its infancy. However, although the field of non-market valuation is relatively new, one cannot wait for more precise estimates. The State of California, and local jurisdictions, need to incorporate non-market values into their adaptation planning and decision-making in general. Fortunately, many trustees do indeed try to account for non-market values despite the relatively little information available. This report will spend a significant amount of time detailing the methods necessary for a proper non-market valuation of coastal EFGS.

Economists use a variety of methods to value ecosystem services. For ecosystem services that produce marketable products, the value of the ecosystem can be estimated based on the market price of those goods and services. In these cases, productivity is derived from the income based on the production of goods and services (Raheem 2009). Much of the world's GDP is based on natural resources, especially those in the coastal zone. For environments such as timber, grassland, and consumables, or services such as recreation, there may be a monetary value already assigned to that ecosystem. However, it is important to note that without valuation of non-market goods, "hidden ecosystem benefits," which can be useful for planning, may be ignored (Börger 2014).

Many ecosystem services—including those that produce marketable products—require non-market valuation. Various techniques are used to estimate the value of these ecosystems in the absence of an explicit market price. It is important to note that all of these techniques determine value in anthropogenic (human-centered) terms, based on the use a particular ecosystem provides to humankind. To determine the value of that use, "all non-market valuation methods essentially attempt to identify an individual's maximum willingness to pay (WTP)" (Shaw and Wlodarz 2012). In many cases, "the aggregate willingness to pay for these benefits is not revealed through market outcomes" (Barbier 2011). In California, one of the best example are its beaches, which are free by law, but still have value. Economists base their estimates of a day at the beach on studies of WTP to go to the beach, since it is free, but not lacking value. According to one of the leading environmental economists, "the economic benefit provided by an environmental good or service is the sum of what all members of society would be willing to pay for it'' (Barbier 2011). As we will see below, even using this admittedly anthropocentric assumption, California's beaches have enormous value.

A.1.1 Methods for Estimating Non-Market Value

One method of deriving WTP is through Stated Preference techniques. Stated Preference models use surveys of choice and willingness to pay. Broadly speaking, there are two main techniques: Contingent Value and Choice Experimentation. The Contingent Value Method (CVM) aims to elicit economic responses to hypothetical scenarios that allow the estimation of economic values of attributes of environmental quality. With careful consideration to the clarity of the questions and representativeness of the sample, respondents are asked a series of independent dichotomous choice WTP questions. Choice Experimentation (CE) involves choosing between two scenarios with associated benefits and costs, where the options are often presented as "side-by-side" comparisons. This method can yield more in-depth details about consumer preferences. In terms of estimating value, a recent study found the two methods highly comparable; Loomis and Santiago found that "in terms of resulting: (a) statistical significance of the beach attribute coefficients; (b) increment in value per day from improving beach quality attributes; and (c) precision of the incremental value estimates." The two methods 90% confidence intervals overlap, suggesting they are similar in results. Both CVM and CE can yield statistically significant estimates of value, however, they can be costly and time consuming to conduct (Raheem 2009, Loomis & Santiago 2013).

In addition to Stated Preference techniques, non-market value can also be estimated via Revealed Preference. Revealed preference is based on the costs associated with the use of a particular ecosystem service (Raheem 2009). There are several methods of revealed preference modeling, each deriving value from a distinct type of payment. Hedonic Pricing considers the value of homes in relation to proximity of a given ecosystem (Raheem 2009). Hedonic pricing models are often used to price environmental amenities (e.g., living near a wetland). Their use is generally limited to the residents and homeowners in a particular area, however, and hedonic studies would typically not include values of people who live far away from an amenity, such as beach visitors from California's central valley.

Travel Cost estimates are based on the time and distance users are willing to travel, and standardized monetary costs of that travel, capturing a version of opportunity cost (Mehvar 2018, Raheem 2009). Many studies of the recreational value of beaches rely on travel cost methods since they are relatively easy to implement—a travel cost study only requires knowledge of: (a) how many people visit a site; (b) what is the distribution of visitors by distance from the site. This data can be collected relatively easily with surveys including visitors' zip codes and attendance counts of visitors.

An additional method, developed in part because of controversy over the use of CVM and replacement cost methods, is Habitat Equivalency Analysis (HEA). While Shaw and Wlodarz (2012) argue for utilizing a combination of HEA and non-market analysis estimates, HEA is an alternative to these methods which is based on tradeoffs between lost and restored services. The goal of HEA is that the "value of habitat services gained with appropriate compensatory restoration equals the value of the lost services prior to resource injury." HEA and methods like it, including Florida's Uniform Mitigation Assessment Methodology (UMAM) consider both the magnitude/size of restoration efforts and the quality of those services. Quality is especially important given that it may take decades for a replacement or restored service to equate to what was lost (Shaw and Wlodarz 2012).

TABLE A-1: METHODS FOR ESTIMATING NON-MARKET VALUE

METHOD	DEFINITION
Stated Preference	Models based on surveys which attempt to capture respondent willingness to pay for certain services **Contingent Value Method (CVM):** uses hypothetical situations with associated costs and benefits to capture public preferences **Choice Experimentation (CE):** has respondents choose between side-by-side alternatives with associated costs and benefits
Revealed Preference	Models use data on associated costs related to the use of an ecosystem service to derive willingness to pay **Hedonic Pricing:** uses home values **Travel Cost:** based on the opportunity cost of visiting a site in terms of the time and cost of travel **Replacement Cost:** based on the cost of the man-made replacement for lost or adversely impacted resource
Habitat Equivalency Analysis	Compares the lost ecosystem service function to the replacement service on a one-to-one basis, considering quantity and quality of the replacement in terms of ecosystem function

A.1.2 Benefit Transfer Method

Simply put, benefit transfer involves "obtaining an estimate for the value of ecosystem services through the analysis of a single study or group of studies which have been previously carried out to value similar goods or services" and applying that estimated value to the site in question (Liu 2010). This allows for an accurate estimate of the value of a particular ecosystem service, provided sufficient primary data on comparable service sites exists. One of the problems with benefit transfer, however, is the lack of primary data (Börger 2014).

Liu and Constanza (2010) conducted an analysis of available data for benefit transfer and found significant gaps in the research. This is cause for concern, as estimates derived from benefit transfer models are only as good as their primary data sources. According to their analysis, whole categories of ecosystem services lack sufficient data; "several ecosystem services which we might reasonably expect to be delivered by functioning forests, wetlands, and riparian buffers simply remain unaccounted for in present-day analysis" (Liu and Costanza, 2010). However, in California there are significant studies on the non-market value of certain resources, including recreational and ecological services.

One of the critical requirements of the benefit transfer method is not only that the research exists, but that the chosen estimates come from quality research that is applicable to the specific site. This may mean looking to other states, or even other countries, for sites that share common characteristics with the project site. Furthermore, value estimates often have to be converted to current US dollars.

A.1.3 Applying the Benefit Transfer Method to Beach Recreation

For beach recreation, the value depends on the direct use of the site: The attendance or visits per year. The same benefit transfer method can be applied to any of these recreational uses so long as we consider how best to calculate the impacts of sea level rise on annual use.

After conducting a literature search including several studies of recreational value, one can take the average of day use value estimates (adjusted for inflation into current dollars) and simply apply the per-visit value to the attendance at the specific site. This is a simple type of benefits transfer, but one that is commonly used and good practice. In the case of a day at the beach, this average day use value is based upon a number of peer-reviewed studies by economists. In addition to being a relatively simple way to determine non-market value, applying one standard for all beaches in California may also be more equitable, since both revealed and stated preference studies are likely to indicate that higher income groups have higher willingness to pay.

This step is critical and often the most difficult. Sea level rise will lead to a diminution of valuable coastal ecosystems. However, applying a day-use benefits transfer approach implies that any reduction in non-market value is proportional to a reduction in use. Following this approach, losses in use depend on largely on loss of "carrying capacity." We recommend interviewing experts on the given activity—which can include people like lifeguards, harbor masters, surf instructors etc. on current visitation patterns and site accessibility. If access to the site is lost or severely inhibited due to sea level rise, there will be significant losses in attendance. In other cases, such as trails, marinas, or surfing, there may be an increased number of hours in the day when the waves and tide patterns make the site unsafe or unusable. This would impact the turnover rate, thus decreasing the carrying capacity.

In all of these cases, rather than applying the loss in area (as many trustees have done), one should estimate the loss in attendance. Anticipating the impacts of sea level rise on recreational value in all cases requires estimating the impact of sea level rise on attendance.

A.1.4 Beachgoing

California's beaches provide enormous non-market value since beaches are open to the public free of charge (though some beaches may charge for parking). As sea levels rise, beaches will lose area and some will vanish all together, impacting annual beach visits significantly. Understanding the benefit of these visits can help managers and planners better adapt to sea level rise.

A.2 Non-market value of beach recreation

In order to estimate the impact of sea level rise on recreational value, the value of beach visitation must first be estimated. As with most EFGS, beach access is generally free, and therefore has a non-market value.

As discussed in Section A.1.1, economists determine the non-market values like recreation, using the concept of WTP. The recreational value of beaches in California has been studied extensively, typically in terms of WTP for a trip to the beach. Economists can measure WTP by estimating the travel cost to and from the site (revealed preference) or by asking visitors how much they would be willing to pay (stated choice). Most of the studies cited in Table A-2 below are travel cost models (e.g., see Parsons 2003). This WTP is typically expressed as a "day-use value."

As indicated in the table below, estimates of day-use value vary by study and by beach with valuations ranging from $15 to $119 per day (2020 dollars). As indicated in Table A-2 below, the average price is $51.13 (2020 dollars). However, following the recommendation of Pendleton and Kildow (2006), this methodology uses a median value of $42.71 per visitor per day (in 2021 dollars) rounded to $42 per person per day. This method is also consistent with a recent California Coastal Commission decision in Solana Beach (CCC 2017). Several local coastal programs employed this method in determining the non-market value of beaches including: The City of Carpinteria, the City of Pacifica, the City of Oceanside, and Ventura County.

TABLE A-2: ESTIMATES OF DAY-USE VALUE FOR CALIFORNIA BEACHES

REGION	COUNTIES	USAGE LEVEL*	STUDIES	CS VALUES ($2020)	
Southern	San Diego Orange Los Angeles Ventura Santa Barbara	High	12	$15.97[1]	
				$23.08[2]	
				$25.90[3]	
				$29.64[2]	
				$32.45[2]	
				$35.95[1]	
				$37.25[4]	
				$40.68[2]	
				$48.265	
				$101.66[1]	
				$112.19[6]	
				$119.01[6]	
		Low	0		
Central	San Luis Obispo Monterey Santa Cruz San Mateo San Francisco	High	1	$51.30	
		Low	0		
Northern	Marin Sonoma Mendocino Humboldt Del Norte	High	0		
		Low	0		
CA Average		N/A		$51.13	
Midpoint Kildow & Pendleton (2006)		N/A		$42.71	

[1] *Leeworthy & Wiley (1993)*

[2] *King (2001) – midpoint between two methods*

[3] *Chapman and Hanemann (2001) – corrected for inflation using CPI*

[4] *Lew and Larson (2005)*

[5] *Lew (2002)*

[6] *Leeworthy (1995)*

A.2.1 Applying Day Use Value to Sea Level Rise Projections

Having a standard value for a beach trip allows city planners and researchers to understand the value of existing patterns of beach recreation and attendance. Applying this methodology to the future of California's beaches, however, requires additional calculations. Fundamentally, estimating the impact of sea level rise on the recreational value of beaches depends on the impact sea level rise has on beach attendance.

As sea levels rise, beaches will lose area, and this loss in area will lead to a loss in attendance. The relationship between lost area and lost attendance can be modeled using the carrying capacity of a given beach. Carrying capacity, in this case, is the number of visitors that can visit a beach at one time; essentially, the maximum occupancy of a beach. Beachgoers generally require about 100 square feet of "towel space." However, most beachgoers do not spend an entire day at the beach. Thus, one must account for the turnover rate (the rate at which visitors leave the beach and are replaced). While the turnover rate may vary site to site, King and McGregor (2012) found that turnover rates at southern California beaches, based on midday counts, were approximately 1.5. Of course, these turnover rates vary, and some types of recreationists, for example surfers, have very different patterns of visitation. (Surfers tend to visit early and later during the day.)

For traditional sunbathing, where one must place a towel in the sand, the carrying capacity is determined by dividing the area by required towel space and multiplying the result by the turnover rate. For example, a beach with 100,000 square feet has a carrying capacity of 1,000 (100,000/100) at one time; however, a turnover rate of 1.5 implies the beach can "carry" 1,500 people per day.

Daily attendance is rarely equivalent to carrying capacity, except for at the more popular beaches in high season. Therefore, models of sea level rise impact need to adjust for the average utilization rate at a given beach, or how close daily visitation is to the maximum occupancy (carrying capacity) of the beach. Many beaches are highly seasonal, with more than half of all visits taking place in the summer high season. At some of these seasonal beaches, the beach may be nearly at capacity for much of the summer (high utilization), and nearly empty in the winter (low utilization). Thus, a loss of area would impact the summer attendance far more than low season attendance. Models of sea level rise's impact need to also take seasonality into account.

A.2.2 Carrying Capacity and Beach Value

These methods allow planners to determine the estimated impact of sea level rise on the recreational value of beach visits given (1) annual attendance, (2) the nature of visits (seasonal/consistent), (3) the existing beach area, and (4) the expected loss in area. The method for seasonal beaches modifies the standard model to account for seasonal attendance fluctuations.

In both cases, the basic assumption is that once a beach loses enough area to suffer lost carrying capacity, attendance will decrease to the maximum occupancy of that beach. Thus, up until that point, occupancy and crowding will increase at the beach until it becomes so crowded that people choose to go elsewhere or decide not to go. Recreational value depends on attendance, not on area, at least up to the point that the loss in area impacts attendance.

Therefore, one needs to determine the impact of lost area on attendance. However, in most cases, the loss in attendance is not directly proportional to the loss in beach area, because beaches (currently) are rarely at full occupancy. A proportional drop in attendance, reflects the difference between the original carrying capacity and the impacted carrying capacity. The difference between the new carrying capacity and the previously daily attendance offers the most conservative estimate of the loss in attendance. Because the remaining carrying capacity is directly proportional to the remaining area, the proportion of current attendance remaining is that proportion of the initial carrying capacity as a percent of initial daily attendance. Unless a beach was so popular it was always at initial carrying capacity year-round, the loss in attendance will always be less than the loss in carrying capacity. As we endeavor to model annual attendance, direct proportionality is not relevant, especially when beaches are sparsely populated in the colder months.

This method provides a conservative estimate of annual losses in recreational value, as it assumes that once the carrying capacity is reached, the maximum number of visitors that can be supported at that site will visit. However, given that it is possible beachgoers in the summer/peak season may choose to visit a fully occupied beach and thus exceed the carrying capacity, this model allows room for those instances. Furthermore, this model does not take into account that the majority of beach visits take place on weekends. While this may change as crowding increases and beachgoers opt to visit on weekdays, it is likely that the impact of sea level rise on attendance will be greater on popular weekend days than a seasonal average suggests, likely leading to a greater than expected loss in attendance.

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