Final Draft

SEA-LEVEL RISE ADAPTATION PLAN

Pacifica, CA

Prepared for

City of Pacifica

September 2018

Near-king tides and high surf at Beach Boulevard on November 30, 2017 (J. Jackson)

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CHAPTER 1
Planning for Sea-Level Rise in Pacifica

1.1. Purpose of the Adaptation Plan

The purpose of the Adaptation Plan is to inform the development of new sea-level rise policies that will be integrated into the City's Local Coastal Program (LCP) via an LCP update. This Adaptation Plan and the preceding Vulnerability Assessment documents are subservient to the succeeding LCP policies. The Adaptation Plan was developed for the entire Pacifica coastline and covers both public and private shorefront properties, though each property owner is responsible for implementing their own adaptation strategies consistent with policies in the LCP. The adaptation alternatives included are based on the technical analysis from the Vulnerability Assessment (ESA 2018b; Appendix A), as well as input from the public, community workgroup and technical workgroup. This Adaptation Plan follows the California Coastal Commission's (CCC) Sea Level Rise Policy Guidance (2015) for addressing sea-level rise in LCPs. Additional information on the City's LCP Amendment is available on the City's website[1].

This project will inform the City's long-term effort to address a range of coastal and climate change hazards in planning and regulatory processes. This information will assist the City in making informed decisions regarding land use and development standards from the project-level to the plan- and policy-level by providing an estimate of the costs and benefits of different adaptation strategies. This Adaptation Plan includes an analysis of specific adaptation alternatives to illustrate the potential costs and benefits of different approaches and provides recommendations of near term actions for adaptation to inform policy development. The alternative adaptation strategies must be explicitly defined through time to yield cost-benefit outputs that can indicate what is feasible and can be referred to for future funding pursuits. The alternatives adaptation strategies that are analyzed in this plan are not meant to define which adaptation is best for the City and nor does it define the policies that shall be pursued by the City. Adaptation alternatives that are analyzed in this plan include planning-level engineering cost estimates, but the alternatives have not gone through a thorough engineering feasibility and design process. The specific engineering designs required for each adaptation strategy shall be determined in the future.

The California Coastal Act defines coastal resources to include coastal development; public access and recreation; coastal habitats; Environmentally Sensitive Habitat Areas and wetlands; water quality and supply; archaeology and paleontological resources; and scenic and visual resources. Key coastal assets in Pacifica include community assets such as homes, businesses and infrastructure for the well-being of its residents and visitors and the City's sandy beaches for public access and enjoyment as well as ecosystem services such as storm damage protection and sensitive species habitat (e.g. Western Snowy Plover).

On March 26, 2018, the City Council unanimously adopted the following goals for the Draft Local Coastal Land Use Plan Update and Adaptation Planning:

[1] Pacifica Sea-Level Rise webpage can be accessed here: :www.cityofpacifica.org/sealevelrise

1. **Bolster efficacy of public safety efforts.** Evacuations of bluff top homes have been necessary to protect the health, safety, and wellness of residents. The Adaptation Plan will assist the City to protect human life, property, and critical infrastructure in response to a catastrophic event.

2. **Respond to climate change.** The Adaptation Plan will allow Pacifica to prepare for sea level rise and climate change impacts by identifying policies that enhance the coastal zone's adaptive capacity.

3. **Preserve Existing Neighborhoods and Promote Environmental Justice and Local Economic Vitality.** Pacifica's Coastal Zone, i.e. the land area west of Highway 1, includes:

    - 12% of the City's population
    - The majority of older, and therefore more affordable, housing stock
    - Five of six hotels (80% of the rooms) that generate transient occupancy tax revenues for City operations and bring visitors who patronize businesses
    - More than half of commercial businesses, which provide vitality to the community and tax revenue for City operations
    - Public facilities that include City Hall, North Coast County Water District, Ingrid B. Lacy Middle School, the Pacifica Pier, drainage outfalls, waste water pumping stations, sewer force mains, and the Calera Wastewater Treatment Plant
    - Significant historical and public recreational assets including beaches, coastal trails, the Beach Blvd. promenade, parks and golf course.

    The loss or disruption of these assets could have far reaching impacts and affect everyone in Pacifica, not just those living or doing business in the Coastal Zone. The Adaptation Plan will allow the city to create policies that will protect these areas from the impacts of sea level rise, erosion, and coastal flooding. Consistent with the Coastal Act, the Adaptation Plan shall protect existing homes, businesses, and infrastructure in Pacifica.

4. **Preserve and enhance coastal access.** Beach and bluff access to the coastline is a crucial element of Pacifica's coastal character and is valued by the community. The Adaptation Plan will allow the city to identify where bluff erosion, sedimentation, and sea level rise may threaten coastal access.

It should be noted that not all properties within the coastal zone, as defined by the CCC, are affected by this adaptation plan or subsequent associated LCP Policies. Adaptation policies addressing sea level rise related coastal hazards only apply to areas that are affected by existing and or projected to be affected by future coastal erosion, storm flooding or tidal inundation as shown in the Final Vulnerability Assessment.

Property and infrastructure exposures to coastal flooding and erosion hazards can be determined using the online webmapper provided on the City's SLR webpage, which contains the coastal hazard zones that were considered for the Vulnerability Assessment and that influenced the specific strategies presented in this Adaptation Plan.

1.2. Planning Process and Goals

Rising sea levels increase the risk of hazards to coastal communities from storms, flooding, and erosion. In response to the increased risks of coastal hazards, the California Coastal Commission (CCC) is working with local governments, such as the City of Pacifica, to complete LCP updates that address the impacts of sea-level rise. An updated LCP can help cities address new coastal management challenges that result from sea-level rise and climate change.

Planning for sea-level rise includes identifying and applying different adaptation mechanisms based on the California Coastal Act requirements (Section 2.1), acceptable levels of risk, and community priorities. By planning ahead, communities can reduce the risk of costly damage from coastal hazards, can ensure the coastal economy continues to thrive, and can protect coastal habitats, public access and recreation, and other coastal resources for current and future generations. Adaptation strategies should be chosen based on the specific risks and vulnerabilities of a particular region or project site and consider private property rights in the context of applicable Coastal Act and LCP requirements.

1.3. Updating Pacifica's Local Coastal Program

The Coastal Act requires local governments in the State's Coastal Zone, such as the City of Pacifica, to create and implement LCPs to manage coastal development and protect coastal resources. Pursuant to the California's Coastal Commission LCP Update Guide (CCC 2013), the City's LCP should include policies and regulations that ensure new development minimizes risks to life and property in areas of high geologic, flood, and fire hazard consistent with Coastal Act section 30253. The best scientific estimates of projected sea level rise should be considered and factored into the City's LCP standards that require new development to evaluate and avoid or minimize risks from flooding, wave run-up, coastal erosion, and extreme events such as tsunamis.

This document, Pacifica's Sea-Level Rise Adaptation Plan, evaluates local adaptation goals and strategies to address the identified vulnerabilities. The Adaptation Plan assumes a long-range planning horizon and takes a phased approach that will involve future updates to the Adaptation Plan as needed. Preparation of the Pacifica Sea-Level Rise Adaptation Plan followed the steps outlined in the CCC's Sea Level Rise Policy Guidance document as follows:

Step 1. Establish the Projected Sea-Level Rise Ranges

Table 1 shows projected future sea-level rise from the latest guidance from the State of California (CalNRA & OPC 2018) for the San Francisco area which includes Pacifica. The rate of sea-level rise is projected to accelerate in the future. The sea-level rise projections are based on the latest "best available science" for/by the State of California based on the state-commissioned study "Rising Seas in California: An Update on Sea-Level Rise Science" by Griggs et al (2017). Background and additional information on SLR can be found in the memo Future Conditions Scenarios for Pacifica LCP Update (ESA 2017).

Table 1:
Sea-Level Rise Scenarios Used In This Study with Probability of Occurrence (CalNRA & OPC 2018)

Year	Low Risk (17% chance)	Med-High Risk (0.5 % chance)	Extreme risk (n/a)*
2050	1 ft	2 ft	2.7 ft
2100	3 ft	6 ft	10 ft

* The 2050 Extreme SLR scenario was not examined and is only provided for reference to other scenarios. SLR of 6 ft at 2075 was considered in place of 10 ft at 2100 to assess flooding impacts under the Extreme scenario because available hazard models do not have results for 10 ft of SLR.

The Pacifica Sea-Level Rise Adaptation Plan acknowledges that the processes causing sea-level rise and the science of projecting sea-level rise are inherently uncertain. For example, the rate of sea-level rise is highly dependent on whether global greenhouse gas emissions will continue to increase or whether global emissions will be reduced. The rate of sea-level rise could be higher, or lower, than the above projections. Given the uncertainties, the Adaptation Plan is, therefore, not tied to specific timeframes or years, but rather uses thresholds based on amounts of sea-level rise of up to 5.5 feet and responses to climate change, such as flood event frequency and coastal erosion distances.

Step 2. Identify Potential Impacts from Sea Level Rise

Based on the best available hazard data from OCOF (produced by USGS) and the Pacific Institute, the potential hazards for land within the City were identified in the Future Conditions Scenarios Memorandum (ESA 2017) and evaluated in the Vulnerability Assessment (ESA 2018b). Dominant coastal hazards in Pacifica include the following:

- long-term shoreline erosion
- storm-event coastal erosion of bluffs and beaches
- coastal flooding associated with major wave events
- rising groundwater levels in Linda Mar
- flooding from Laguna Salada and San Pedro Creek

Action is needed to manage impacts as each of these hazards increases with sea-level rise. This adaptation plan sets forth approaches to prepare for and manage impacts from each hazard source.

Step 3. Assess the Risks and Vulnerabilities to Coastal Resources and Development

In the Sea-Level Rise Vulnerability Assessment (ESA 2018b, Appendix A), the following public and private assets were determined to experience some form of existing or future risk and related vulnerability to sea-level rise (e.g. coastal erosion and/or flooding):

A. Property (public land and structures, private land and structures including homes, hotels, businesses, etc.)

B. Public Roads (local and regional)

C. Water system

D. Wastewater pipes, mains and pump stations
E. Stormwater pipes and pump stations
F. Parks, trails, coastal public access
G. Beach and wetland habitats
H. Other Utilities (e.g. communications, electricity, gas)

The City is currently vulnerable to coastal flooding and erosion, with significant damages experienced in the recent past (SLR Vulnerability Assessment, ESA 2018b). With future climate change and sea-level rise, the City's current vulnerabilities are projected to increase in both frequency and intensity, which can result in greater damages to much of Pacifica including low-lying areas and areas near coastal bluffs.

Step 4. Identify Adaptation Measures

The Pacifica Sea-Level Rise Adaptation Plan can be considered a "toolbox" with a variety of adaptation measures that can address the short-term and long-term needs of property owners (public and private) for protection, accommodation, and retreat as necessary to keep development safe and resilient, avoid flooding and erosion hazards, and incorporate safe setbacks. Consistent with Coastal Commission Guidance and comments received from the public, the Adaptation Plan includes a variety of adaptation approaches, nature based or green infrastructure solutions, and multi-objective measures that incorporate environmental considerations and a holistic approach, rather than focusing on independent solutions to protection.

The Adaptation Plan phase of this planning effort has included several documents and public comment periods leading up to the release of this Final Draft Adaptation Plan with Response to Comments. This document considers the 118 received comment letters and includes prepared responses to each letter (Appendix K).

As part of the Draft LCP Policy phase of this planning effort, the City has released for public review and comment draft sea level rise policies to be included in the Draft LCP. The City will prepare responses to comments on the draft policies prior to Planning Commission and City Council consideration. Once approved by local decision makers, the Draft LCP will go to the California Coastal Commission for consideration and certification. The certified LCP will be brought back to the City Council for adoption before the LCP becomes effective.

1.4. Historical Coastal Hazard Response in Pacifica

Land in the City of Pacifica has experienced damage from coastal flooding and erosion hazards that has required actions to protect existing development and people. Various approaches have been employed by the City and private property owners to adapt to coastal hazards, including protection (e.g., coastal armoring), accommodation (e.g., Beach Boulevard is frequently closed during large winter storm events to accommodate flooding due to wave action) and retreat (e.g., the Pacifica State Beach project at Linda Mar in 2005). Development along Esplanade that could no longer be protected from shoreline wave attack has also been removed.

Since the mid-20th century, the shore has entered an accelerated erosion phase of unknown genesis but potentially related to Pacific Decadal Oscillations and El-Niño Southern Oscillation[2] conditions and potentially due to human activities including reduction of sand runoff from watersheds, and potentially a pulse and then decrease of sand associated with hydraulic mining in the mid-1800s (e.g. gold rush).

The 1982-83 El Niño caused major erosion events resulting in armoring efforts along Pacifica's coast that have since continued. At the time, the Beach Boulevard seawall north of the pier was under construction to quickly prevent additional loss of land and improvements to erosion in West Sharp Park. Beach erosion is exacerbated in areas where the built environment meets the beach (Figure 1). Since 1983, coastal erosion has reached a greater density of built assets and property creating chronic shore management issues and resulting in much of the City's shore being armored.

Pacifica LCP 170663

SOURCE: Adelman & Adelman 2013

Figure 1

Pacifica Skies Estates Mobile Home Park; fill on beach and armoring in 1972

All shore protection structures require maintenance that can be costly, and even the most robust have been frequently augmented with new rock and other actions (e.g. Beach Boulevard and Land's End [more recently known as Oceanaire Apartments] seawall repairs). The seawalls at Beach Boulevard and Rockaway are overtopped by waves and damage landward of these structures has occurred () and can be expected in the future. More recently, the Land's End seawall failed (Figure 3) and the vertical public access is currently undergoing repair. Much of the armoring has been supported by the City of Pacifica and State and Federal agencies in order to protect public infrastructure. Armoring has also been constructed by private property owners. Following the 1983 El Niño and subsequent El Niño's of 1997-98, 2009-10, and 2015-17, coastal armoring structures were constructed or repaired along Esplanade, Beach Boulevard, SF RV Resort, Rockaway and other locations. Recently, the City of Pacifica has supported the City of San Francisco in their request to permit after the fact the levee at the Sharp Park Golf Course in order to prevent flooding in the West Sharp Park neighborhood (CCC 2017). An alternative approach was taken by the City at the Pacifica State Beach[3,4], where the natural shore was restored and the public parking area was reconstructed about 50 feet farther landward (Figure 4). This project has resulted in almost no costs to the City since construction in 2005.

[2] Pacific Decadal Oscillations and El-Niño Southern Oscillations are patterns of climate variability that affect sea surface temperatures, Pacific tropical cyclone activity, and local storm surge, which in turn affect coastal flooding and erosion along the coast of CA.

[3] Kershner, J. (2010). Restoration and Managed Retreat of Pacifica State Beach [Case study on a project of ESA PWA]. Product of EcoAdapt's State of Adaptation Program. (Last updated December 2010) http://www.cakex.org/case-studies/restoration-and-managed-retreat-pacifica-state-beach Last visited December 2016.

[4] Philip Williams & Associates, Ltd. (PWA) Pacifica State Beach Restoration Phase 1. Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002, PWA Ref. # 1547

Pacifica LCP 170663

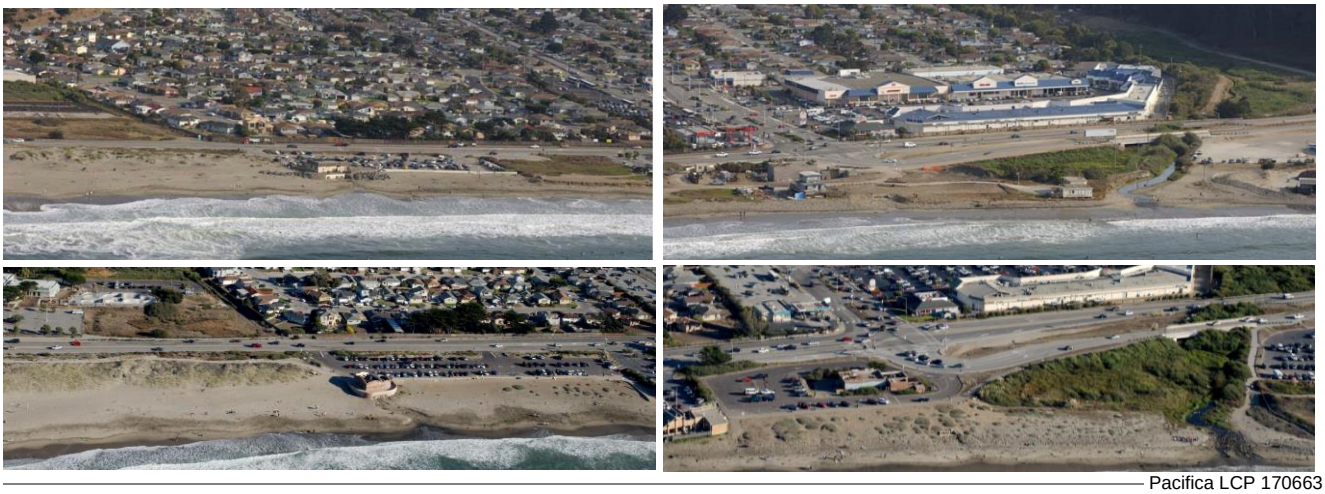
SOURCE: B. Battalio, J. Jackson

Figure 2
Wave overtopping at Beach Blvd (left) on January 22, 2016 and seawall damage (center); Rockaway on November 30, 2017 (right)

Pacifica LCP 170663

SOURCE: J. Jackson

Figure 3
Structural failure of Land's End Seawall (left) and erosion beyond end (right)



Pacifica LCP 170663

SOURCE: Adelman & Adelman 2013

Figure 4
Managed retreat at Pacifica State Beach pre (2002, top) and post (2013, bottom) project

The area south of the Pacifica Pier to Clarendon was renovated after the 1983 erosion damage by constructing a seawall and a park where private residential property had previously existed (Figure 5), a good example of a hybrid approach to shoreline adaptation. The project was funded by public sources and was initiated after storm damage to the private properties. A similar approach was employed at Esplanade following the 1997-1998 El Niño winter, in which damaged homes were removed and converted to a bluff top trail, a rock revetment was constructed at the bluff toe (completed in 2000). The Esplanade project is being completed with the recent demolition of the last two bluff-edge homes in the 500-block and repairs to the revetment, the trail is also being extended to a large portion of the 400 block.

Pacifica LCP 170663

SOURCE: Adelman & Adelman 2013

Figure 5

Beach Blvd in 1972 (top) and 2017 (bottom) showing removal of development, seawall construction and setback with public park.

In summary, coastal armoring has been the primary strategy employed in Pacifica to mitigate erosion and flood hazards, with mixed results in terms of protecting property but with uncertain resilience and future costs. Beaches and access have largely diminished where the armoring has occurred (Figure 6) and shoreline erosion continues seaward of armoring; beaches are absent even during low tides at some armoring locations. As the beach (a buffer to backshore erosion) erodes, greater wave loading on the armoring and increased overtopping leads to higher maintenance of the structure as well as damage of landward assets. However, where shores are unarmored or armoring fails, the backshore erodes and pocket beaches persist. This indicates that a hybrid approach of armoring with gaps that form coves of sandy beaches with access is a potential adaptation strategy if not the expected outcome of the existing ad hoc shore management practices.

Pacifica LCP 170663

SOURCE: Geomatrix Consultants 1987 (left); B. Battalio 2002 (right)

Figure 6

Beach Blvd seawall in 1985 (left) after construction (tide is estimated to be medium to low) and in 2002 (right) showing no beach at high tide.

Recent coastal erosion and flooding impacts and private and public responses in Pacifica are summarized below from north to south:

- Land's End Apartments – seawall failure, temporary loss of vertical access
- Manor Apartments (300 block Esplanade Ave) – demolition of apartments after erosion endangered the apartments despite an existing rock revetment (shotcrete wall was not completed, loss of beach area).
- The Bluffs Apartments – loss of lateral access along rock revetment due to beach erosion
- 500 block Esplanade Ave – remaining two homes demolished, and prior bluff top trail endangered.
- West Avalon Drive at Esplanade Ave – loss of lateral access along 500 block Esplanade rock revetment due to beach erosion
- SF RV Park – emergency rock revetment constructed after bluff erosion and loss of bluff-top access trail; storm drain damaged just south of the RV park at the public parking lot and erosion of vertical access ramp.
- Pacific Skies Estates (a.k.a. Cottages at Seaside) to Beach Boulevard – loss of lateral access along revetments and seawalls
- Beach Boulevard – failure of retaining wall structure north of pier (1/11/2001 and 1/22/2016) and regular overtopping of both structures north and south of pier.
- Rockaway – wave overtopping of seawall caused hotel damage (1/21/2017), loss of lateral access along seawall from beach erosion is greatest at high tide.

CHAPTER 2
Relevant Plans and Guidelines

2.1 California Coastal Act

The Legislature declares that the basic goals of the State for the coastal zone are to:

1. Protect, maintain, and where feasible, enhance and restore the overall quality of the coastal zone environment and its natural and manmade resources;
2. Assure orderly, balanced utilization and conservation of coastal zone resources taking into account social and economic needs of the state;
3. Maximize public access to and along the coast and maximize public recreational opportunities in the coastal zone consistent with sound resource conservation principles and constitutionally protected rights of private owners;
4. Assure priority for coastal-dependent development over other development on the coast;
5. Encourage state and local initiatives and cooperation in preparing procedures to implement coordinated planning and development for mutually beneficial uses, including educational uses, in the coastal zone.

Any request for permit approval of shoreline protection within the City of Pacifica is within the jurisdiction of the CCC. The standard of review for approval of this this type of permit is the Coastal Act and the City's certified LCP.

Section 30001 of the California Coastal Act declares:

- That the California coastal zone is a distinct and valuable natural resource of vital and enduring interest to all the people and exists as a delicately balanced ecosystem;
- That the permanent protection of the state's natural and scenic resources is a paramount concern to present and future residents of the state and nation;
- That to promote the public safety, health, and welfare, and to protect public and private property, wildlife, marine fisheries, and other ocean resources, and the natural environment, it is necessary to protect the ecological balance of the coastal zone and prevent its deterioration and destruction.
- That existing developed uses, and future developments that are carefully planned and developed consistent with the policies of this division, are essential to the economic and social well-being of the people of this state and especially to working persons employed within the coastal zone.

2.3 Pacifica Local Coastal Program

Pacifica's LCP guides development and protects coastal resources within the Coastal Zone. LCPs must be consistent with the California Coastal Act of 1976, as amended. Pacifica's LCP is made up of two parts: (1) the Land Use Plan (a compilation of goals, policies, and recommended programs), and (2) Implementation Plan Ordinances (regulations that implement the provisions of the Land Use Plan and the California Coastal Act). The City's 1980 Local Coastal Land Use Plan is currently in effect and is supported by Articles 43 and 44 of the Pacifica Zoning Ordinance (Title 9, Chapter 4) as the implementation plan. These articles of Pacifica's Zoning Ordinance discuss the applicability of Coastal Development Permits and coastal development regulations. As previously discussed, this Adaptation Plan will inform policies that will be incorporated into a LCP Update. The Pacifica Zoning Ordinance may need to be amended in the future to be consistent with the updated LCP.

2.4 Other Pacifica Plans

The following plans for Pacifica and San Mateo County contain specific information relevant to this Plan.

Climate Action Plan, Appendix E[5]

Plan Projected San Francisco Bay Area Climate Impacts includes the following discussion of adaptation planning (Page E-5):

- Even if we stopped emitting GHGs tomorrow, the climate would still continue to change due to the length of the carbon cycle — the ability of the earth to absorb the excess carbon in the ocean and plants. Therefore, it is noted briefly here that cities should take the lead in planning for adaptation to climate change. The Climate Action Plan Task Force was not commissioned to provide specific recommendations as to adaptation planning for climate change and this aspect of the plan will be developed by the City independent of the Climate Action Plan Task Force. The Climate Action Plan Task Force recommends that Adaptation Planning be incorporated into the General Plan and the Local Coastal Plan.
- Effective adaptation planning and management entails dealing with uncertainty. It is a long-term process that should allow immediate action when necessary and adjust to changing conditions and new knowledge. Pacifica plans to initiate an inclusive planning process that ensures the resulting actions are feasible and widely accepted. Adaptation will likely be an ongoing process of planning, prioritization and specific project implementation." (Page E-5)

Hazard Mitigation Plan[6]

The City of Pacifica hazard mitigation action plan includes the following actions (Vol. 2 Page 252):

- PA-3— Pacifica has updated its flood damage prevention ordinance to mitigate against damage of residential and commercial property in flood prone areas (Ordinance effective October 11, 2017. PMC Title 7, Chapter 5),
- PA-4—Pacifica will seek to encourage and assist in the acquisition of grants for the purchase or relocation of property and structures in high hazard areas to mitigate against damage to vulnerable structures and infrastructure

[5] Accessible at: http://www.cityofpacifica.org/civicax/filebank/blobdload.aspx?blobid=7490

[6] Accessible at: https://planning.smcgov.org/sites/planning.smcgov.org/files/documents/files/San%20Mateo%20HMP%20-%20Volume%20II%20-%20Final%20083016.pdf

- PA-5— Pacifica will pursue opportunities to preserve and protect critical transportation infrastructure to mitigate against isolation, economic loss and ensure public safety.
- PA-7— Pacifica will preserve, protect, or relocate hazard prone infrastructure to maintain critical services and maintain the environment
- PA-8— Pacifica will develop and deliver business outreach programs to mitigate against the functional loss of community businesses and promote business resiliency.
- G-4—Where feasible, implement a program to record high water marks following high-water events.

2.5 CCC Sea-Level Rise Policy Guidance

In 2015, the CCC adopted the Sea Level Rise Policy Guidance document to aid jurisdictions in incorporating sea level rise into LCPs, Coastal Development Permits, and regional strategies (CCC 2015a). The document outlines specific issues that policymakers and developers may face as a result of sea level rise, such as extreme events, challenges to public access, vulnerability and environmental justice issues, and consistency with the California Coastal Act. It organizes current science, technical, and other information and practices into a single resource to facilitate implementation of the Coastal Act by coastal managers at the state and local level. The policy guidance document also lays out the recommended planning steps to incorporate sea level rise into planning strategies to reduce vulnerabilities and guide adaptation planning. The policy guidance has a strong emphasis on using soft or green (i.e. nature-based) adaptation strategies. The Pacifica Sea-Level Rise Adaptation Plan was prepared in accordance with the Coastal Commission Guidance document.

CHAPTER 3
Adaptation Planning Concepts

3.1 Adaptation Plan Overview and Process

The Adaptation Plan provides a framework for the City to prepare for identified vulnerabilities, monitor effects of coastal erosion and flooding with sea-level rise, and near-term recommendations for adaptation measures. Adaptation should be flexible or adaptive as strategies are tested, sea level rise science advances and actual conditions are monitored into the future. Project-level planning and approvals will be required to further develop and implement the adaptation measures included in this Adaptation Plan. The process should continue to involve the local community, and reflect the Pacifica community's risk tolerance, local conditions, and adaptation vision.

In accordance with CCC guidance (CCC 2015a), the Pacifica 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 measures, including managed retreat for public property, within the three general categories of adaptation: Protect, Accommodate, and Retreat; and

The CCC further guides that, after evaluating vulnerability and establishing policies for areas with identified hazards, communities can begin the process of evaluating and choosing adaptation strategies for specific areas. In most cases, especially for LCP land use and implementation plans, multiple adaptation strategies will be needed and every community will need to assess their risks and their potential options. There are a number of options for how to address the risks and impacts associated with sea-level rise.

3.2 Monitoring Change

The Adaptation Plan includes measurable thresholds that, if and when they occur, call for the implementation of adaptation measures to limit risks. The Adaptation Plan sets planning-level adaptation thresholds such that adaptation measures can be implemented to reduce future risks before they become critical. The City will need to monitor and evaluate the trajectory towards these thresholds to track whether and when these thresholds are met. For monitoring change such as beach widths or bluff top offsets, an established nearby survey benchmark is needed. Adaptation thresholds (triggers) and monitoring are summarized below.

Sea-level Rise Amount

Certain adaptation measures will need to be taken when sea-level rise has risen by a certain amount (e.g., 1 ft, 2 ft, and 3 ft of sea-level rise). To monitor sea-level rise and progress towards the sea-level rise amount thresholds specified in Table 2, the City will follow sea-level rise reports from the State and Scripps Institute

of Oceanography (SIO) and sea-level rise data from the nearby NOAA tide gage at San Francisco[7]. Sea level is inherently variable in response to predictable astronomical tides and less-predictable atmospheric events such as El Niño and individual storms; however, sea-level rise can increase the impacts of fairly routine storms that already impact Pacifica's coastline. Tracking sea-level rise may, therefore, allow the City to anticipate and act in advance of the projected effects of sea-level rise.

Flooding and Storm Damage Frequency

In addition to the amount of sea-level rise, the frequency or risk of flooding and storm damage can be used as a threshold for adapting to sea-level rise. To monitor the frequency of flooding and storm damage, the City can track and keep records of coastal and river flooding and storm damage events and information. This could be a collaborative effort between City staff and residents in which reports, pictures, and videos are collected. The date, type, location, and severity of flooding (e.g., depth, duration, wave height), and damages can be collated into a file. The intent will be to track the frequency, extent, and severity of flooding to assess if and how the frequency of flooding is increasing. If significant and/or extreme flood events occur, then storm data (e.g. water levels, wave conditions) can be collected and storm frequencies can be recalculated to quantify the increase in flood risk.

Beach Width

Considering the recreational and ecological values of maintaining a beach as well as the erosion and flooding buffer that beaches provide, beach width is used in this Adaptation Plan for considering when beach adaptation measures would be implemented (sand placement, revetment construction/maintenance). Specific beach width thresholds are discussed in Section 5 and should be further detailed as part of subsequent monitoring, analysis, and planning beyond this study. A long-term beach monitoring program including all of Pacifica's beaches is recommended for consideration as part of the implementation of the Adaptation Plan. Beach width in this study refers to the distance from the backshore (toe of dune, bluff, or armoring structure) to the mean high tide line (5.3 feet NAVD88 at San Francisco Golden Gate tide gauge).

Bluff Top Offset

The Adaptation Plan uses the bluff top offset or distance between the edge of the bluffs and assets such as streets and infrastructure as a threshold for bluff adaptation measures. When the bluff edge reaches the threshold set based on the distance at which the safety of the asset is at risk, the Adaptation Plan calls for implementation of bluff adaptation measures. Similarly, new development setbacks for hazard avoidance shall be based on bluff erosion rates and structure design life. Site specific bluff top setbacks are not recommended in this Adaptation Plan but should be developed by a licensed geotechnical engineer or engineering geologist.

Table 2 presents sub-area specific thresholds for erosion and flooding adaptation actions in Pacifica. These thresholds are based on historic bluff and shoreline erosion rates, projected increases in future erosion rates with SLR, coastal and fluvial storm flood hazard exposure, and existing conditions along the Pacifica coastline. The City could compile readily available data for annual status reports and can consider preparation of a more comprehensive sea-level rise monitoring and thresholds analysis report on a regular cycle to identify significant changes or progress towards thresholds, evaluate if and when thresholds are reached, and plan next steps towards

[7] NOAA station home page for San Francisco can be accessed here: https://tidesandcurrents.noaa.gov/stationhome.html?id=9414290

implementing adaptation measures. The City may conduct this process in consultation with technical experts and will seek public input and review. The City may also consider participating in regional efforts, if initiated, to monitor and track sea-level rise and related effects.

Table 2 contains ranges for thresholds in some sub-areas due to the variations in topography and locations of assets relative to erosion and flooding hazards which are explained in footnotes below the table. Beach nourishments would ideally occur through time to maintain a wide beach; the stable beach widths specified in Table 2 could accommodate seasonal shoreline fluctuations (beaches are generally widest in late summer/fall and narrowest in late winter/spring) as well as recover after shoreline erosion during a coastal storm event. The bluff erosion offsets specified in Table 2 are based on two factors: bluff erosion offsets are recommended for northern Pacifica based on a stable slope offset of 2:1 (Collins & Sitar 2008) starting from the bluff toe; bluff erosion offsets are recommended for other areas based on a safety buffer to account for episodic failure (due to storms and/or from prior wave attack and triggered by terrestrial loadings such as rainfall runoff, groundwater piping or earthquake); dune erosion offsets are based on 100-year storm erosion distances from the Pacific Institute study (PWA 2009, PI 2009). Coastal storm flooding and tidal inundation adaptation thresholds in Table 2 are based on observed SLR amount that would expose areas to increased coastal flooding from a 100-yr storm or regular tidal/groundwater inundation.

Table 2: Adaptation Triggers/Thresholds for Hazard-Specific Measures in Pacifica

	Adaptation Trigger / Threshold			
Sub-area	Beach Nourishment (stable beach width, feet)	Coastal Erosion Actions (bluff/dune erosion offset, feet)*	Coastal Storm Flooding Adaptation (feet SLR)	Tidal Inundation Adaptation (feet SLR)
Fairmont West	75	260	n/a	n/a
West Edgemar and Pacific Manor	75	220	n/a	n/a
Northwest Sharp Park	50	70	1	n/a
Sharp Park, West Fairway Park and Mori Point	50-170[1]	35	0-3[4]	Not reached[6]
Rockaway Beach (not Headlands)	75	30	0	n/a
Pacifica State Beach	150	100	0-2[5]	n/a
West Linda Mar	n/a	n/a	0	2
Pedro Point	n/a[2]	100-110[3]	0	n/a

Notes:
* Bluff erosion offsets have not been certified by a licensed geotechnical engineer or engineering geologist. Site specific offsets shall be developed as needed for individual projects.
1. Stable beach width along Beach Boulevard is 50 feet, stable beach width along Sharp Park Golf Course is 150 feet
2. Beach nourishment calculations are included in Pacifica State Beach
3. Shoreline erosion buffer at beachfront homes is 100 feet to shoreline, bluff erosion buffer is 110 feet for Bluff top property
4. Beach Blvd. seawall is overtopped and Clarendon floods with 0 ft SLR, West Fairway Park storm flooding occurs with 3 ft SLR
5. Anza Pump Station and commercial floodproofing needed with OR Linda Mar Pump Station floodproofing
6. No tidal inundation impacts for Sharp Park, West Fairway Park and Mori Point sub-area within the SLR amount analyzed

For reference, Table 3 contains existing shoreline conditions for each Pacifica Sub-area. Beach width and bluff or dune toe offset vary along the coast, so the average beach width and range of offsets are provided. Historic

shoreline and bluff erosion rates were developed by the USGS and are publicly available (Hapke et al 2006 & 2007). The presence of coastal structures, many of which predate the Coastal Act, may have affected the background erosion rates shown in Table 3.

Table 3: Sub-areas and coastal attributes in Pacifica.

Sub-area	Beach Length (ft)[1]	2017 Average Beach Width (ft)	Existing Bluff/Dune offset (ft)[2]	Historic Shoreline Erosion Rate (ft/yr)[3]	Historic Bluff Erosion Rate (ft/yr)[4]
Fairmont West	3030	42	150-400	0.3	2.4
West Edgemar and Pacific Manor	4300	36	35-100	1.5	2.4
Northwest Sharp Park	2840	26	10-35	1.9	2.4[5]
Sharp Park, West Fairway Park and Mori Point					
North of Clarendon	*2620*	*44*	*0*	1.7	2.4[5]
South of Clarendon	*3570*	*163*	*10*	3.9	n/a
Rockaway Beach	1840	75	65-100	3.2	0.5 (headlands)
Pacifica State Beach	3950	198	0-90	1.5	n/a
West Linda Mar	n/a	n/a	n/a	n/a	n/a
Pedro Point Bluffs	See PSB	See PSB	130+	n/a	1.5

Notes:

1. The 2017 average beach width was determined from San Mateo County aerial imagery by digitizing the mean high tide line in GIS (corresponding to the wet-dry line in the aerial) and backshore locations and calculating the average width per each sub-area from the sub-area length and beach area digitized.
2. Ranges in Bluff/Dune offset are provided to illustrate the range of asset locations relative to the dune or bluff toe.
3. Erosion rates developed from Hapke et al 2006.
4. Erosion rates developed from Hapke et al 2007.
5. Erosion rate from Fairmont West and West Edgemar/Pacific Manor, due to lack of historic data.

3.3 Project-Level Planning

The Adaptation Plan identifies adaptation measures at a conceptual planning-level of detail and discusses potential benefits and effects of adaptation measures. Additional detailed project-level planning and design would be required to implement adaptation measures. For adaptation measures involving construction, the project-level planning and design may include:

- Feasibility study including additional technical analyses, development and assessment of project alternatives and details, conceptual and preliminary engineering design, and cost estimating.
- California Environmental Quality Act (CEQA) and possibly National Environmental Policy Act (NEPA) environmental review and regulatory permitting. Regulatory permitting could require approvals and permits from the US Army Corps of Engineers, US Fish and Wildlife Service, National Oceanic and Atmospheric Administration, California State Lands Commission, California Coastal Commission, California Department of Fish and Wildlife, 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 strategies discussed in the Adaptation Plan require substantial lead time. For example, levees, comprehensive armoring and sand retention structures can require significant lead time.

3.4 Reevaluation

The Adaptation Plan is intended to establish a process in which new data and information will be assessed, as needed, to inform adaptation decisions and actions. As such, it is anticipated that the Adaptation Plan will be re-evaluated and updated in the future to capture advances in sea-level rise science and adaptation strategies.

CHAPTER 4
Pacifica's Sea-Level Rise Adaptation Plan

The Adaptation Plan provides a general set of adaptation measures for each sub-area that focus on the immediate and near-term to address existing vulnerabilities, while also leaving options open in the future. By definition, adaptation should be an adaptive exercise that will evolve through time as specific adaptation strategies are implemented and monitored for efficacy and future conditions are better understood through advances in sea-level rise science.

Much of the backshore in Pacifica is already vulnerable to erosion and flooding. Therefore, the adaptation plan focuses on immediate and near term actions for the City Sub-areas. Generally, many adaptation measures should be implemented within the next 10-20 years to reduce coastal hazard vulnerabilities. On public lands, exposure to coastal erosion should be managed with armoring maintenance and construction within 10 years to protect public infrastructure that is directly exposed (i.e. not landward of shoreline private property). On private lands where the City has limited authority and/or funding to implement adaptation measures, exposure to erosion should be managed by private armoring maintenance. Presuming the cost to reconstruct armor is prohibitively expensive for most private property owners, we have assumed that as-needed maintenance of the existing armor would continue and be sufficient, and new construction may be delayed for 20 years.

The adaptation plans emphasize protection of the backshore based on community values derived from the public process to date and City Council adopted project goals. While Pacifica has previously found funding for armoring and is pursuing funding at this time for areas damaged recently, the sources of the funds for the protection actions in this adaptation plan are not known and in fact may not be available. Therefore, the adaptation plan is somewhat aspirational. The plan includes contingency actions such as infrastructure realignment to mitigate the risk of damages if armoring is not adequate or if funding is unavailable. Also added are ecology and public access planning elements to mitigate the adverse effects of armoring on coastal resources.

Supporting information for the Adaptation Plan, including development of alternative adaptation strategies, cost benefit analysis methodology and results are presented in Chapter 5 Adaptation Alternatives Analysis.

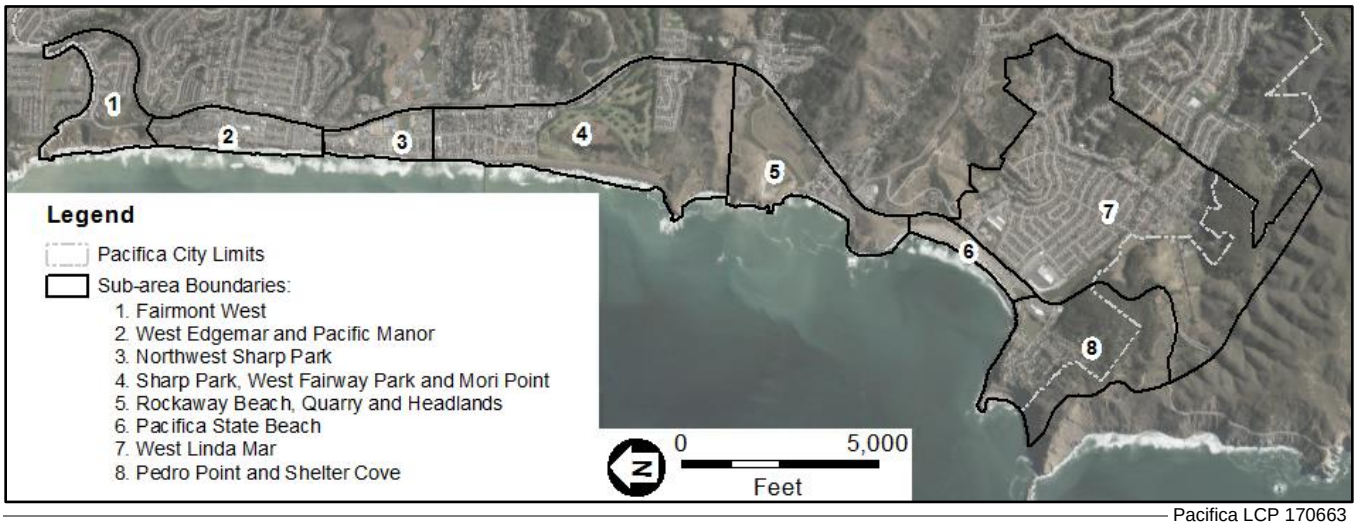
4.1 Sub-area Adaptation Recommendations

Near-term sea-level rise adaptation priorities for each sub-area in Pacifica are presented in the sections below. Sub-areas are shown in Figure 7. These priorities were developed based on existing conditions and existing/near term vulnerabilities for each sub-area, the City's adopted goals for the project that include protecting existing development as well as preserving and enhancing coastal access along Pacifica. While the cost-benefit results indicate that managed retreat/realignment may be a long-term cost effective option in many sub-areas, the immediate costs and impacts to the City's adopted goals would be severe compared to the benefits speculated in the long-term, which makes this option difficult to support and implement in the near-term. Accordingly, the adaptation priorities discussed below can buy time for the City by protecting at-risk assets in the near term and leaving options open for the long term.

The years specified for each adaptation measure are based on when triggers in Table 2 are met under the medium-high risk aversion SLR projection of 6 feet by 2100 and provided only as an example scenario used for the cost-benefit analysis. Real adaptation triggers may be met earlier or later in the future. The City shall monitor erosion, flooding, and sea level rise amount into the future as discussed in Section 3.2 to identify triggers for adaptation measures are met and not define adaptation schedules according to the years provided alone. Many initial actions are required regardless of future SLR due to existing coastal hazard conditions.

Generally, for all lands within the 2050 Pacific Institute erosion hazard zone, utilities, roadways and other public infrastructure should be floodproofed (and allow private owners to do the same), unless other adaptation alternatives are implemented and performing well. The City should incentivize risk reduction (floodproofing etc.) that property owners can invest in with funding or code updates. In addition, the City should consider realigning infrastructure (utilities, roadways) that may be exposed to coastal erosion and flooding to reduce the consequences of under-performance of protection measures (construction and maintenance of armoring structures). Other City-wide strategies that should be employed include siting new development to avoid future hazsards, beach nourishment (subject to future feasibility studies) and flooding accommodation through elevation or other retrofits and/or retreat.

Our adaptation analysis (Chapter 5) presumes that the coastal armoring would be reconstructed about once every 20 years owing to degradation under waves and erosion and also to accommodate greater water levels and breaking waves. The costs are very high and exceed the value of the backshore development, even assuming a constant unit cost for armoring, hence sustainability is indeed questionable. For lower elevation locations, roughly anywhere where the back shore is lower than elevation 30' NAVD, wave overtopping will impact back shore development requiring elevation on piles and or retreat. These thresholds in terms of amounts of sea level rise are listed in Table 2 but generally armoring alone becomes dubious with about 3 feet of SLR.



Pacifica LCP 170663

SOURCE: San Mateo County, City of Pacifica

Figure 7
Pacifica Sub-areas

Fairmont West

The roadway and utilities are at risk after one to two feet of sea-level rise. Some beach width exists for access and other coastal resources, but there is not adequate vertical access to the beach from the bluff top.

Armoring

Due to the undeveloped conditions of the bluffs in this sub-area, the majority of armoring is not required immediately.

- **2030-2040** (~1 ft SLR) – private armoring structures are maintained/upgraded by property owners
- **2040-2050** (~1-2 ft SLR, or bluff toe within 260 feet of infrastructure) – construct armoring to protect public road and sewer line if beach is not nourished and erosion continues.

Beach nourishment

Beach nourishment, while a lower priority for this sub-area compared to other more developed sub-areas in city, nourishment could take place at a later date with a larger volume of sand. Coarse sand and/or gravel sources are also preferable and would be more cost effective than finer sands due to sediment transport regimes in this sub-area. By constructing sand retention structures along north Pacifica, the efficacy of beach nourishments can be increased.

- **2050-2060** (~2 ft SLR, or bluff toe within 260 feet of infrastructure) – place large (200-300 foot) beach nourishment to buffer against backshore erosion and provide recreation and ecology benefits. Repeat to maintain wide beach as an alternative to coastal armoring structures. Sand retention structures will increase the efficacy of beach nourishment (at an additional cost).

Transfer of Development Credits

Employed under any strategy to allow natural erosion of the open bluffs to help maintain a beach, TDRs can begin immediately.

- **2020+** (immediately) – initiate transfer of development credits at option of property owner, ongoing until all credits are exhausted.

Managed Retreat/Realignment

In absence of armoring or beach nourishment, managed realignment of public infrastructure will be needed during the study timeframe.

- **2060-2070** (~2-4 ft SLR, or bluff toe within 260 feet of infrastructure) – realign Palmetto Ave and sewer pipeline if coastal armoring or beach nourishment is not feasible. Palmetto serves as the primary access route for the Fairmont West neighborhood so a detailed transportation study will be required if managed realignment of Palmetto is considered. A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

West Edgemar and Pacific Manor

Built assets and property are at risk from bluff erosion where un-armored now. Much of the armored areas may be overwhelmed by waves with as little as one foot of sea-level rise, due to scour and structure sloughing, increased

wave loads and overtopping of the structure. Beaches tend to exist in pockets, with armoring impeding lateral access from the degraded vertical access ways.

Armoring

Existing property and infrastructure is at risk to coastal erosion so actions should be taken soon. A public access improvement plan should be included as part of any erosion-specific adaptation strategy.

- **2020-2030** (immediately) – maintain and expand armoring structures to protect public infrastructure. The City is currently proceeding with new armoring along bluffs between Bill Drake Way and Manor Dr. to protect Esplanade Ave. and public utilities.
- **2030-2040** (~1 ft SLR) – property owners may maintain and expand armor on private property

Beach nourishment

Due the potential lead time of establishing a sand source, beach nourishment planning should begin immediately. Coarse sand and/or gravel sources are also preferable and would be more cost effective than finer sands due to sediment transport regimes in this sub-area. By constructing sand retention structures along north Pacifica, the efficacy of beach nourishments can be increased.

- **2020-2050** (immediately) – nourish beach to reduce armoring maintenance requirements and provide recreation and ecology benefits. Sand retention structures will increase the efficacy of beach nourishment (at an additional cost).

Managed Retreat/Realignment

In absence of any armoring or beach nourishment, managed relocation of private property by private property owners (optional) and public infrastructure will be needed before 2100.

- Timing is dependent on presence and condition of coastal armoring structures, location of built assets relative to the bluff edge, and willingness of property owners to engage in managed retreat, and availability of public funding for relocation of public infrastructure. Managed retreat in this sub-area could affect Highway 1 by 2100 assuming the med-high SLR scenario, the City shall coordinate with Caltrans while developing any plans for managed retreat. A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

Northwest Sharp Park

The backshore is armored but may be overwhelmed by waves with as little as one foot of sea-level rise, due to scour and structure sloughing, increased wave loads and overtopping of the structure. Beaches tend to exist ephemerally in pockets, with armoring impeding lateral access from the degraded vertical access ways.

Armoring

Existing property and infrastructure is at risk to coastal erosion so actions should be taken soon. A public access improvement plan should be included as part of any erosion-specific adaptation strategy.

- **2020-2030** (immediately) – maintain and expand armoring structures to protect public infrastructure.
- **2030-2040** (~1 ft SLR) – property owners may maintain and expand armor on private property, armor upgrades to limit wave overtopping will also be needed without beach nourishment.

Beach nourishment

Due the potential lead time of establishing a sand source, beach nourishment planning should begin immediately. Coarse sand and/or gravel sources are also preferable and would be more cost effective than finer sands due to sediment transport regimes in this sub-area. By constructing sand retention structures along north Pacifica, the efficacy of beach nourishments can be increased.

- **2020-2050** (immediately) – nourish beach to reduce armoring maintenance requirements, reduce wave run-up and overtopping and provide recreation and ecology benefits. Sand retention structures will increase the efficacy of beach nourishment (at an additional cost).

Flood Protection

- **2030-2040** (~1 ft SLR) – enable property owners to manage wave overtopping with structural improvements or raising structures.

Managed Retreat/Realignment

In absence of any beach nourishment, managed relocation of private property by private property owners (optional) and realignment of public infrastructure will be needed before 2050 even if coastal armoring structures are maintained in their current elevations (up to the edge of bluff).

- **2030-2050** (1-2 ft SLR) Timing is dependent on location of built assets relative to the bluff edge and implementation/efficacy of protection strategies. Private structures are at the threshold for significant damage from wave run-up and overtopping of the armored bluff face. Managed retreat in this sub-area could affect Highway 1 by 2100 assuming the med-high SLR scenario, the City shall coordinate with Caltrans while developing any plans for managed retreat. A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

Sharp Park, West Fairway Park and Mori Point

Most of the area is armored. The northern section between the pier and Paloma is subject to frequent wave overtopping and damages to homes have occurred: Therefore, we believe this area is on the threshold of further damages and establish threshold of one foot of sea-level rise. Beaches are narrow and ephemeral, with armoring impeding lateral access from the degraded vertical access ways.

South of the pier, the beach tends to be more persistent and wider, and there is usually an accessible beach in the vicinity of the end of Clarendon, with reliable vertical and lateral beach access. The sea-level rise threshold for this area is estimated to be 1 to 2 feet. South of Clarendon to Mori Point, the beach persists although wave run-up can reach the levee and there is some armoring. The sea-level rise threshold for this area is estimated to be about 2 to 3 feet.

This sub-area is exposed to flooding due to rainfall runoff which cannot flow directly to the ocean. The Clarendon area is exposed to flooding now, and the West Fairway development may be exposed to flooding if sea-level and ground water levels rise over 3 feet.

Armoring

Existing property and infrastructure is at risk to coastal erosion so actions should be taken soon. San Francisco will maintain the SPGC berm and armoring in accordance with Coastal Development Permit (CDP 2-17-0702) to

prevent ocean-driven flooding in the sub-area. Adaptation planning undertaken for the SPGC, which is under the authority of San Francisco, should be coordinated with the City of Pacifica to ensure the consistency with Pacifica's adopted policies and community values. A public access improvement plan should be included as part of any erosion-specific adaptation strategy.

- **2020-2030** (immediately) – Maintain and expand armoring structures to protect public infrastructure. Includes expanding the south Beach Boulevard seawall to the SPGC berm. The City is currently planning to update the Beach Boulevard retaining wall north of the pier to a seawall. Wave overtopping of both north and south Beach Boulevard structures is currently an issue.
- **2030-2040** (~1 ft SLR) – Armor upgrades to limit wave overtopping will be needed without beach nourishment.
- **2050** (~2 feet SLR) – Wave overtopping may become unmanageable with 2-3 feet of SLR and further actions such as elevating structures may be needed. If seawalls are not raised and/or SLR exceeds 2-3 feet, further actions may be needed such as utility relocation and further reducing the usage of Beach Boulevard and closing it during storm events.

Beach nourishment

Due to the potential lead time of establishing a sand source, beach nourishment planning should begin immediately. Coarse sand and/or gravel sources are also preferable and would be more cost effective than finer sands due to sediment transport regimes in this sub-area. By constructing sand retention structures along north Pacifica, the efficacy of beach nourishments can be increased.

- **2020-2050** (immediately) – Nourish beach to reduce armoring maintenance requirements and provide recreation and ecology benefits. Sand retention structures will increase the efficacy of beach nourishment (at an additional cost).
- **Ongoing –** San Francisco should nourish the beach in front of the SPGC berm as needed to maintain the current beach width.

Flood Protection

Flood protection is already needed for homes and businesses along Clarendon Avenue during rain events and will need to be improved around the SPGC to manage flooding of Laguna Salada regardless of the condition of the SPGC berm. San Francisco is expected to maintain the SPGC berm which protects the Sharp Park neighborhood from the coastal flooding source, but existing pumping facilities in SPGC are not designed to mitigate flooding in and around the course during significant rainfall events (i.e., a portable pump station is currently used to manage rainfall-runoff flooding along Clarendon Avenue). The priority recommendations for flood protection surrounding SPGC are therefore based on the rainfall (fluvial) flood source, but would also be effective during a major coastal storm if the SPGC berm is overtopped or breached. Flooding due to wave run-up landward of Beach Boulevard seawalls is already an issue. If the seawalls are not properly maintained and upgraded in the future to accommodate higher sea-levels, private landowners will need other mechanisms to adapt to flood risks such as raising homes.

- **2020-2030** (immediately) – Construct Clarendon Ave stormwater basin, pump station, and interior SPGC levee to protect homes and businesses from existing fluvial storm flood hazard zone.
- **2060-2070** (~3 ft SLR) – Construct West Fairway Park stormwater basin, pump station, and interior SPGC levee to protect western homes from future coastal/fluvial flood hazard zone.

Managed Retreat/Realignment

In absence of any armoring or beach nourishment, managed relocation of private property by private property owners (optional) and realignment of public infrastructure will be needed by 2050.

- Timing is dependent on presence and condition of coastal armoring structures, location of built assets relative to the bluff edge and or flood hazard zone, willingness of property owners to engage in managed retreat, and availability of public funding for relocation of public infrastructure. A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

Rockaway Beach, Quarry and Headlands

The armoring near the end of Rockaway Blvd is overtopped by waves under present conditions, with occasional damages. Hence, we estimate that this area has very little capacity and will have a noticeably degraded condition with as little as one foot of sea-level rise. There is no beach in this area, with waves crashing directly into the armor structures. The shore becomes more accessible with distance northward but is also given a threshold of 1 foot of sea-level rise. The south end of rockaway is unarmored, has a persistent beach and the backshore is estimated to will be impacted with about 2 feet of sea-level rise. Recommendations for timing of specific adaptations measures are presented below.

Armoring

A shoreline access plan will be needed with armoring strategies by 2050.

- **2020 to 2030** (immediately) – upgrade existing public armoring structures along north cove
- **2050 to 2060** (~2-3 ft SLR, or when backshore is within 100 feet of Hwy 1 embankment) – install revetment for Highway 1 embankment

Beach nourishment

Due to the cove configuration of Rockaway Beach, we consider it a great candidate for beach nourishment. We recommend that Rockaway is used as a pilot project for beach nourishment in Pacifica. In the pilot project, the City will go through the overall process for beach nourishment and identify available sources in the region and corresponding sediment characteristics and costs, evaluate the performance of the nourishment and enable the City to reevaluate nourishment along northern Pacifica and perform a more thorough assessment for a larger scale nourishment project.

- **2020-2030** (immediately) – plan and implement beach nourishment of entire cove. Rockaway is a favorable location with best potential for testing nourishment as an adaptation strategy. By nourishing the beach, maintenance needs for backshore armoring are reduced.

Transfer of Development Credits

- **2020+** (immediately) – TDRs could also be implemented for private property at the Quarry and Headlands.

Development Setbacks

- **2020-2030** (immediately) – Establish set-back requirements for new development in the Quarry and Headlands areas. The Pacific Institute erosion hazard for 2100 can serve as a reasonable approximate for long term erosion with a safety buffer for erosion and geological uncertainty. Future setbacks should be determined

based on the best available sea-level rise science and subject to geotechnical, seismic and terrestrial erosion analyses.

Flood Protection

- **2030** (immediately) – Improve coastal armoring to reduce wave overtopping. Beach nourishment can be effective at reducing wave run-up on the backshore and overtopping.

Managed Retreat/Realignment

In absence of any armoring or beach nourishment, managed relocation of private property by private property owners (optional) and public infrastructure will be needed before 2100.

- **2060-2100** – Remove/relocate south cove public parking and restrooms when impacted by erosion.
- Timing of other asset removal/relocation is dependent on presence and condition of coastal armoring structures, location of built assets relative to the bluff edge and or flood hazard zone, willingness of private property owners, and availability for public funding for relocation of public infrastructure. A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

West Linda Mar & Pacifica State Beach

As described in Chapter 5 of this document, adaptation recommendations for Pacifica State Beach and West Linda Mar are presented together because actions taken at Pacifica State Beach influence coastal hazard exposure to West Linda Mar. Much of the Pacifica State Beach sub-area has a persistent, relatively wide beach with bulkheads in the south transitioning to dune fields in the north. Hence, this shore and roadway can withstand at least 2 feet of sea-level rise. However, the West Linda Mar sub-area east of Highway 1 has a low elevation and is subject to flooding from high creek flows and rising groundwater associated with sea-level rise. The Pacifica State Beach/Linda Mar planning area also contains one major shopping center and several smaller shopping areas including grocery stores which are vital to the community. If these shopping areas are impeded by flooding or other coastal hazards for a significant time, there could be significant losses to the Pacifica community, both economic and non-economic, beyond those estimated in this study. Therefore, adaptation planning must address these issues. As flooding issues become more chronic, the viability of these centers could be in jeopardy.

Armoring

Due to the existing beach widths in Pacifica State Beach and existing coastal armoring, armoring actions are not a near term priority. However, conditions of existing armoring at the Anza pump station should be monitored to ensure protection in the near term.

- **2050-2060** (~2 ft SLR or 100 foot offset from shoreline to assets) – build/upgrade armoring along parking lot and construct new armor at south parking lot/Linda Mar pump station.
- **2050** – City to engage with Caltrans to protect Highway 1, to be constructed by 2100.

Beach nourishment

Nourishment of Pacifica State Beach should be initiated using the shoreline-backshore offset for the main parking lot. Beach nourishment projects should include dune restoration to maintain ecology, protect the sewer force main

that is buried in existing dune field north of the main parking lot/Anza pump station as well as provide flooding protection of Highway 1 and West Linda Mar.

- **2050-2060** (~2 ft SLR or 100 foot offset from dune toe to Highway 1) – nourish beach and restore dunes as needed to maintain 100-foot buffer seaward of the sewer force main and/or Highway 1. Repeat nourishments as needed.

Flood protection

Pump stations at Pacifica State Beach are vulnerable to wave run-up and require floodproofing in place. West Linda Mar neighborhood is also vulnerable to flooding from San Pedro Creek based on existing FEMA hazard maps and will become more vulnerable as SLR increases the flood levels in the creek via its ocean boundary condition.

- **2020-2030** (immediately) – construct floodwall along commercial property to manage flooding from San Pedro Creek under existing conditions with SLR allowance. Future flood studies that include climate-driven changes in precipitation should inform any floodwall design. Alternatively, flooding could be accommodated in West Linda Mar by raising structures on piles or constructing floats for structures.
- **2020-2030** (immediately) – floodproof Anza pump station (stormwater) to mitigate existing coastal storm flooding vulnerabilities to wave run-up.
- **2050-2060** (~2 feet SLR) – floodproof Linda Mar pump stations (sewer and stormwater) to mitigate future coastal storm flooding vulnerabilities to wave run-up. Beach nourishment could be effective in delaying the need to floodproof Linda Mar pump stations. Reevaluate flooding protection and risks in West Linda Mar as the future conditions provide more context.

Groundwater Management

West Linda Mar neighborhood was constructed in a former lagoon and experiences groundwater issues in the lowest areas, which is evident by existing wetlands around the skate park and homes furthest west. Groundwater in low areas near the ocean are directly influenced by the sea-level, and thus groundwater issues will increase with SLR.

- **2030-2050** (~0-2 feet SLR) – begin groundwater monitoring to determine needs for dewatering wells in the lowest portions of the West Linda Mar neighborhood. Because the area already has wetlands close to backyards, the tidal inundation hazard zones used to estimate groundwater daylighting impacts may underestimate the risk. Even a small rain event could cause significant flooding in the neighborhood if groundwater levels are close to the ground surface.

Managed Retreat/Realignment

In absence of any armoring or beach nourishment, managed relocation of private property by private property owners (optional) and public infrastructure in Pacifica State Beach will be needed before 2050.

- Timing is dependent on presence and condition of coastal armoring structures, location of built assets relative to the bluff edge and or flood hazard zone, willingness of property owners, and availability of public funding for relocation of public infrastructure. Managed retreat in this sub-area could affect Highway 1 by 2100 assuming the med-high SLR scenario, the City shall coordinate with Caltrans while developing any plans for managed retreat. A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

- **2050** (2 feet SLR) – Revaluate ongoing protection/accommodation strategies. If groundwater and SLR issues warrant and or other strategies are ineffective, explore other adaptation strategies.

Pedro Point and Shelter Cove

Potential bluff erosion may reach the most seaward bluff top properties at Pedro Point by about 2050 with 1 to 2 feet of sea-level rise. Waterfront properties in this sub-area that are southwest of San Pedro Creek and within Shelter Cove are exposed to storm wave run-up under existing conditions.

Armoring

Private property is mostly armored along the water (boat docks/homes) but require upgrades by property owners, while bluff top properties have limited ability to prevent bluff toe erosion due to parcel limits.

- **2020-2030** (immediately) – enable property owners to update coastal armor structures to more resilient designs
- **2050-2100** (when bluff erosion infringes on property) – private property is vulnerable to bluff erosion, but implementing bluff toe armoring would be complicated due to land ownership. Develop a hazard mitigation program: The program would be subject to available funding and voluntary action by property owners.

Beach nourishment

Beach nourishment implemented for Pacifica State Beach will have less effect on private oceanfront properties in this sub-area due to the orientation of the shoreline but could provide benefits to some properties closer to San Pedro Creek. Details are discussed for Pacifica State Beach above.

Flood protection

Private oceanfront properties are within the existing FEMA wave run-up hazard zone. Vulnerability to wave run-up during storms will increase with SLR with or without upgrading coastal armoring structures.

- **2030-2040** (~0-1 feet SLR) – amend zoning and policy documents to allow private property owners to raise homes and other structures above wave run-up hazard.

Transfer of Development Credits

- **2020+** TDRs could be implemented on undeveloped parcels to limit future vulnerability to bluff erosion.

Managed Retreat/Realignment

In absence of any armoring to protect of oceanfront and blufftop properties against coastal erosion, managed relocation of private property by private property owners (optional) and public infrastructure will be needed by 2050.

- Timing dependent on presence and condition of coastal armoring structures, location of built assets relative to the bluff edge and or flood hazard zone, willingness of property owners, and availability of public funding for relocation of public infrastructure. Triggers for bluff and dune toe offsets provided in Table 2 should be considered in planning for retreat, and . A managed retreat alternative will require significant lead time for both public and private property, so planning and feasibility should be pursued as soon as possible.

4.2 Potential Funding Sources

As indicated in the cost-benefit analysis in Section 4.3, adapting for sea-level rise will be costly. This section provides a brief overview of some of the existing state and federal funding sources as well as potential sources for local revenue streams to implement future coastal erosion and flooding mitigation projects for public property and infrastructure in Pacifica. Private property owners would be responsible for funding coastal erosion and flooding mitigation projects protecting their property, but the City can play a role in assisting private property owners to identify potential grant funding or other methods to fund adaptation.

In 2002, the California Department of Boating and Waterways (now Division of Boating and Waterways [CDBW] within State Parks) and the State Coastal Conservancy (SCC) estimated the cost[8] to protect and restore California's beaches. They found that:

> The State of California needs to invest $120 million in one-time beach nourishment costs and $27 million in annual beach maintenance costs. These projects would directly replenish 24 miles of heavily-used public beaches and collaterally benefit more than twice that length due to alongshore sand transport. Through cost-sharing partnerships with the U.S. Army Corps of Engineers, federal funding for these shoreline projects could reduce the state's burden to $42 million (65% reduction) and $13.5 million (50% reduction) for restoration and maintenance costs, respectively (CDBW and SCC 2002, p. xvii).

This summary of known options is provided as an initial overview for review by community and agency managers who may choose to undertake projects. Further research would be needed to determine applicability of a potential source for a given project and the optimum mixture of revenue streams and funding sources. Successful implementation of the Adaptation Plan may require a combination of local, state, and federal funding sources and the coordination of applicable agencies to develop funding plans further. The relative contribution of each source will reflect the prevailing political climate and the state of the economy and budgetary constraints, priorities, and opportunities working within each individual funding and revenue source.

At this time, the most promising potential funding sources include Geologic Hazard Abatement District assessments, the CDBW Public Beach Restoration Program, the USACE Continuing Authorities Program, and increasing the transient occupancy and local sales taxes (listed in Table 4). Further exploration of these potential sources is recommended ahead of the need to complete an adaptation project.

8 Note that costs estimated in 2002 will be larger today because of inflation. For example, assuming environmental conditions are static (for the purposes of analysis) total one-time beach nourishment costs have increased from $120 million in 2002 to approximately $156 million in 2013.

Table 4: Potential funding sources and measures for sea-level rise adaptation projects.

	Top Funding Source or Revenue Measure (Increase in)	Feasibility/Factors to Consider
1	Geologic Hazard Abatement Districts	• Used elsewhere for coastal erosion projects • Formation must be abandoned if more than 50% of property owners object • Funds can be raised through supplemental property assessments collected on property tax bills
2	Prop 1A Grants	• Could fund habitat restoration projects, e.g. natural armoring approaches including dune and wetland restoration.
3	Hazard Mitigation Grants	• FEMA funding to mitigate existing hazards, routed through CA OES to City construction. • Funding could be available to address disasters caused by an erosion event. • City's Hazard Mitigation Plan can be used to facilitate access to Hazard Mitigation funds.
4	California Division of Boating and Waterways Public Beach Restoration Program	• Little competition for funding in Northern California, • Funding inconsistent • Each project requires budgeting
5	U.S. Army Corps of Engineers Continuing Authorities Program	• Continued funding subject to political climate • Only certain authority sections would apply to Region
6	Transient Occupancy Tax	• Funds can be dedicated to a particular use (specialty taxes) or for general use, with different voter approval thresholds. • Consistent and substantial funds • More politically feasible, as fees are generally placed on nonresidents • Existing tax rates would have to be increased to accommodate the funding requirements
7	Sales Tax	• Consistent and substantial funds • 2/3 vote approval required for funds to be dedicated to coastal protection as a specialty tax • Existing tax rates would have to be increased to accommodate the funding requirements
8	Adaptation Planning Grants (e.g. Coastal Commission, Coastal Conservancy, Ocean Protection Council, Caltrans, NOAA)	• State and Federal funding options vary over time

4.3 Future Adaptation Aspirations

This section provides a summary of future efforts that could be undertaken by the City to improve coastal access, recreation and ecology, as well as engage regionally as the City plans and implements strategies to adapt to sea-level rise.

Shoreline and Beach Access Plan

There is limited existing vertical and horizontal access along north Pacifica from Esplanade Ave to Clarendon Ave. Similarly, coastal access is impaired at northern Rockaway Beach. As such, improvements to public access should be considered as part of any adaptation strategy as the Coastal Act requires protection of public access. Different shoreline conditions will require different approaches to maintain vertical (from upland to beach) or lateral access (along the beach and bluff top).

Coastal Natural Resources Management and Enhancement Plan

Coastal zone ecological goals could be established for City of Pacifica. The City has lost considerable beach area due to erosion and armoring structures. We recommend that a City-wide plan be developed to maintain and potentially enhance beaches, dunes and wetlands via public and private actions that would help to guide individual projects that must comply with the Coastal Act which requires protection of these natural resources. Natural infrastructure approaches to hazard mitigation should also be considered.

Regional Collaboration

The City should engage with the following entities to ensure compatibility other regional adaptation planning and implementation efforts:

- Caltrans – a Highway 1 transportation corridor adaptation plan would directly influence the City's vulnerabilities.
- San Mateo County – The City should coordinate with the County on SeaChange and any other adaptation planning efforts.
- US Army Corps of Engineers – is directly involved in beach nourishment and armoring projects in the region, and would be a valuable partner for implementing strategies (funding and/or assistance with sourcing sand for nourishment).
- City of Daly City – border with Pacifica and proximity of assets from each city.
- City and County of San Francisco – Adaptation considered at Sharp Park Golf Course should be coordinated with the City of Pacifica to ensure consistency with community values and adopted policies.
- CA Coastal Commission – most activities related to SLR adaptation will occur in or near jurisdiction
- CA Coastal Conservancy – an important partner in habitat and access related projects along the coast
- Golden Gate National Recreational Area (National Parks Service) – manages lands within Pacifica.

CHAPTER 5
Adaptation Alternatives Analysis

This chapter presents the adaptation alternatives analysis conducted to inform the priority adaptation recommendations in Chapter 4 as well as the policy updates that will be developed in the next task of this project. To start the conversation on adaptation to address coastal erosion, flooding and sea-level rise, ESA prepared a memo, Pacifica Sea Level Rise Adaptation Background and Example Strategies (2018c). The memo includes a summary of Pacifica's recent experience adapting to coastal hazards, background information on the range of adaptation measures that may be appropriate in Pacifica, as well as example strategies for each of the City planning sub-areas. The public and Community Workgroup convened on April 26, 2018 to discuss the memo, and provide comments and input to the City and consultants.

Considering feedback from the public and workgroups on the Adaptation Background and Example Strategies memo and engineering feasibility, ESA coordinated with the City to develop a selection of alternative adaptation alternative strategies for each sub-area that address the coastal flooding and erosion vulnerabilities identified in the Vulnerability Assessment. These alternative strategies were discussed with the public and workgroup members on May 31, 2018 and discussed at a public workshop on June 23, 2018.

Once the adaptation alternatives were confirmed by the City, the ESA team modeled changes to hazards associated with each adaptation alternative, estimated the cost of implementing each adaptation measure included in the alternatives, and analyzed the changes in impacts to coastal hazards resulting from each adaptation alternative. A cost benefit analysis was then conducted using the aforementioned data and is presented below.

The adaptation alternatives analysis and cost-benefit results below are a comparison of three approaches to SLR adaptation for one example SLR scenario, the CalNRA & OPC (2018) Med-high SLR scenario of 6 ft SLR by 2100. This scenario is recommended by the Coastal Commission for planning-level studies to best understand the potential worst case so that the City can prepare, for example by pursuing funding mechanisms as needed. Thus, the timing (i.e. triggering) of individual adaptation measures in the three alternatives in the analysis are based on the Med-High SLR scenario but this timing is not meant to direct the timing of actions by the City or private landowners. The actual timing of adaptation actions to be taken by the City and private landowners will depend on the actual SLR and erosion that occurs in the future, as described in Section 4.

5.1 Adaptation Measures

The alternative adaptation strategies (an approach consisting of one or more actions or "measures") that are analyzed in this Plan employ various adaptation measures (specific actions) originally presented in the memo on Pacifica Sea Level Rise Adaptation Background and Example Strategies (ESA 2018c). Most strategies are hybrids that include more than one measure that fall into the protect, accommodate, or retreat categories specified in the Coastal Commission guidance. All measures that are a part of any sub-area adaptation alternative are described below.

Setbacks for Development / Hazard Avoidance

Use of setbacks is a long-used technique in California, implemented at a local policy level and by the state Coastal Commission, which requires new development to be located so that it can be safe from erosion and slope failure for some identified time period – typically the expected economic life of the development. Eventually the development can be expected to be at risk from erosion. In current practice, new structures would be required to be removed or relocated (not protected in place) if they ever become unsafe due to sea level rise and/or erosion. Setbacks are relevant for all areas with private and public property and most relevant for any coastal parcel potentially facing erosion and flood hazards being developed or redeveloped.

The cost of development setbacks is relatively minor compared to some of the other land use planning tools. The largest cost is likely to be used for obtaining the site specific erosion rate and/or vegetation line data necessary to calculate the setback distance. This cost would be borne by a private property owner/developer. A major benefit of development setbacks, in addition to keeping lives and property safe, is that they maintain natural shoreline dynamics, including preserving beaches for recreational and ecological value.

Managed Retreat or Relocation of Buildings and Facilities

Managed Retreat is a broad strategy that can encompass the use of all erosion mitigation measures while allowing long term shore recession over time, requiring the removal or relocation of structures and infrastructure, realignment of roads, etc. Often, managed retreat is really "retreat and then manage" over a period of decades until erosion hazards become significant again. ESA has completed various projects in the past that implemented retreat of public oceanfront development to restore beaches and shoreline habitat[9,10,11,12]. The cost of these managed retreat projects ranged from about $4.5 million to $45 million per acre of beach: The lower value is associated with built assets that are public and limited (e.g. parking lot) while the higher value entails high-value utilities. A more recent re-analysis of these values results in $2,000 to $20,000 per foot of shore and $1 Million to $10 Million per acre of beach for low asset density backshores.

Managed retreat is often assumed incorrectly to mean essentially "allow erosion" and remove built assets. However, Managed retreat is intended to realign assets landward with the migrating shore, and can include shore protection structures (e.g. seawalls), sand placement and accommodation such as raising buildings on pile-foundations to "buy time" for funding, etc. For example, the Ocean Beach Master Plan (SPUR et al. 2012) is a managed retreat plan that includes armoring to protect wastewater infrastructure through 2050, with a range of possible actions after that (removal, reconstruction landward, enhance armoring). Infrastructure functions are often maintained through construction of replacements farther landward (e.g. the new parking lot at Pacifica State

[9] Philip Williams & Associates, Ltd. (PWA) PACIFICA STATE BEACH RESTORATION PHASE 1 Prepared for RRM Design Group and City of Pacifica, January 16, 2002, Amended May 22, 2002, PWA Ref. # 1547

[10] Philip Williams & Associates, Ltd. (PWA) SURFER'S POINT MANAGED SHORELINE RETREAT & ACCESS RESTORATION Preliminary Design Prepared for RRM Design Group and the City of Ventura, August 2, 2005 PWA Ref. # 1708.

[11] ESA, 2015. ESA,SPUR, Moffatt & Nichol, McMillen Jacobs Associates, AGS, Inc., Coastal Protection Measures & Management Strategy for South Ocean Beach, Ocean Beach Master Plan: Coastal Management Framework, Prepared for the CCSF Public Utilities Commission. Project D120925.00

[12] PWA 2008. Goleta Beach County Park, Park Reconfiguration Alternative, Prepared for The Coastal Fund at UCSB, Surfrider Foundation – Santa Barbara Chapter, Environmental Defense Center, Prepared by Philip Williams & Associates, Ltd. November 24, 2008, PWA REF. #1940.00

Beach). Allowing erosion is a "low-management" level or retreat, similar to the recent retreat in Pacifica whereas managed retreat implies planning and avoiding crises and emergencies, and reducing costs.

With regard to private properties, managed retreat is considered an *optional* adaptation measure. A recent example of optional retreat was 528 Esplanade where the property owner approached to City to voluntarily donate the land for public purpose. It is City staff's understanding is that this provided tax benefits to the owner.

Transfer of Development Rights

Transferable Development Rights (TDR) programs allow the transfer of the development rights from one parcel to another parcel. These programs are tools used by land use planners to direct development away from certain sensitive areas (sender sites) and into areas that can better accommodate it (receiver sites). TDRs could be applied where undeveloped sensitive or hazardous parcels exist (to transfer potential development from) and desirable areas to transfer potential development to are available. TDR programs are widespread throughout the country and vary based on local land use planning priorities and needs. Pacifica's General Plan and Zoning Ordinance identifies sender sites (from which a development right is voluntarily transferred by the owner) and receiver sites (to which a development right is added). The owner of a sender site can sell a TDR to the owner of a receiver site. The seller typically retains ownership of the "sending" property, but relinquishes the right to develop it via a recorded property restriction, while the buyer is able to intensify development on the receiver site more than would otherwise be permitted under existing zoning. Sending sites may be sensitive land areas such as endangered species or wetlands habitat, or areas prone to coastal hazards such as erosion or landslides. Owners of sender sites receive monetary compensation from the sale of the TDR and in the form of potentially smaller property taxes, while owners of receiver sites have assurance of future development rights on their site, sometimes at a higher density than may be allowed by the base zoning. TDR programs may provide greater certainty over traditional zoning efforts because of the specificity of amounts and locations of future development. Other considerations could include access to services, water limitations, agricultural conversion, staff time and zoning changes. As with other mechanisms to avoid hazardous shoreline areas, TDR programs may result in significant public benefits in the form of beach preservation.

Beach and/or Dune Nourishment

Beach nourishment refers to placement of sand to widen a beach. The beach then provides flood and erosion protection to the backshore. However, it is generally assumed that the nourished beach will diminish with time, requiring "re-nourishment". As sea level rises, the frequency of required nourishment increases because the rate of sand addition to build the beach up increases. Potential problems with beach nourishment include the construction impact to people and beach ecology, and changes to shore conditions that may result from difficulty in finding sand with the desired grain sizes. The success of the nourishment depends on the volume of nourished material, the grain size, and the proximity or use of sand retention structures. Dune nourishment would include placement of sand, graded and planted to form back beach dunes. Dune nourishment is recognized as a natural way of mitigating backshore erosion as well as maintaining a wider beach through sacrificial erosion of the dunes (sand replenishes the beach as waves erode the dunes, slowing the overall shoreline erosion). A variant includes placement of cobble (rounded rock) which is often naturally present as a lag deposit[13] below California beaches.

[13] Lag deposit refers to coarser sediments that accumulate over time at lower elevations during periods of eroded beaches, and subsequently covered by sand after the beaches recover.

Considered as an adaptation measure in Southern Monterey Bay (ESA PWA, 2012), Opportunistic Beach Nourishment uses sand that is extracted from a flood channel, debris basin, navigation channel, harbor area, a by-product of construction or other source, where the main reason for extracting the sand is not to use it for beach nourishment. Costs associated with Opportunistic sand can be low, especially when providing a cost savings to the entity providing the sediment source by avoiding or reducing transportation and disposal costs. Beach Nourishment may be a viable short term solution in areas with low erosion rates, but the long-term effectiveness of this measure for reducing erosion is doubtful.

Seawalls and Revetments

Seawalls are vertical structures along a beach or bluff, used to protect structures from wave action as a course of last resort. A seawall works by absorbing or dissipating wave energy. They may be either gravity- or pile-supported structures. Seawalls can have a variety of face shapes. Seawalls and bulkheads are normally constructed of stone or concrete, however other materials can be used. Current seawall projects usually require design elements that allow the structure to resemble the natural environment in that area, in order to blend in with the existing geologic conditions. Effectiveness is dependent on the design and location of the seawall and other factors such as whether the ends of a structure are connected to adjacent stable structures or bluffs, etc.
Revetments provide protection to existing slopes affronting a threatened structure, and are constructed of a sturdy material such as stone. Similar in purpose to a seawall, revetments work by absorbing or dissipating wave energy. They are made up of: an armor layer--either stone or concrete rubble 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 toe--which adds stability at the bottom of the structure. Revetments are the most common coastal protection structure along the shore of Pacifica. In comparison to seawalls, revetments tend to have greater visual impacts and require a larger footprint, which leads to a larger placement loss of beach area and impacts to public access along the shore. Both seawalls and revetments lead to the "passive erosion" loss of the beach if the shoreline is eroding yet the back beach cannot retreat. This impact will be accelerated by sea level rise. These structures may also introduce active erosion effects which accelerate beach loss when beach width narrows and wave run-up frequently reaches the structure. As the beach disappears and sea level rises, wave run-up and overtopping will also worsen over the structure as the waves begin to discharge near or on the structure, which will require more frequent maintenance or reconstruction. Both seawalls and revetments have a high construction cost (ESA PWA 2012), and high cost to public and private beach resources.

Sand Retention Structures

These large coastal engineering structures are often used in conjunction with large beach nourishment efforts to retain sand. The retention structures essentially slow the rate of sand transport away from the nourishment area, thereby slowing the rate of beach width reduction. These solutions have a high construction cost.

Offshore artificial reefs consist of fill in the surf zone that reduces the wave power reaching shore and changes the pattern of sand transport, thereby conceptually reducing transport of sand from the nourished area. Artificial reefs installed to act as submerged breakwaters have received increased attention in recent years as a means of shore stabilization and erosion control, primarily due to their low aesthetic impact and enhanced water exchange relative to traditional emergent breakwaters (Vicinanza et al., 2009) and the potential to enhance local surfing conditions (Ranasinghe & Turner, 2006). They however can pose a navigation hazard. **Artificial headlands with stems** are proposed as a large scale coastal engineering solution to manage erosion and maintain beaches along

Northern Pacifica. This type of sand retention structure scheme is comprised of a series of engineered rock headland units with submerged reefs and a jetty (or stem) connecting the headlands to the backshore (different than smaller structures known as groins). By segmenting the coast into smaller cells, the system would aid in maintaining a wider beach for a longer period after beach nourishments, with the widest beach located updrift of each unit such has formed north of Mori Point. This concept is shown in Figure 8 below.

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SOURCE: ESA

Figure 8

Artificial headlands concept for north Pacifica (nourished beach not shown)

Traditional and Horizontal Levees

Levees have been the standard practice for flood protection in riverine and estuarine environments. Where constrained by infrastructure or commercial/residential structures, raising existing levees may be an effective adaptation strategy, but the risk to assets behind levees and maintenance costs may increase as sea level rises. Levees are typically constructed of compacted earth fill and can be susceptible to erosion if exposed to wave action. Small levees are proposed to mitigate flood source of Laguna Salada (from either coastal or riverine flooding) for adjacent Sharp Park and West Fairway Park neighborhoods.

The horizontal levee (ecotone levee) is a barrier to coastal storm surge that combines the function of a linear flood protective device (levee) with the natural flood protection benefits of wetland habitat. Instead of a traditional levee, the horizontal levee is comprised of a levee or other structure set back from the coastline with a wide flat slope between the structure and the water that is vegetated with native wetland vegetation. The flat vegetated slope provides a natural buffer from storm surge and wave action. This concept has been developed for and applied to areas with limited wave energy, such as San Francisco Bay (USACE 2015). The horizontal levee concept could take the form of dune restoration and a setback levee at the Sharp Park Golf Course to provide room for shoreline recession with SLR while improving beach ecology, for example. Like beach nourishment, this type of dune restoration would provide an erosion buffer to the smaller levee behind it but would need to be rebuilt periodically depending on shoreline erosion trends.

Structural Adaptation/Elevation

Structural Adaptation is the modification of the design, construction and placement of structures sited in or near coastal hazardous areas to improve their durability and/or facilitate their eventual removal. This is often done through the elevation of structures or specific site placement. Structural modification entails reconfiguring development to withstand progressively increasing coastal hazards. Examples are pile foundations that support development above projected flood elevations and that allow wave run-up and erosion to progress without damage to structures, and waterproofing or reinforcing for severe events. Structural adaptation can be applied to any parcel or infrastructure although the cost and technical feasibility of an effective modification would be

required. Cost may be high depending on the density of development on the coast. As part of the Climate Ready Southern Monterey project, ESA developed unit cost estimates for elevating structures in both flood zones and in wave impact zones where wave impact results in increased loads on the structure (Table 14).

Elevate / Reconstruct Road

As part of the Climate Ready Southern Monterey project, ESA developed unit cost estimates for elevating roadways with bridges or trestles, as well as cost for reconstruction of a secondary roadway (Table 14). Critical roadways determined at risk in the vulnerability assessment could be improved by a combination of elevation by earth fill and armoring. Roads exposed to wave action on the coast will require heavier armoring in order to be kept in place, while roads that are not exposed to significant wave impacts may be sufficiently armored with a lower cost revetment or combined with a fronting ecotone slope.

5.2 Development of Alternative Adaptation Strategies

The adaptation measures listed in Section 5.1 above were narrowed down from a larger list of adaptation measures presented in Pacifica Sea Level Rise Adaptation Background and Example Strategies (ESA 2018c) that were identified as being potentially suitable for Pacifica. A series of meetings were held with the Community Working Group (CWG) and the Technical Working Group (TWG) to gather input and get feedback on documents posted on the City's Sea-level Rise website. To develop the preferred adaptation strategies, ESA and the City reviewed the potential adaptation measures with respect to each sub-area, and considered the following factors:

- Does the measure protect existing development (where applicable)?
- Does the measure align with community values (City Council goals, Community Work Group and public input received throughout project to date)?
- Compatibility with geographic/morphologic setting (is there space/right conditions for success)?
- Does the measure support and/or improve existing recreational and ecological functions?

Table 5 below lists all adaptation alternatives that were compiled for Pacifica, with measures that are included in one or more sub-area alternatives shown in bold. Pros and Cons are listed for each measure that is also ranked as positive (+), neutral (=) or negative (-) in terms of suitability in each sub-area considering the factors listed above and whether the measure protects existing development (a top priority for the City). Managed retreat (optional strategy for private property) was identified as appropriate for the Fairmont West and Pacifica State Beach sub-areas due to lower density of assets and land ownership, but it is also considered for the other sub-areas at the direction of the Coastal Commission (Appendix B, Technical Working Group meeting on May 31 2018).

Private property owners are responsible for funding the adaptation strategy(ies) used to protect their properties.

Table 5. Adaptation Measure Suitability Matrix

Measures	Pros	Cons	Fairmont West	West Edgemar and Pacific Manor	Northwest Sharp Park	Sharp Park, West Fairway Park and Mori Point	Rockaway Beach, Quarry and Headlands	Pacifica State Beach	West Linda Mar	Pedro Point and Shelter Cove
Setbacks for Development	Avoid hazards, enables natural shoreline, sustains beach	development at risk if erosion is worse than estimated, need open space	+	+	+	+	+	+	-	+
Deed Restrictions and Conservation Easements	Conserves views, natural shoreline and beach,	Needs open space to initiate	=	-	-	-	=	+	-	-
Rolling Easements	Conserves views, natural shoreline and beach,	Complicated once easement reaches development, need open space	+	-	-	-	+	+	-	-
Fee Simple Acquisition	Avoid hazards, enables natural shoreline, sustains beach	Expensive, requires landowner agreement.	=	-	=	-	=	=	=	=
Managed Realignment or Relocation	Avoid hazards, enables natural shoreline, sustains beach	Expensive in developed areas, need place to relocate.	+	-	-	=	=	+	-	-
Transfer of Development Rights	Avoid hazards, enables natural shoreline, sustains beach	Land must be undeveloped	+	-	-	-	+	-	-	-
Beach Nourishment	Habitat and recreational value, buffers against backshore erosion	Limited sand available, high rates needed with SLR.	+	+	+	+	+	+	+	n/a
Dune Restoration / Nourishment	Habitat value, buffers against backshore erosion and flooding	Require space, monitoring	-	-	-	=	-	+	n/a	-
Horizontal Levee (Ecotone Levee)	Habitat value, buffer against erosion and flooding forces	Require space, monitoring	-	-	-	=	-	-	-	-
Structural Adaptation/Elevation	Raise structure above flood hazard zone, limit damages	costly, alters exposure landward of structure, may need to raise again	-	-	+	+	+	+	+	+
Elevate / Reconstruct Road	Reduces flood exposure, uses available space.	May need wider easement to raise on fill, does not address erosion alone.	-	-	=	=	=	+	+	-
Seawalls and Revetments	Familiar/in use, prevents erosion, maintains property in place	Costly construction and maintenance, esp. with sea level rise, loss of beach on eroding shores	+	+	+	+	+	=	+	+
Sand Retention Structures	Helps retain sand, potential recreation and habitat function	costly, not effective without beach, requires maintenance with sea level rise, ocean impacts	+	+	+	+	=	=	n/a	-
Traditional Levee	Prevents flooding	Require space, not suitable for wave action .	-	-	-	+	-	-	=	-

Notes: Bold text indicates measures that were used in adaptation strategies for one or more sub-areas
+ measure is suitable for the sub-area
= measure may be suitable for sub-area
- measure is not suitable for the sub-area
n/a indicates that the measure is not applicable for the sub-area due to existing land uses or ownership, level of development, or geographic conditions

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The alternatives presented for each sub-area in the subsections below and corresponding economic cost-benefit results (Section 4.3) are meant to inform the policies to be developed for the LCP update. Please note that the order of the alternatives listed in the tables below is not listed in any order of preference, they are numbered only to identify analysis results in figures and tables in the report. The alternatives are defined through time to enable the cost-benefit analysis, and are dependent on SLR projections from State guidance. In reality, erosion and sea-level rise will likely not behave as modeled for the alternatives analysis. That said, the adaptation alternatives analysis process and results provide an indication of what may be feasible in the future and illuminates the scale of funding that will be needed to adapt to sea-level rise.

Readers may refer to Appendix C of this report for sea-level rise vulnerability and adaptation overview sheets prepared for each of the sub-areas discussed below. The overview sheets include the following:

- Plan view figure showing the sub-area (included in the sections below)
- Summary table of asset exposures from the Vulnerability Assessment
- Table of the adaptation alternatives analyzed (included in the sections below)
- Results of future beach widths as determined from the shore response modeling
- Results of the economic cost-benefit analysis
- Near-term priority recommendations for sea-level rise adaptation

The following sections describe the adaptation alternatives developed for each sub-area. They are based on community values and concerns, applicability of adaptation measures, vulnerabilities to erosion and flooding, and feedback from the Public, Technical and Community Workgroups and City staff.

Fairmont West

Bluff top assets in the Fairmont West sub-area (shown in Figure 9) are primarily subject to coastal erosion hazards. Due to the high bluffs, SLR adaptation strategies to address flooding are not applicable in this sub-area. To address coastal erosion hazards with SLR while addressing the above values and concerns, proposed adaptation strategies for this area include protection measures such as revetments and beach nourishment, as well as retreat due to the relatively low asset density on the bluffs. Details on alternative adaptation strategies analyzed for this plan are presented in Table 6Table 7 below.

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the Fairmont West sub-area:

- *Tobin's Folly photographic spot*
- *Manmade historic spot (Dollaradio)*
- *GGNRA Mussel Rock trail hiking and dog walking*[1]
- *Parking/trail access*[14]
- *Hang gliding area*[14]

The managed retreat alternative involves relocating the road and sewer infrastructure at a future date. The road (Palmetto Ave) is the main access route for the neighborhood to the rest of Pacifica, so it cannot be removed without an established alternate route (this level of planning is beyond the scope of this study).

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SOURCE: ESA, Pacifica, San Mateo County

Figure 9
Fairmont West Sub-area and existing coastal armor

Table 6. Fairmont West Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Accommodate / Protect Hybrid	Transfer of development rights, Armor	**Now:** Allow erosion to proceed, option to transfer development rights. Maintain Dollaradio and armoring. **Future**: Assumes existing armor is maintained at Dollaradio. Backshore is allowed to erode until need to armor to protect road and utilities.
2 Protect	Armor, Beach nourishment, Sand retention structures, Transfer of development rights	**Now:** Place 100ft wide beach nourishment. Maintain Dollaradio and armoring. Build sand retention structures (part of overall artificial headlands strategy for north Pacifica). **Future:** Place sand: 100ft beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates.
3 Retreat	Managed retreat of infrastructure, transfer of development rights	**Now:** Allow bluff erosion to proceed, maintaining beach area. Assume Dollaradio armoring is maintained. Implement TDR (optional) and hazard avoidance measures in undeveloped parcels. **Future:** relocate road with consideration to maintain access to private property, relocate wastewater main away from erosion hazard.

West Edgemar and Pacific Manor

Bluff top assets in the West Edgemar and Pacific Manor sub-area (shown in Figure 10) are primarily subject to coastal erosion hazards. Due to the high bluffs, SLR adaptation strategies to address flooding are not applicable in this sub-area. To address coastal erosion hazards with SLR while addressing the above values and concerns, proposed adaptation strategies for this area include protection measures such as rock revetments and beach nourishment. The adaptation strategy of retreat was also included at the direction of the CA Coastal Commission (Appendix B). Details on the alternative adaptation strategies analyzed for this plan are presented in Table 7 below.

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the West Edgemar and Pacific Manor sub-area:

- *Trailheads for Milagra Ridge Trail*
- *Bluff/gateway to Pacifica*
- *Economic center*
- *Structures hang over bluffs*
- *Coastal trail loss*
- *TWG input: California State Lands Commission has lease rock revetment adjacent to 528-572 Esplanade Avenue*

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SOURCE: ESA, Pacifica, San Mateo County

Figure 10
West Edgemar and Pacific Manor Sub-area and existing coastal armor

Table 7. West Edgemar and Pacific Manor Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	**Now:** Armor bluffs between Manor Dr and Bill Drake Way and along SF RV Resort. **Future:** Maintain armor as needed to remain effective.
2 Protect	Armor, Beach nourishment, Sand retention structures	**Now:** Place 100ft wide beach nourishment. Maintain armoring and build armor between Manor Dr and Bill Drake Way and SF RV Resort. Build sand retention structures (part of overall artificial headlands strategy for north Pacifica). **Future:** Place sand: 100ft beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates.
3 Retreat	Managed removal/ relocation of assets	**Now:** Option to private property owners to remove or abandon existing armoring structures protecting property once it is damaged or no longer effective and to allow erosion. **Future:** Purchase property when buildings at risk, Remove or relocate public structures and infrastructure when at risk as erosion progresses.

Northwest Sharp Park

High bluff top assets in the Northwest Sharp Park sub-area (Figure 11) are primarily subject to coastal erosion hazards. Due to the high bluffs, SLR adaptation strategies to address flooding are not applicable in this sub-area. Alternative adaptation strategies for this sub-area include protection measures such as revetments and beach nourishment. The adaptation strategy of retreat was also included at the direction of the CA Coastal Commission (Appendix B). Details on the alternative adaptation strategies analyzed for this plan are presented in Table 8 below.

Community values and concerns received in the draft Vulnerability Assessment public engagement meetings for the Northwest Sharp Park sub-area were minimal and more focus was given to the neighboring sub-area to the south.

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SOURCE: ESA, Pacifica, San Mateo County

Figure 11
Northwest Sharp Park Sub-area and existing coastal armor

Table 8. Northwest Sharp Park Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	**Now:** Maintain existing armor, build new armoring elsewhere. **Future:** Maintain armor as needed to remain effective.
2 Protect	Armor, Beach nourishment, Sand retention structures	**Now:** Maintain existing armor, build new armor elsewhere. Nourish beach by 100 feet. Build sand retention structures (part of overall artificial headlands strategy for north Pacifica). **Future:** Maintain armoring and sand retention structures. Place sand: 100ft beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates.
3 Retreat	Managed removal/ relocation of assets	**Now:** Option to private property owners to remove or abandon existing armoring structures protecting property once it is damaged or no longer effective and to allow erosion. **Future:** Purchase property when buildings at risk, Remove or relocate public structures and infrastructure when at risk as erosion progresses.

Sharp Park, West Fairway Park and Mori Point

The backshore along the Sharp Park, West Fairway Park and Mori Point sub-area (shown in Figure 12) is low enough such that assets and property are subject to wave run-up and overtopping under existing conditions. Sea level rise adaptation strategies thus must address coastal flooding as well as erosion. Current management at Clarendon includes beach berm building between the Beach Blvd seawall and SFGC levee, which leads to storm water ponding on the landward side and requires a portable pump station. Aside from coastal flooding from wave run-up and overtopping, flooding hazards at Sharp Park include rainfall-runoff entering Laguna Salada during storm events which cannot drain directly to the ocean due to the presence of the levee and limited capacity pump station. To address the coastal erosion and flooding hazards with SLR while addressing the above values and concerns, the proposed adaptation strategies include protection measures such as revetments and beach nourishment as well as flood management measures for Laguna Salada. The adaptation strategy of retreat is also included at the direction of the CA Coastal

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the Sharp Park, West Fairway Park and Mori Point sub-area:

- *Old Wastewater Treatment Plant property is an economic asset*
- *Surfing, fishing*
- *Potential Snowy Plover habitat*
- *Snake and frog protective area*
- *Sharp Park Golf Course*
- *GGNRA – Mori Point Trails*
- *Open Salada Creek to ocean*
- *Berm Trail*
- *Mori Point trailheads for neighborhoods*
- *Mori Road/Trail Beach access from Moose Lodge*
- *Palmetto Ave: historic district and home of Pacific Coast Fog Fest*
- *What is being used to consider the life of new/current projects and cost/benefit ratio?*
- *Whale watching at Sharp Park beach*
- *Golf course acts as a protective structure*
- *Whale watching at Mori Point*
- *Boardwalk to Mori Point*
- *Snake and frog habitat in Sharp Park, particularly in the golf course*
- *Beach Boulevard Promenade*
- *Promenade (Seawall) too low to protect the neighborhood*
- *Gap at Clarendon between seawall and levee*
- *WSP and Fairway Park need a protective levee for flooding in golf course*
- *Sharp Park Golf Course acts as flood control infrastructure*
- *Wetland at golf course acts as hazard mitigation*
- *Lake in golf course is too shallow and always floods*
- *Water from Highway 1 flooding inundates golf course*
- *Concern over protective devices (armor, etc.) to environmental assets*

Technical workgroup feedback includes:

- *Western Snowy Plover habitat at Sharp Park Beach*
- *Future stairways to beach and overlook*
- *California coastal trail/emergency access route*
- *Coastal Commission retained jurisdiction (former tidal lands)*
- *CRLF & SFGS habitat*
- *State Lands Commission leases at: fishing piers; sewer outfall; riprap adjacent to Beach Boulevard, between Bella Vista Avenue and Santa Rosa Avenue; storm water outfall at Clarendon Avenue and Beach Boulevard.*
- *Recognize wetlands as flood control structure and natural asset flood control*

Commission (Appendix B). Details on the alternative adaptation strategies analyzed for this plan are presented in Table 9 below.

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SOURCE: ESA, Pacifica, San Mateo County

Figure 12
Sharp Park, West Fairway Park and Mori Point Sub-area and existing coastal armor

Table 9. Sharp Park, West Fairway Park and Mori Point Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor, levees	**Now:** Maintain existing armor, extend seawall to close Clarendon gap to SPGC levee. Assumes SF will armor and maintain SPGC levee. Build stormwater detention basins with setback levees and stormwater pump stations at Clarendon/Lakeside Ave and end of Fairway Drive. **Future:** Maintain armoring structures.
2 Protect	Armor, Beach nourishment, Sand retention structures, Levees	**Now:** Maintain existing armor, extend seawall to close Clarendon gap to SPGC levee. Nourish beach by 100 feet. Build stormwater detention basins with setback levees and stormwater pump stations at Clarendon/Lakeside Ave and end of Fairway Drive to prevent flooding from Laguna Salada during rain events. Build sand retention structures (part of overall artificial headlands strategy for north Pacifica). **Future:** Maintain armoring and sand retention structures. Place sand: repeat 100-foot beach nourishment every time beach width falls below minimum threshold, increasing frequency as SLR accelerates.
3 Retreat	Managed removal/ relocation of assets	**Now:** Option to private property owners to remove or abandon existing armoring structures protecting property once it is damaged or no longer effective and to allow erosion. **Future:** Purchase property when buildings at risk, Remove or relocate public structures and infrastructure when at risk as erosion progresses.

Rockaway Beach, Quarry and Headlands

Adaptation alternatives in the Rockaway Beach, Quarry and Headlands sub-area (shown in Figure 13) primarily focus on existing development along Rockaway Beach. To address coastal erosion and flooding hazards with SLR while addressing the above values and concerns, adaptation strategies include protection measures such as revetments and beach nourishment for the Beach while development setbacks are considered for the Quarry and Headlands. The adaptation strategy of retreat is also included at the direction of the CA Coastal Commission (Appendix B). Details on the alternative adaptation strategies analyzed for this plan are presented in Table 10 below.

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the Rockaway Beach, Quarry and Headlands sub-area:

- *Highway 1*
- *Lack of data for potential restoration of historical wildlife corridors along Highway 1*
- *Quarry has an accessible trail*
- *Could city purchase quarry to keep it open as a barrier?*
- *North Coastal trail provides beach access*
- *Viewpoint*
- *Fishing*
- *TWG: flood mitigation bank potential for quarry*

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SOURCE: ESA, Pacifica, San Mateo County

Figure 13
Rockaway Beach, Quarry and Headlands Sub-area and existing coastal armor

Table 10. Rockaway Beach, Quarry and Headlands Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect / Accommodate Hybrid	Armor, managed removal of assets, Development setbacks	**Now:** Maintain existing armoring structures, allow erosion in south cove (City owned). Development setbacks for quarry property. **Future:** Erosion continues in south cove until Hwy 1 threatened, assume Caltrans armors embankment or takes an alternative adaptation strategy. Relocate south cove public facilities as needed. Upgrade armoring as needed to maintain efficacy
2 Protect / Accommodate Hybrid	Armor, Beach nourishment, Development setbacks	**Now:** Place sand: 100ft beach initially and every time beach width falls below minimum threshold. Development setbacks for quarry property. **Future:** Nourish 100ft beach every time beach width falls below minimum threshold to delay need to armor Hwy 1 and reduce maintenance needs for existing armor, increasing nourishment frequency as SLR accelerates.
3 Retreat / Accommodate Hybrid	Managed removal/ relocation of assets, Development setbacks	**Now:** Option to private property owners to remove or abandon existing armoring structures protecting property once it is damaged or no longer effective and to allow erosion. **Future:** Purchase property when buildings at risk, Remove or relocate public structures and infrastructure when at risk as erosion progresses.

Pacifica State Beach

The Pacifica State Beach sub-area (shown in Figure 14) is less developed, but provides a buffer for West Linda Mar from coastal hazards. Adaptation strategies proposed for this Sub-area take this into account along with the above values and concerns, and include protection measures such as revetments and beach nourishment as well as a retreat/protect hybrid. Details on the alternative adaptation strategies analyzed for this plan are presented in Table 11 below.

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the Pacifica State Beach sub-area:

- *Western Snowy Plover habitat at Pacifica State Beach*
- *CRLF habitat at San Pedro Creek*
- *Construction at Parks Building*
- *SLR level of 5.7ft could underestimate flooding which will affect approval of new development, cost of protecting current assets, adequacy of protection options, effects on environmental assets*
- *Spring flowers along coastline*
- *Surfing at Linda Mar Beach*
- *Biking/running trails*
- *Public restroom and permeable surfaces*
- *Wildlife concern along Linda Mar Trail – potential to raise land?*
- *Trail concern along Linda Mar Beach St. uphill to Rockaway*
- *How are we considering hazard avoidance for new developments vs. existing infrastructure? According to NRA document, we should avoid new building (and San Pedro Creek area)*

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SOURCE: ESA, Pacifica, San Mateo County

Figure 14
Pacifica State Beach Sub-area and existing coastal armor

Table 11. Pacifica State Beach Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor, Flood protection	**Now:** Maintain existing armoring structures, option to owners to build new armor on private lands south parking and pump stations. Allow erosion of northern dunes. **Future:** Floodproof pump stations. Raise and armor Highway 1 to counteract erosion and wave overtopping exposure for West Linda Mar, coordinate with Caltrans adaptation planning.
2 Protect	Armor, Beach nourishment	**Now:** Maintain existing armoring structures, option to owners to build new armor on private lands south parking and pump stations. Allow erosion of northern dunes. **Future:** Nourish 100' beach and dunes when beach width falls below the minimum beach width. Assumes Caltrans Raises and armors Hwy 1 as needed. Floodproof pump stations as needed.
3 Retreat / Protect Hybrid	Managed retreat, Armor	**Now:** Allow erosion at publicly owned areas (optional for privately owned commercial facility in this sub-area). **Future**: Remove parking and relocate pump stations and realign sewer mains. Raise and armor Highway 1 (part of West Linda Mar hybrid strategy) to counteract erosion and wave overtopping exposure, coordinate Caltrans adaptation planning.

West Linda Mar

The West Linda Mar sub-area (shown in Figure 15) used to be a lagoon and is currently susceptible to high groundwater levels and is vulnerable to flooding from San Pedro Creek (FEMA 2017). Future SLR will further expose this sub-area to flooding from wave run-up and overtopping and will exacerbate groundwater issues and flooding exposure from San Pedro Creek. To address coastal flooding hazards with SLR while addressing the above values and concerns, adaptation strategies for this sub-area focus on reducing flood risks and managing groundwater. A retreat adaptation strategy would entail restoring the neighborhood back to wetlands. While West Linda Mar is outside of the City's coastal zone and not subject to Coastal Commission jurisdiction, retreat is a possible alternative depending on how great SLR and associated ground water issues become. Details on the alternative adaptation strategies analyzed for this plan are presented in Table 12 below. Adaptation strategies that are implemented at Pacifica State Beach have implications for the West Linda Mar sub-area. Accordingly, results of the cost benefit analysis for these two sub-areas is presented together in Section 5.4.

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the West Linda Mar sub-area:

- *Linda Mar Boulevard floods*
- *San Pedro Creek Trail – wildlife EOR & creek*
- *Plans to relocate gas stations?*
- *Adaptation requirements for local businesses?*
- *Adaptation to floods along river as sea level rises?*
- *Storage unit concerns*
- *Work with school to update infrastructure adaptation plan*

Pacifica LCP 170663

SOURCE: ESA, Pacifica, San Mateo County

Figure 15
West Linda Mar Sub-area and existing coastal armor

Table 12. West Linda Mar Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor/Flood Protect	**Future:** Assumes Caltrans will raise Highway 1 (with armor) to protect the highway from wave overtopping (which will also provide protection to the neighborhood). Build levee/floodwall along San Pedro Creek to limit river flooding exposure and coastal exposure with future SLR. Add wells and pumps to manage rising groundwater with SLR in lowest areas of neighborhood.
2 Accommodate	Elevate structures, Groundwater management	**Now:** Follow requirements of City's Flood Damage Prevention Ordinance. **Future:** install wells and pumps to manage rising groundwater with SLR. (~120 structures affected by 2100 groundwater, ~300 structures affected by 2100 coastal storm (100-yr))
3 Retreat	Managed removal/ relocation of assets	**Now:** Monitor SLR and groundwater issues in West Linda Mar. Option to private property owners to remove structures at risk. **Future:** Explore program to implement retreat of lowest neighborhood. Option to private property owners to remove structures at risk. Remove or relocate public structures when impacted by rising groundwater and/or average rainfall events and restore to wetlands.

Pedro Point and Shelter Cove

To address coastal erosion and flooding hazards with SLR for the Pedro Point and Shelter Cove sub-area (shown in Figure 16) while addressing the community values and concerns, the adaptation alternatives include protection measures such as revetments and beach nourishment. The adaptation strategy of retreat is also included at the direction of the CA Coastal Commission (Appendix B). Details on the alternative adaptation strategies analyzed for this plan are presented in Table 13 below.

The following community values and concerns were received and documented in the draft Vulnerability Assessment public engagement meetings for the Pedro Point and Shelter Cove sub-area:

- *Adaptation needed for local businesses*
- *Adaptation to floods needed along river as sea level rises*

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SOURCE: ESA, Pacifica, San Mateo County

Figure 16
Pedro Point and Shelter Cove Sub-area and existing coastal armor

Table 13. Pedro Point and Shelter Cove Sub-area Adaptation Alternatives

Adaptation Alternative	Adaptation Measures	Description
1 Protect	Armor	**Now:** Assume existing private armoring structures are maintained and expanded by property owners along Shoreside Dr. Armoring of the headland is included in the form of a rock revetment but detailed slope stability and engineering analyses would be required to validate any design to limit erosion of the headland. **Future:** Maintain armored toe of headland. Shelter Cove not considered in this plan due to access issues.
2 Protect / Accommodate Hybrid	Armor, Beach nourishment, Elevate structures.	**Now:** Assume armor is maintained and expanded by property owners along Shoreside Dr. In conjunction with Pacifica SB nourishment, nourish 100' beach as part of Pacifica State Beach alternative. **Future:** Nourish 100' beach when beach width falls below the minimum beach width, increasing frequency as SLR accelerates. Raise buildings above coastal flooding elevation.
3 Retreat	Managed removal/ relocation of assets	**Now:** Option to private property owners to remove or abandon existing armoring structures protecting property once it is damaged or no longer effective and to allow erosion. **Future:** Purchase property when buildings at risk and remove structures and utilities, Remove or relocate public structures and infrastructure when at risk as erosion progresses.

5.3 Methodology for Cost-Benefit Analysis of Alternative Adaptation Strategies

Pacifica is already experiencing impacts from coastal flooding and erosion. Sea-level rise will lead in increased coastal flooding and erosion risks to public and private property in the City of Pacifica. The economic analysis prepared for this study is designed to help guide the City and other stakeholders by estimating the value of public and private property and improvements at-risk due to coastal hazards, specifically flooding, inundation, and erosion.

A benefit-cost analysis provides a useful tool when evaluating different options in an adaptation analysis. For example, suppose the City is considering two different adaptation options: a) armoring (or reinforcing existing armoring), or b) beach nourishment. These two options will have different engineering costs and will yield different benefits to the community in terms of protecting the community from coastal hazards and providing the community with coastal recreation. The economic analysis can be used to help inform adaptation decisions. Adaptation to sea level rise often involves compromise. For example, the decision to armor a portion of the coast involves a number of economic tradeoffs. First, the City of Pacifica, or private property owner, or some other entity, must pay for the costs of building and maintaining coastal armoring. Second, armoring protects public and private property from coastal erosion and storms. Third, armoring may reduce beach width, reducing coastal recreation, and interfere with other coastal ecosystem processes.

The economic analysis presented in Section 5.4 uses the best available data on property values, coastal recreation and tax revenues. The limitations of the data and analysis are discussed in more detail below. Although this analysis includes some estimates of tax revenues generated/lost by various strategies, this type of data is typically not incorporated directly into a benefit-cost ratio analysis. This data, however, may be used to help stakeholders make informed decisions since the City of Pacifica also needs to understand the impact of adaptation strategies upon their tax base. Consequently, this analysis does include a discussion of potential impacts on property taxes from the loss of property as well as potential loss in sales taxes and transient occupancy taxes (TOTs) within two planning sub-areas: West Linda Mar and Rockaway Beach, Quarry and Headlands.

It should also be noted at the outset that the purpose of the benefit-cost analysis, is not to prescribe or proscribe any specific policy, but rather to inform local decision-makers and stakeholders about the economic considerations associated with various sea-level rise scenarios and adaptation options available to the City. by giving the City and public a hypothetical alternatives played out over an example SLR scenario.

The alternative adaptation strategies presented in Section 4.2 were analyzed using a cost-benefit analysis (consistent with the methodology detailed in the memorandum by ESA and Dr King (2018) included as Appendix E to this report). The cost benefit analysis was conducted using engineering unit cost estimates for adaptation measures and asset replacement, scheduling (and costing) of adaptation measures through time using shoreline evolution model and flooding thresholds, and conducting a GIS exposure analysis for the alternative adaptation strategies considered in each sub-area. Each of these cost-benefit components is discussed in the following sections. Cost-benefit results for the alternative adaptation strategies are then presented for each Sub-area in the following sections, and are also summarized for each sub-area in Appendix C to this report.

Scheduling of Engineering Measures for Alternative Adaptation Strategies

To estimate the total cost of each adaptation strategy over the study period for the purpose of the cost benefit analysis, alternative adaptation strategies (protect, accommodate, hybrid etc.) were defined through time by assigning schedules for individual adaptation measures (at what year to build/maintain armor, (re)nourish beach, build floodwall etc.). The schedules were determined based on the projected coastal erosion, storm flooding and tidal inundation hazard extents relative to the adaptation triggers and thresholds presented in Table 2.

For erosion-specific adaptation measures, a shoreline evolution model was applied to track beach width, shoreline erosion and backshore erosion (where applicable) through time. Considering the thresholds for stable beach width and bluff erosion offset in each sub-area among other parameters such as historic erosion rates and sea-level rise, the timing of armoring construction and/or maintenance and beach nourishment could be determined. The model output of beach width also enables the valuation of recreational benefits and discussion of ecology for each adaptation strategy. Details on the shore evolution modeling are presented in Appendix D. New armor construction for bluff backshores was determined using two offset approaches. For the more erodible bluffs in northern Pacifica, a stable slope offset of 2:1 (Collins & Sitar 2008) was applied to the bluff height in each sub-area to determine the minimum bluff offset between infrastructure/assets and the bluff edge to initiate new armor construction. For tall bluffs at Pedro Point, the erosion uncertainty distance from the Pacific Institute study (2009) was used. For storm flooding- and inundation-specific adaptation measures, specific sea-level rise thresholds were identified by reviewing the coastal hazard maps used for the study (CoSMoS for future conditions, FEMA for existing conditions). For example, under an accommodate adaptation strategy a structure is assumed to be elevated at 2050 if it falls within the coastal flooding hazard zone at that year.

Coastal Armor Renovation Requirements

Coastal armor structures such as rock revetments and seawalls are subject to degradation over time and require maintenance (USACE, 1984)[14], and revetments and seawalls in Pacifica are frequently maintained. Coastal structures are designed for a particular condition, such as wave height, which may be exceeded due to an occurrence of a more severe storm event. A 2017 review of coastal structures using visual survey methods[15] indicated that many of the armoring structures in Pacifica have degraded and are in the process of progressive failure. In fact, there have been multiple failures of coastal structures in the last few years and historically (e.g. Land's End seawall and Beach Boulevard; described in ESA 2018c). Consequently, we assume the useful life of existing coastal armoring structures in the City are limited.

Because waves can get quite large in Pacifica, most coastal armoring structures are exposed to the "depth-limited wave" in the shallow, near-shore at the toe (seaward limit) of the structure. Larger depth-limited waves can occur when the depth of water at the structure is greater than that assumed in the design. The water depth increase can be caused by local scour, overall erosion of the beach, and sea-level rise. Once the water depth increases, the potential wave height increases and the structural loading increases, and the wave run-up and overtopping increases. An increase of the design wave by 50% is expected to result in coastal armoring structural failure

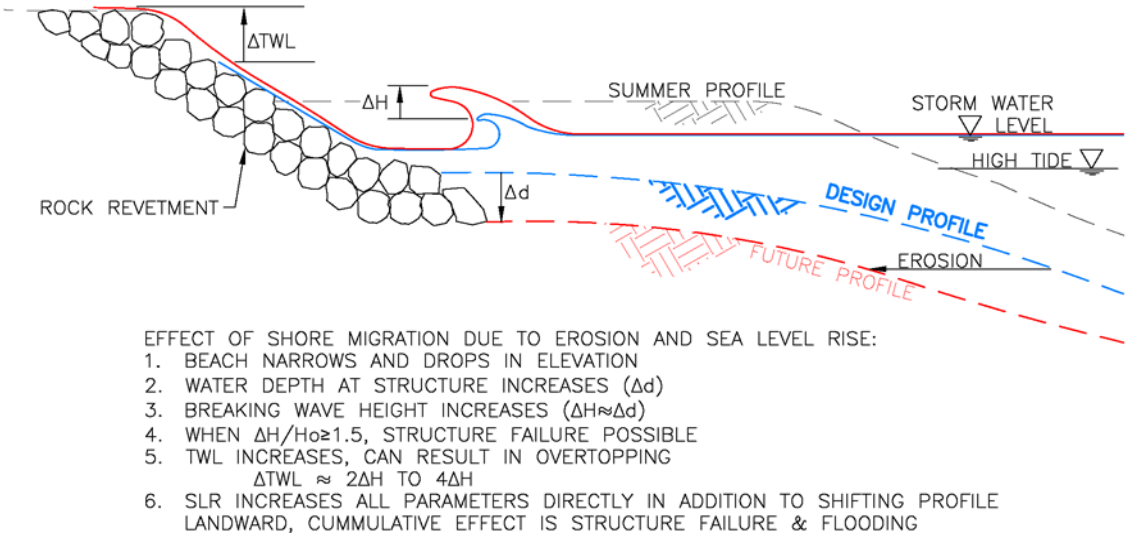
[14] U.S. Army Corps of Engineers (USACE), 1984, Shore Protection Manual, 4th ed., 2 Vol., U.S. Army Engineer Waterways Experiment Station, U.S. Government Printing Office, Washington, D.C., 1,088 pp.

[15] Patrick, P., Collins, B., and Sitar, N., 2006, Investigation of Seawall Effectiveness Against Coastal Erosion, San Mateo County, California, University of California, Berkeley, Department of Civil and Environmental Engineering, June 2006.

(USACE, 1984). Given the historic erosion of Pacifica's beaches and the age of the coastal structures, it is not surprising that the structures are being degraded. The larger waves can also induce deeper local scour at the toe of the structure, resulting in sloughing of rocks down and into the ocean, and undermining of seawalls and scour of backing soils. These processes are evident at the Beach Boulevard and Rockaway structures, among others. In summary, we can expect progressive degradation and failure of coastal armoring in Pacifica, requiring extensive maintenance and reconstruction.

The same progressive increase in loading is expected to increase in wave overtopping that will causes high-velocity flows that can damage structures and erode behind the armoring (Battalio et al, 2016)[16]. Consider the rock revetment in Figure 17. Assuming the wave run-up is controlled by a depth-limited wave near the shore, an increase in water level due to sea level rise would increase the depth and the maximum wave height. Using a typical breaker ratio of about 0.8 times the water depth, the wave height would increase about 0.8 for every foot sea level rise, and the run-up would increase about 1.6 to 2.4 times the amount of sea level rise. Adding the sea-level change results in a total water level increase of 2.6 to 3.4 times the increase in depth, due to sea-level rise or erosion or both.

Therefore, we have assumed that coastal armoring will be reconstructed every 20 years in areas where the fronting beach width is below the stable thresholds tabulated in Table 2. The costs to maintain are applied as a lump sum cost that (assumed constant thorough time) to rebuild at each 20-year increment for the economic analysis in this study, but could otherwise be modeled as a 5 percent per year amortization rate. Note that the projected accelerating sea-level rise would indicate an exponential cost increase for armoring, but for simplicity this added costs is ignored. Depending on the amount of SLR that occurs, even higher armoring costs could make the alternative financially infeasible.



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SOURCE: ESA

Figure 17

Response of coastal armoring to erosion and SLR is progressive structural overloading, overtopping and failure, requiring maintenance and reconstruction for higher loadings

[16] Battalio, R. T., P. D. Bromirski, D. R. Cayan, L. A. White (2016). Relating Future Coastal Conditions to Existing FEMA Flood Hazard Maps: Technical Methods Manual, Prepared for California Department of Water Resources and California Ocean Science Trust, Prepared by Environmental Science Associates (ESA), pp. 114.

GIS Exposure Analysis of Alternative Adaptation Strategies

The economic analysis provided for this study is based on geospatial data. All of the land, structures and infrastructure analyzed have specific geospatial references, which can be overlaid with the hazard zones to assess impacts from coastal flooding, inundation, and erosion. The economic analysis employed San Mateo County Assessor's parcel data and City land use data, to identify property boundaries, location and size of the parcel along with other information such as zoning and current use. The use of geospatial analysis also allows one to incorporate the length and width of beaches, coastal trails, access points and other pertinent information about coastal recreation.

Following the development of adaptation strategies and timing for each sub-area, new sets of coastal hazard maps were produced to reflect changes in hazard exposure associated with adaptation strategies based on the med-high SLR scenario. For example, under the protect adaptation strategy where backshore armor is built and or maintained to limit bluff erosion, the associated erosion hazard for that area was clipped at the armoring structure. Similarly, if flooding prevention measures were applied for an adaptation strategy, such as raising structures or building floodwalls/levees, the flooding hazard layer for that area was clipped. The resulting adaptation strategy-specific exposure maps were then overlaid with the assets in GIS to calculate impacts to property and assets for each alternative. These impacts were then processed by the economists using asset replacement costs in Table 14 to combine with the cost of engineering measures described above to calculate the total cost of each adaptation strategy. Revised asset exposure counts in each sub-area for each adaptation alternative that were used to assess the economic impacts of each alternative are provided in Appendix I to this report. Specific data sources for coastal hazard zones and modifications made for the adaptation alternatives analysis are described under the subsections below.

Coastal Hazard Zone Data Sources and Modifications for Adaptation Alternatives, Quantifications of Impacts from Coastal Hazards

Erosion

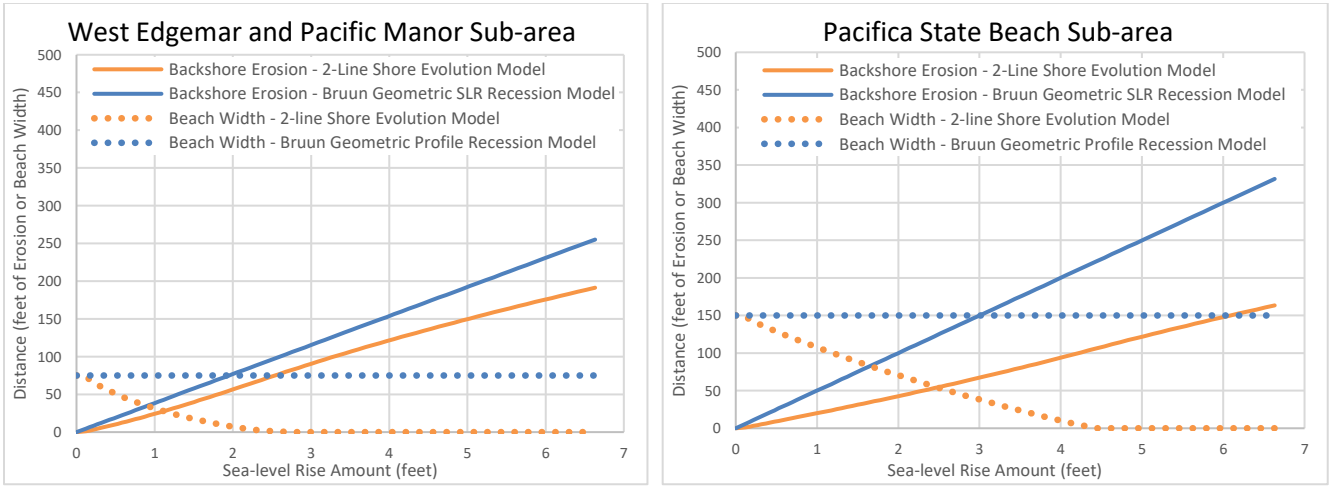
Backshore erosion hazard zones were updated considering the med-high SLR scenario using the shoreline evolution model (described in Appendix D) which tracks shoreline and backshore erosion. For shores protected new or existing by armoring, erosion landward of the structure was clipped in GIS. For shores that were allowed to erode (undeveloped bluffs and dunes under Alternatives 1 and 2; all bluffs and dunes under Alternative 3 Managed Retreat), backshore erosion outputs from the shoreline evolution model were used in place of the Pacific Institute erosion zones considered in the Vulnerability Assessment. Infrastructure exposed to erosion are lost completely and need to be rebuilt in another location so a cost factor of 2x was applied to account for the demolition of existing infrastructure and replacement at a landward location (this is what the City has used when evaluating alternatives for Esplanade housing demolition when seeking emergency grant funding). Under a managed retreat alternative, the length of needed infrastructure such as water and wastewater pipes would be reduced as less buildings need service, so the cost factor of 2x may overestimate managed retreat costs associated with infrastructure in the long term. A detailed description and discussion on the modeling approach for managed retreat are provided in Appendix H.

Estimating precisely when a parcel loses value is challenging. Coastal erosion may lower the property value as people's expectations about future erosion change. However, this analysis assumed that the land value of a parcel loses value in proportion to the loss in property—i.e., if a parcel loses 20% of its land value, it loses 20% of its

economic value. Once erosion hits a structure, this study assumed that the structure is lost along with its associated market value since it must be abandoned. In practice, it's likely that a structure will lose its value before erosion hits the structure. This treatment is applied to parcels of all sizes and is based on feedback on the Economic Methods Memo (Appendix E) which previously treated small parcels (less than ¼ acre) as lost once any part of the parcel is impacted.

Erosion and Beach Width Modeling Comparison

The goal of protecting blufftop development against erosion often conflicts with the goal of maintaining a beach for recreational and ecological values. To better understand the range of implications of a managed retreat adaptation alternative on backshore development and beach width (i.e. recreation and ecological value), ESA compared the 2-line shoreline evolution model outputs of erosion and beach width against the commonly applied geometric shoreline response model of Bruun (1962) for a range of SLR. As shown in Figure 18 below, the Bruun model for shoreline retreat predicts greater bluff and dune backshore erosion distances but assumes that the stable beach width is maintained with SLR. For a tall bluff backshore such as West Edgemar and Pacific Manor, the Bruun geometric model predicts backshore erosion distances that are 50-140% greater than erosion distances predicted with the shoreline evolution model (average % increase over values shown for the West Edgemar and Pacific Manor and Pacifica State Beach sub-areas, respectively). Also, the Bruun model assumes the beach width is maintained as the profile transgresses with sea-level rise implicitly. However, it is not clear that there is enough sand supply and the existing sand in the uplifted bluffs is locally too fine in grain size to maintain a beach in front of the bluffs. Thus, the projected impacts to backshore development and ecological/recreational implications for a managed retreat adaptation alternative can vary significantly depending on the erosion model used, the actual distance of backshore erosion and maintained beach width may fall between these two projections.



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SOURCE:
ESA

Figure 18

Comparison of Backshore Erosion and Beach Width Projections with Sea-level Rise from 2-line Shore Response Model and Bruun (1962) Geometric Profile Recession Model

Flooding

Coastal flooding for each adaptation alternative is based on OCOF coastal storm flooding hazard zones used in the Vulnerability Assessment under the med-high SLR scenario. These hazard zones were updated as needed to reflect adaptation alternatives. Where adaptation alternatives address storm flooding exposure, the addressed area was clipped out of the OCOF flooding hazard zone in GIS to represent the hazard reduction. In addition to updating flooding exposure for alternatives that include engineering solutions, coastal storm wave run-up hazard zones were also updated to represent the wave overtopping momentum zones (e.g. FEMA VE zone) that can damage property and injure people. Wave run-up exposure was computed using standard methods for flood hazard mapping (FEMA, 2005) for the January 22, 2016 wave event for the bluffs along the Sharp Park area and FEMA coastal flood hazard maps for Pacifica and Rockaway. Future maximum run-up elevations and landward extents of wave run-up were calculated for each sub-area using a methodology that relates existing FEMA flood maps to future conditions with sea-level rise (Department of Water Resources Technical Methods Manual, Battalio et al. 2016). Depths of flooding were calculated for structures using the OCOF storm flooding depth grids associated with each time horizon, depths calculated for fluvial flooding with SLR as described in the Vulnerability Assessment, and depths calculated from the wave run-up updates. For structures that are within the existing or future wave run-up hazard zones, an area-weighted depth was applied which equaled one-third of the maximum depth of run-up at bluff edge or other backshore barrier (assumes that the depth in reality ranges from the maximum height at the backshore and slopes to the ground surface, or zero depth, at the landward limit).

Flood damages to structures were estimated by applying the U.S. Army Corps of Engineers depth damage curves (USACE, 2003) which estimates damages as a percent of the total value of the structure over a range of flooding depths. The Corps method also allows one to estimate the average damage to the contents of the structure (e.g., furniture, inventory, etc.). These curves translate flood depth into a percentage loss as a function of the total value of the structure. The percentage loss also varies with the number of stories, type of construction, and other factors. Give that flood damages also depend upon the length of the flooding, the force of the waves, and other unknown variables, the flood estimates provided in this study have a greater margin of error than many other estimates, but still provide a useful base for comparing alternatives.

Tidal Inundation and Groundwater

Exposure to chronic tidal inundation is based on the OCOF hazard layers used in the Vulnerability Assessment that represent the med-high SLR scenario which is also considered for low lying areas as exposure to elevated groundwater since the tide range has a boundary effect on groundwater in these coastal areas. Similar to the storm flooding and coastal erosion exposure modifications made for each of the adaptation alternatives, tidal inundation/groundwater hazard zones were clipped out for areas where engineering adaptation solutions address the hazard exposure. Economic impacts to property exposed to permanent tidal inundation/groundwater is lost (proportional), structures are lost when they are exposed at all, similar to erosion. Infrastructure (pipes, roads, other utilities) that is exposed to permanent inundation is rendered inaccessible, so it must be removed and/or relocated.

Valuing Land and Structures

In the State of California, most private property (except for some non-profit organizations) is assessed for property tax purposes and the assessed value of each is included in the parcel data along with geospatial references which include the location, shape and size of the parcel. Further, this parcel data generally includes an

assessed valuation for both the land and "improvements" -- the assessed value of the structure(s) on the land. Unfortunately, the assessed value of property often differs markedly from the actual market value, especially in California where Proposition 13 limits any increase in value to 2 percent a year. Since the inflation rate for houses and other property has been significantly higher than 2 percent for many years, using assessed value may lead to significant underestimates of the market price of a property today[17].

To adjust for the inherent bias in assessed data, this analysis used the best available housing price data to construct a housing priced index (HPI) for the City of Pacifica, which converts the original sales price into current market prices. Since Pacifica's housing market is unique, this study employed a local index based on data from Zillow[18]. In summary, this report first reduced the assessed property value by 2% (due to Prop 13) each year, going back to the original assessment date in order to calculate its original valuation, and then adjusted that value upward based on the chained price index provided by Zillow in order to approximate the current market value of the parcel.

In California, parcels owned by government entities (Federal, State, local including school district property) and non-profit organizations (e.g., churches) are not subject to property taxes and hence not assessed. This analysis used recent transactions for coastal property by governmental and non-governmental agencies to value land owned by government agencies[19]. The City of Pacifica provided this study with estimates of the replacement cost of numerous structures, (e.g., the City Community Center, Council Chambers) which were incorporated into the analysis. Pacifica's beaches and the Sharp Park golf course (owned by the City of San Francisco) were valued separately as recreational assets, as discussed below. One limitation of using current market prices for land is that these prices depend critically on zoning. Land zoned for residential use will have a different market price than land zoned for commercial uses, or land zoned for other uses. Since zoning could change in the future as a result of sea level rise and climate change, these values could change. Similarly, the threat of coastal erosion and flooding may also lower the value of property at-risk in the future, and possibly increase the value of property not at-risk. These possibilities are beyond the scope of this analysis.

Valuing Infrastructure and Adaptation Alternatives

The adaptation alternatives discussed above include conceptual level engineering cost estimates that were developed using the unit costs provided in Table 14 below. Detailed engineering cost schedules for the three adaptation alternatives in each sub-area are provided in Appendix J to this report. Table 14 also includes infrastructure replacement costs used to estimate damages. These costs were compiled from past studies and/or estimated for this project by ESA, or provided by asset owners and the City of Pacifica. The goal of engineering cost estimates is to set the tone on the order of magnitude of costs and are early conceptual estimates for concept screening of alternatives that are not meant to substitute a detailed engineering cost estimate. The actual costs may

[17] For example, for residential housing, according to the Case-Shiller housing Index, housing prices in San Francisco in January 2018 are 4.91 times higher than in January 1988, 30 years ago. (St Louis Federal Reserve Bank, 2018) However, even if housing prices were adjusted every year by 2%, the increase would only be equal to 1.81 times January 1988 prices17 which is less than half of the market increase in value.

[18] See https://www.zillow.com/research/data/. For the City of Pacifica, we used the "Quarterly Historic Metro ZHVI: Home values are chained back in time using Moody's home value data from 1979 until the start of the Zillow Home Value Index" available for the San Francisco metro area.

[19] Appraisal of the Community Center and Council Chambers were provided by the City of Pacifica Planning Department..

be 50% less to 100% greater than the costs developed for this study (AACE 2016) which is consistent with the industry standard practice for this planning level of analysis.

Table 14: Engineering Unit Cost Estimates for Infrastructure Replacement and Adaptation Measures

Engineering unit costs

Adaptation Measure	Cost	Unit	Description	Source
Elevate Buildings	$ 150	per SF	In Flood Zone	ESA engineering cost estimate
Elevate Buildings	$ 250	per SF	In Wave Zone	ESA engineering cost estimate
Elevate Road	$ 800	per SF	Elevate on bridge/trestles	City of Pacifica estimate
Rock Revetment	$ 7,576	per LF	Quarry stone	City of Pacifica estimate
Seawall	$ 18,371	per LF	Reinforced Concrete	City of Pacifica estimate
Sand retention structure	$ 14,394	per LF	Quarry stone (offshore reef, or artificial headland)	ESA engineering cost estimate
Horizontal Levee	$ 2,000	per LF	Flat wide levee	City of Pacifica estimate
Traditional Levee	$ 54	per CY	Clay Levee	ESA engineering cost estimate
Bulkead/Floodwall	$ 5,000	per LF	Floodwall for Linda Mar/San Pedro Crk	City of Pacifica estimate
Beach Nourishment	$ 22	per CY	Imported sand	ESA engineering cost estimate
Dune Restoration	$ 220,000	per acre	Vegetated sand dune with buried cobble	ESA engineering cost estimate
Seawall Upgrade	$ 20,000	per LF	Upgrade/raise existing BB north retaining wall	ESA engineering cost estimate
Seawall Maintenance	$ 10,000	per LF	Raise BB south seawall	ESA engineering cost estimate
Demo Building	$ 16	per SF	Demolish buildings	ESA engineering cost estimate
Demo parking	$ 1	per SF	Demolish parking lot	ESA engineering cost estimate
Demo seawall	$ 350	per LF	demo seawall and haul nearby	ESA engineering cost estimate
Demo Revetment	$ 640	per LF	demo revetment and haul nearby	ESA engineering cost estimate

Asset replacement costs

Infrastructure Category	Cost	Unit	Asset	Source
Water	$ 360	per LF	Main (average replacement cost)	NCCWD contractor estimate
Communications	$ 100	per LF	ComcastConduit	Comcast estimate
Wastewater	$ 190	per LF	Wastewater Pipe	City of Pacifica estimate
Wastewater	$ 380	per LF	Wastewater Main	City of Pacifica estimate
Transportation	$ 400	per LF	Roads	City of Pacifica estimate

Pump station replacement and floodproofing cost estimates

Sub-area	Cost	Unit	Action	Source
PacificaSB-LindaMar	$ 25,400,000	ea	LindaMar pump station replacement (sewer and stormwater)	City of Pacifica estimate
PacificaSB-LindaMar	$ 800,000	ea	LindaMar pump station floodproof (sewer and stormwater)	ESA engineering cost estimate
PacificaSB-LindaMar	$ 12,900,000	ea	Anza pump station replacement	City of Pacifica estimate
PacificaSB-LindaMar	$ 600,000	ea	Anza pump station floodproof	ESA engineering cost estimate
Rockaway	$ 12,800,000	ea	Rockaway pump station replacement	City of Pacifica estimate
Rockaway	$ 300,000	ea	Rockaway pump station floodproof	ESA engineering cost estimate
Sharp Park Etc	$ 14,200,000	ea	SharpPark pump station replacement	City of Pacifica estimate
Sharp Park Etc	$ 300,000	ea	SharpPark pump station floodproof	ESA engineering cost estimate
Sharp Park Etc	$ 12,400,000	ea	DavidDavis pump station replacement	City of Pacifica estimate
Sharp Park Etc	$ 200,000	ea	DavidDavis pump station floodproof	ESA engineering cost estimate

SF=square foot; LF=linear foot; CY=cubic yard; ea=each

Data gaps

As with any large scale analysis, there are data gaps that remain for infrastructure location and values. The following infrastructure types were not included in this analysis because data on location and cost were not available:

- PG&E gas and electricity lines
- AT&T telecommunications lines (Comcast network was included)
- Street lighting, benches and other public improvements.

Valuing Recreational Resources

The City of Pacifica also has numerous recreational resources subject to coastal hazards. Unlike many other services, these recreational services are typically provided for free (e.g., hiking on trails) or subsidized (e.g., golfing.). These services are discussed in this section.

Beach Recreation

In California all beaches below the mean high tide and are considered public property; by law, beaches cannot be bought or sold in California, so a market price cannot be established. In addition, since everyone in California has access to beaches, there is no price for admission, though many beaches (including Pacifica State Beach) do charge for parking in official beach parking lots. Even though beaches other recreational amenities are free to use, they still have value to the public. Economists measure the value of these non-market resources by estimating what consumers would be willing to pay (WTP) for the services. These methods are generally referred to as non-market valuations and are discussed in more detail in Appendix E.

For beach recreation, this study applies a day use value of $40 – that is a day at the beach is worth $40 per person. This valuation is consistent with a recent case before the Coastal Commission in Solana Beach.[20] The $40 per person per day estimate is based on numerous studies of the non-market value of beaches in California. (CCC 2015b). To estimate the total value of beach recreation, one multiplies the day use value ($40) by the number of people attending the beach. For example, if 100,000 people attend a beach in 2018, the value of the beach is equal to $40*100,000, which is equal to $4 million. The City of Pacifica keeps detailed records on parking at the three lots adjacent to Pacifica State Beach. These parking counts are used to estimate attendance at the beach and submitted to the California Coastal Commission. The economic consultant preparing this report spoke with several City officials and examined this data carefully. He concluded that the method used by the City of Pacifica to estimate attendance is sound and based on reasonable assumptions. The California Coastal Commission has also approved these attendance estimates[21]. For other beaches in Pacifica, this study used estimates from the Coastal and Regional Sediment Master Plan (ESA 2015), updated for increases in population in San Mateo County[22]. A sensitivity analysis was performed on the assumed beach recreation valuation which is provided in Section 5.4 for the Sharp Park, West Fairway Park and Mori Point sub-area.

Golfing

The Sharp Park Golf Course, which is owned and operated by the City of San Francisco, is an 18-hole course located within the City of Pacifica. This study used data obtained from the City of San Francisco to value the golf course. In addition, since this is a public golf course, this study examined other golf courses with higher fees in the Bay area in order to determine if the Sharp Park golf course's fees are below market price. Appendix G contains more detail on Sharp Park golf course.

Hiking

The City of Pacifica has a number of hiking trails along the coast, which are popular with hikers and dog-walkers. Unfortunately, this study did not find any specific estimates for trail usage. Further, apportioning a partial loss of

[20] California Coastal Commission, City of Solana Beach Major Amendment LCP-6-SOL-16-0020-1 (May 11, 2017)

[21] City of Pacifica's attendance estimates assume each parked vehicle is equivalent to 1.5 visitors.

[22] State of California, Dept. of Finance population projections to 2050; http://www.dof.ca.gov/Forecasting/Demographics/Estimates/E-1/

coastal trails usage due to erosion or flooding is quite difficult. Given these limitations, this study provides an estimate of the length of trails lost due to erosion or affected by flooding.

Transaction Costs

The City of Pacifica has incurred significant costs relating to mitigation of hazardous conditions along the coastline. It is difficult to estimate these costs precisely since the necessary actions can vary from property to property. The transaction costs can include, among other things, appraisals of the property value, prior damages if any, utility shut-off, structure demolition and site clearing, staff time to apply for grants including estimates of alternative actions, permits and approvals, and legal consultation. A review of recent hazard mitigation grant applications prepared by the City indicates that a budget allowance of 50% of the appraised property value is appropriate. Certainly a lower cost would be preferred and a range of potential transaction costs between 0 percent of the total value of the parcel (no transaction costs) to 50 percent (high transaction costs). These estimates should be considered indicative of the potential range of transaction costs that can be anticipated when evaluating adaptation alternatives.

Summary of Valuation Methods and Sources

Table 15 summarizes the general economic valuation methods and data sources used in this study.

Table 15. Summary of Methods and Data Sources for Economic Analysis

Estimate	Valuation	Method	Source
Residential Land	Market	Update County Parcel Data	San Mateo County, Zillow
Commercial Land	Market	Update County Parcel Data	San Mateo County, Zillow
Publicly Owned Land, Land Trusts	Acquisition Cost	Apply acreage metric	Various
Publicly Owned Buildings	Appraisals		City of Pacifica
Demolition Costs	Removal Costs	Apply sq ft. metric	ESA
Linda Mar Beach	Non-Market Valuation	Day Use Value * Attendance	City of Pacifica
Other Beaches	Non-Market Valuation	Day Use Value * Attendance	Pacifica CRSMP
Trails	None	Estimate Length of Trails Lost	City of Pacifica
Golf Course	Market and Non-Market	See Appendix B	Various
Water Pipes	Replacement Costs	Apply linear ft. metric	NCCWD
Communication Conduits	Replacement Costs	Apply linear ft. metric	Comcast
Wastewater Pipes	Replacement Costs	Apply linear ft. metric	ESA/City
Wastewater Mains/Pumps	Replacement Costs	Apply linear ft. metric	ESA/City
Roads	Replacement Costs	Apply linear ft. metric	ESA/City
Stormwater Pipes/Pumps	Replacement Costs	Apply linear ft. metric	ESA/City

Economic Analysis and the Future

The economic analysis in this study projects the impacts of sea-level out to 2100. However, our current understanding of the impacts of climate change is limited and evolving. In addition, our understanding of future economic conditions and market prices/replacement costs is similarly limited, particularly for longer time horizons.

The economic analysis for this study estimates all prices and replacement cost in (real) 2018 dollars. Effectively this assumption implies that the relative prices/costs of various decisions/options will remain the same over time—that is, the inflation rate for all goods and services will be the same. However, it is likely that some costs/prices will rise faster than others while new technologies or techniques may lower the relative prices of other goods and services.

As is standard in any economic benefit/cost analysis, future costs and benefits must be discounted— future benefits/costs are worth less than the same benefit/cost today. The choice of discount rate is critical in any benefit/cost analysis. Currently there is no consensus among economists as to what the proper discount rate should be.[23] When considering capital investments (e.g., financing a seawall) one should consider the cost of capital—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.[24] Table 16 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-- $8.86 (see Table 16 below). Effectively, a higher discount rate values benefits to future generations much lower than benefits to today's generation. This study employs a 3% discount rate in all benefits and costs projected out to the future.

Table 16: Value of $100 over Time at Various Discount Rates

Discount Rate	0%	1%	3%	4%	5%
2030	$ 100.00	$ 88.74	$ 70.14	$ 62.46	$ 55.68
2060	$ 100.00	$ 65.84	$ 28.90	$ 19.26	$ 12.88
2100	$ 100.00	$ 44.22	$ 8.86	$ 4.01	$ 1.83

Taxes

When comparing alternatives in a benefit/cost analysis of this type, taxes are not typically included. However, the City of Pacifica and other stakeholders may wish to know the local tax implications of different coastal management policies.

The scope of this study only includes a preliminary analysis of the tax revenue implications of these strategies. In addition to the benefit/cost analysis, this study estimated losses in property taxes associated with losses in property due to erosion. The consultants also estimated potential losses in transient occupancy tax (TOT) revenues associated with flooding to hotels in the Rockaway sub-area and loss in sales taxes due to flooding in the Rockaway and Linda Mar sub-area. The City of Pacifica provided recent estimates of yearly sales and transient occupancy taxes in these areas, which were employed in the economic analysis.

[23] For example, see Arrow et. al., 2014 and Zuang et. al. (2007).
[24] *Ibid.*

Costs Not Included in This Study

Secondary costs that are not considered in this economic analysis include relocation costs, insurance and other financial cost increases, disruption and loss of productivity, and potential property value reduction. Estimating these costs is beyond the scope of this planning-level study but should be considered when evaluating individual adaptation projects. The costs of relocating/building new development elsewhere in the City and associated property tax revenues are not included in the cost benefit analysis for Alternative 3, managed retreat.

Note that the unit cost for imported sand for beach nourishment is assumed constant for this study. In reality sand will become scarce in the future as it is a valuable resource for many industries including construction. The cost and availability of sand for beach nourishment will be better understood with a more detailed feasibility study on beach nourishment in Pacifica (e.g. the Rockaway Beach nourishment pilot project recommended in near-term adaptation priorities of Pacifica's Sea-Level Rise Adaptation Plan). Assuming higher sand costs for beach nourishment in the future will increase the costs of Alternative 2, already the costliest option.

Mitigation costs associated with protection alternatives were not included in the cost-benefit analysis, but would be required for sand supply and recreational impacts of armoring.

Costs of ecological goods and services associated with sensitive habitats are not accounted for in this Cost Benefit Analysis, but are discussed below.

Sensitive Habitats

Development and coastal erosion has resulted in significant losses of sensitive habitats in the coastal zone, yet pockets remain (ESA and others 2012). Actions have been taken in Linda Mar (Pacifica State Beach, lower San Pedro Creek, and north Linda Mar dunes) and Mori Point (wetlands, transitional and uplands enhancements) and Sharp Park (Laguna Salada wetlands). While most of the beaches have been lost in north Pacifica and north Rockaway, beaches remain in the Sharp Park, south Rockaway, Linda Mar and Shelter Cove areas. Rocky subtidal and intertidal habitats exist at rocky expressions in north Pacifica, Mori Point – Hidden Cove-Rockaway, and on north and south sides of Linda Mar and Shelter Cover. Some open bluff top space remains, including ancient dune features in north Pacifica, although these are mostly disturbed with human traffic including construction access for coastal armoring or degraded by prior rock quarry activity, and are also threatened by erosion. The following discussion focuses on beach and back-shore wetlands habitats because these features will be affected by the adaptation strategies employed in Pacifica.

Economic Valuation

Ecological values were not "monetized" (estimated in dollars) because there is great uncertainty with such estimates, and as such not included in the Grant Agreement that funded this project. However, beaches and wetland have been valued in dollars by others by others and these values are discussed here to assist in understanding the magnitude and uncertainty relative to coastal ecology losses.

Owing to the rapid loss of tidal wetlands to development, in particular locally in San Francisco Bay, policies were enacted which essentially induce a "no net loss" of wetlands with future development. This means that impacts to wetlands are restricted and if permitted must be mitigated. Often, the amount of wetlands required to be created are much greater than the wetlands impacted, with "mitigation ratios" often on the order of 3:1 (three acres of

wetland creation for every acre of wetland impacted). Further, mitigation requires attaining metrics such as vegetation and even animal populations and documenting success via monitoring and reporting that is typically on the order of 10 years, but sometimes much longer. These mitigation costs can be used as a surrogate for the monetary value of wetlands: That is, the cost to create new wetlands. Even so, there are a range of values associated with wetland mitigation, and site-specific contemporary evaluations are required to develop estimates with the confidence needed for budgeting. A key consideration is what type of wetlands and whether there is land available for mitigation.

The wetlands in Pacifica are typically back-barrier brackish wetlands formed by the wave-built beach ridge blocking drainage and causing lagoon wetlands to form in the inland low lands (ESA PWA et al. 2011). The last remaining expression is Laguna Salada and recently restored wetlands at the foot of Mori Point (Sharp Park) and a small remnant at the San Pedro Creek Mouth (Linda Mar) and pockets in Lower Pedro Point and West Linda Mar. An informal survey of wetland restoration specialists in ESA indicate a range of wetland restoration costs from $30,000 to $100,000 per acre and sometimes higher. A recently constructed lagoon wetland restoration in Santa Barbara cost about $60,000 per acre for the basic restoration (earthwork primarily) and closer to $200,000 per acre when the associated public access trails and bridges and revegetation of adjacent uplands are added (UCSB[25]): These values do not include land purchase and "soft" costs such as design, approvals, and project management.

Valuing beaches is more difficult, partly because the restrictions on impacting beaches by development are not as strict as those for wetlands: For example, a "no-net-loss" policy doesn't exist for beaches as one does for wetlands. Prior studies have used an academic (published) estimate of about $20,000 to $40,000 per acre per year of ecosystem services (ESA PWA 2012). More recently, the cost of restoring beaches in California has been used, analogous to wetlands mitigation costs discussed above (Leo et al. 2017; CCC 2015b). Much like wetland restoration, there is uncertainty about what costs to include or not: For example, should infrastructure relocation cost be included in restoration or should the cost be reduced by the flood-damage reduction value associated with the new roadway located farther inland? A re-examination of the beach enhancement costs did not solve these uncertainties, but did result in a range of about $2,000 to $20,000 per foot of shore and $1 Million to $10 Million per acre of beach restored (Battalio 2018). Pacifica State Beach Managed Retreat was one of the projects used to develop these estimates, establishing the low end of the range, possibly because wastewater treatment facilities were left in place and pump stations were locally armored and integrated into the landscape design.

Beaches and Dunes

While recreational value of beaches is represented in the cost-benefit analysis, the ecological value of beaches and dunes in Pacifica is not included in the analysis. Beaches throughout Pacifica provide foraging and resting area for shorebirds including the Western Snowy Plover.

Existing beaches are narrow along most of northern Pacifica, with the exception of Sharp Park. As shown in Table 17, the shoreline model used in this study shows beaches largely disappearing in 2050 without actions such as beach nourishment or managed retreat. Beaches may not actually disappear by 2100 for Alternative 3 as shown in table above, or may disappear more slowly than indicated by the shoreline evolution model used in this study.

[25] See UC Santa Barbara Habitat Restoration Projects Page here: http://copr.nrs.ucsb.edu/about/programs/habitat-restoration-projects

A comparison of shore evolution model and commonly applied Bruun-type transgression and beach implications are described in section: **Erosion and Beach Width Modeling Comparison** in the report above.

Table 17: Beach Area (acres) today and with Med-High SLR Scenario

	2017	2050			2100		
Sub-area	Existing	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Fairmont West	2.9	0.1	2.4	0.2	0	2.2	0
West Edgemar, Pacific Manor	3.5	0.0	2.6	0.3	0	1.9	0
Northwest Sharp Park	1.7	0.0	0.9	0.4	0	1.1	0
Sharp Park, West Fairway Park and Mori Point	16.0	2.5	14.3	10.7	0	12.0	2.9
Rockaway Beach	3.2	0.0	2.2	0.0	0	2.0	0
Pacifica State Beach (including Pedro Point)	18.0	3.4	14.0	8.2	0	19.5	0

Dune habitat in Pacifica is primarily located at Pacifica State Beach. As shown in Table 18 below, the dune habitat is subject to impacts from shoreline erosion with SLR. Beach nourishment should be coupled with dune restoration in this area as needed in the future to maintain ecological function as well as flood protection and storm erosion buffer that dunes provide for backshore infrastructure. Future dune area could be expanded in a managed retreat scenario by restoring dunes seaward of Highway 1 (or in its place if realigned) as well as restoring parking and commercial areas to dune habitat.

Table 18: Dune Area (acres) today and with Med-High SLR Scenario

	2017	2050			2100		
Sub-area	Existing	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Pacifica State Beach	8.6	1	8.6	TBD	0	8.6	TBD

Wetlands

There are two primary areas of wetland habitat in Pacifica: wetlands in Laguna Salada and wetlands at the mouth of San Pedro Creek. These two areas are described below in relation to future coastal erosion and inundation. Acreages are provided for existing conditions and with each adaptation alternative in Table 19 below. Existing acreages of wetland were determined from the National Wetlands Inventory (USFWS 2014) for Laguna Salada, while the lagoon portion of San Pedro Creek downstream of Highway 1 was digitized in GIS from San Mateo County 2017 aerial imagery.

Table 19: Wetland Area (acres) today and with Med-High SLR Scenario considering erosion

	2017	2050			2100		
Wetland	Existing	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Laguna Salada	32.2	32.2	32.2	32.0	32.2	32.2	29.8
San Pedro Creek	1.5	1.5	1.5	1.5	1.5	1.5	0.7

At Laguna Salada (Sharp Park), the marine terrace slopes below sea level, creating a broad coastal lowland and valley gradient associated with Sanchez Creek. This is the location of a historic barrier beach and back-barrier lagoon wetland complex (Laguna Salada), formed by impoundment of freshwater runoff from the local watershed, and intermittent marine overwash, establishing a fresh-brackish non-tidal wetland gradient. The modern Laguna

Salada is an artificially drained managed pond (water surface elevations normally drawn down to near or below +7.0 ft NAVD due to pump discharge of beach impounded freshwater inflows), with nearly most storm overwash excluded by an earthen berm constructed along the barrier beach crest. The lagoon wetlands are oligohaline (fresh-brackish, 2-4 parts per thousand salinity) despite flushing of freshwater inflows, due to residual sediment salinity, beach groundwater salt seepage, and evaporation.

The Laguna Salada wetland complex supports the highest concentration of special-status wetland wildlife species on the San Francisco Peninsula coast, including the CA red-legged Frog (CRLF) and San Francisco Garter Snake (SFGS). The barrier beach and lagoon ecosystem that supports them is inherently subject to coastal geomorphic and fluvial processes (wave overwash, barrier narrowing and landward transgression/rollover, lagoon fluvial flooding and breaching) associated with shoreline retreat. Wetland habitat in the lagoon has some space available for transgression with SLR into the surrounding golf course that currently constrains the wetland. As seen in Table 19, while protection alternatives 1 and 2 could maintain the wetland in its current state, the existing wetland extent could be maintained in a managed retreat scenario until around 2050 (assuming med-high SLR) with relatively small losses thereafter which could be mitigated for through restoration in the surrounding area. Historically this lagoon had saltwater influence as the barrier beach was overtopped more frequently than the existing access berm. Thus, it is likely not an issue if the lagoon is periodically impacted by saltwater from wave overtopping of the barrier beach, as freshwater habitats that have been fostered by the presence of the golf course and pumping infrastructure would convert to brackish wetlands. Nearby, there are two ponds in Mori Point that were constructed by GGNRA in 2007 to expand local CRLF breeding and enhance local conditions for the SFGS. In the future, lower lying holes could be restored to freshwater wetland terraces to maintain freshwater habitats around Laguna Salada with SLR if managed retreat is required (i.e. to maintain beach area). Storm flooding from rainfall runoff does not pose a threat to long term wetland function as impacts are temporary, with or without retreat. Tidal inundation and/or rising groundwater levels in the lagoon could impact wetland habitats with greater amounts of SLR. If rising water levels in the lagoon are not effectively managed by existing or upgraded pumping infrastructure, the area of wetlands could otherwise me maintained if surrounding golf holes are restored for transgression space.

The mouth of San Pedro Creek Lagoon forms a small freshwater lagoon and marsh that supports a number of species. No data on CRLF are available for the local lagoon, but they are present in the San Pedro Creek watershed upstream. Wetland area in the lagoon could be impacted by shoreline erosion around 2050 (assuming med-high SLR) and has limited adjacent transgression space as it is abutted by roadway embankments, however floodplain area upstream of Highway 1 could serve as wetland transgression space for the lower creek system. Periodic coastal flooding is not an issue for the lagoon. With higher amounts of SLR (4+ feet) the lagoon could convert to a saltier system if the mouth does not aggrade with SLR and marine overwash increases.

5.4 Cost-Benefit Analysis Results for Pacifica Sub-areas

This section presents the benefit/cost results based on the methods described in Chapter 5. The figures and tables below present the results of the benefit/cost analysis for each planning sub-area for three time horizons: 2018, 2050, and 2100 considering the med-high SLR scenario. Benefits and costs are presented as net present value (NPV), discounted at 3% a year from 2018. The benefits and costs are broken down into four categories (and colored in the figures):

- Engineering costs (blue), which include the costs of structures, such as seawalls and revetments, as well as other engineering solutions such as elevating structures or beach nourishment;
- The "vulnerability" (orange and yellow) parts of the estimates includes loss of private and public property due to erosion (orange), and flooding (yellow).
- The recreation (green) part includes (non-market) estimates of the value of beach recreation in each particular sub-area, where relevant.
- The potential transaction costs (grey) present a range of potential costs to the City of 0-50%.

The tables below these figures present the specific dollar values shown in the figures. The "Net Benefits" section adds up all benefits and costs with the exception of the additional transaction costs. Since, in many cases, the City will sustain losses regardless of the solution chosen, the net benefits are often negative, such that the least costly option will be that with the highest net benefits.

The figures and tables also require some explanation regarding how to interpret them:

- The 2018 planning horizon gives a snapshot of the situation today. It also includes any costs that would need to be implemented today.
- The 2018-2050 planning timeframe (2050) combines the value of recreational benefits minus engineering costs, any flooding/erosion losses to private or public property and potential transaction costs. These values have been discounted at 3% a year from 2018.
- The 2051-2100 planning timeframe (2100) combines the value of recreational benefits minus engineering costs, any flooding/erosion losses to private or public property and potential transaction costs. These values have been discounted at 3% a year from 2018.

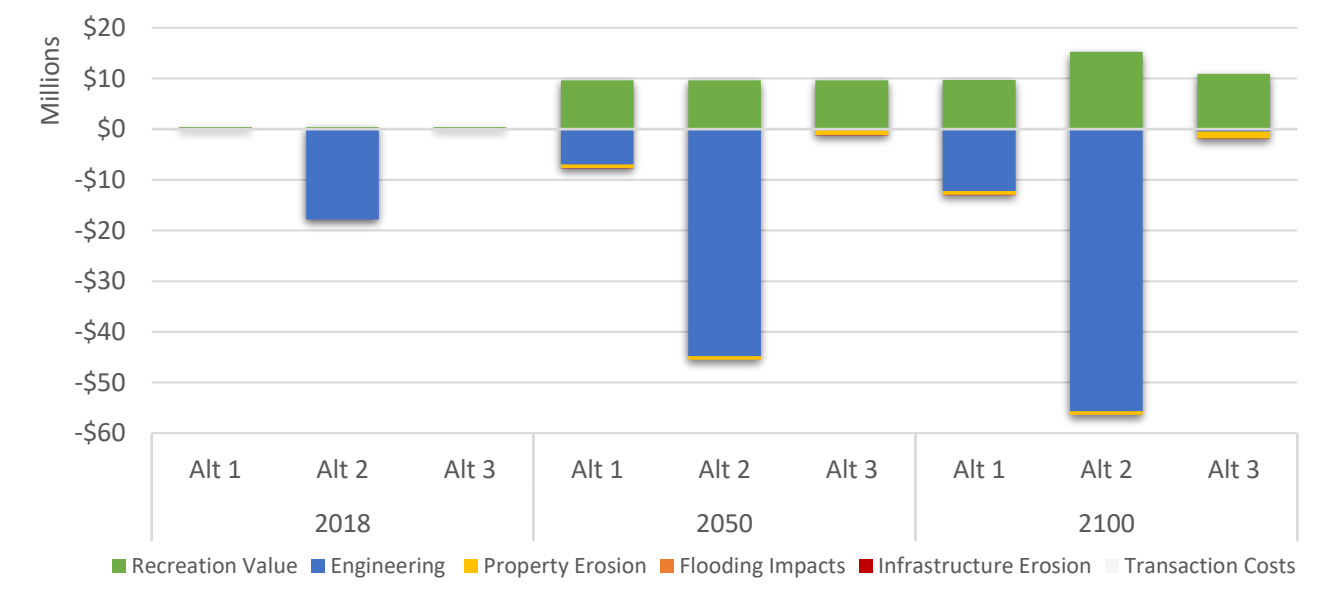
For planning purposes, the 2050 planning horizon is probably the most useful since it provides the City with the best current estimates for the next 32 years. The 2100 planning horizon may also useful for long range planning, but given the level of uncertainty surrounding climate change and sea-level rise, the study authors urge caution in interpreting estimates after 2050. The California Coastal Commission grant funding for the project requires an examination of 2100, but the exact forecast has a wide margin of error.

The exact details of each alternative are discussed in Chapter 5 of this report. Alternative 1 generally entails the use of armoring and other hard structures to protect against chronic erosion and 1% annual probability storm damage. Alternative 2 primarily adds beach nourishment to the protection strategies in Alternative 1, and includes some accommodation alternatives to flooding protection strategies in Alternative 1. Alternative 3 is best described as allowing erosion by removing existing armoring structures, purchasing and clearing property (with owner volunteering) and realigning improvements and infrastructure as needed to avoid impacts to erosion. Alternative 3 is hypothetical (as is 1 and 2) and represents a future in which all private landowners voluntarily agree to sell their property as it is impacted by coastal erosion. Alternative 3 in this document is not a policy or enforceable

commitment by the City to force residents from their homes or businesses, but an alternative analyzed to inform the City about the range of adaptation options.

Fairmont West

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for this sub-area are compiled in Appendix C of this report. In this sub-area only a small number of parcels are vulnerable (22 parcels) and most of the vulnerability is represented by land values. In the Fairmont West sub-area, shown in Figure 19 and Table 20 below, Alternative 3 provides the highest net benefits. The value of the public and private property at-risk is relatively low (e.g., $700,000 for Alternative 1 in 2050) compared to the engineering costs associated with protecting this property. Alternative 2, which adds nourishment, increases recreational value in the 2100 planning horizon, but this increase is lower than the cost of the nourishment. Flooding impacts are not an issue for any of these parcels. Engineering costs include realignment of existing infrastructure (road, pipes). The transaction cost contingency can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure.



Pacifica LCP 170663

SOURCE: ESA,

Figure 19

Benefits and Costs (NPV) of Three Adaptation Alternatives in Fairmont West

Table 20: Detailed Breakdown of Benefits and Costs of Three Alternatives in Fairmont West

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	$0	-$17,800,000	$0
2050	-$7,000,000	-$44,800,000	-$200,000
2100	-$12,200,000	-$55,600,000	-$500,000
Erosion Losses			
2018	$0	$0	$0
2050	-$700,000	-$700,000	-$1,000,000
2100	-$700,000	-$700,000	-$1,400,000
Flooding Damages			
2018	$0	$0	$0
2050	$0	$0	$0
2100	$0	$0	$0
Recreation Value			
2018	$400,000	$400,000	$400,000
2050	$9,600,000	$9,600,000	$9,600,000
2100	$9,700,000	$15,300,000	$10,900,000
Net Benefits (No Additional Transaction Costs)			
2018	$400,000	-$17,400,000	$400,000
2050	$1,900,000	-$35,900,000	$8,400,000
2100	-$3,200,000	-$41,000,000	$9,000,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$400,000
2100	$0	$0	-$500,000

Potential Property Tax Losses

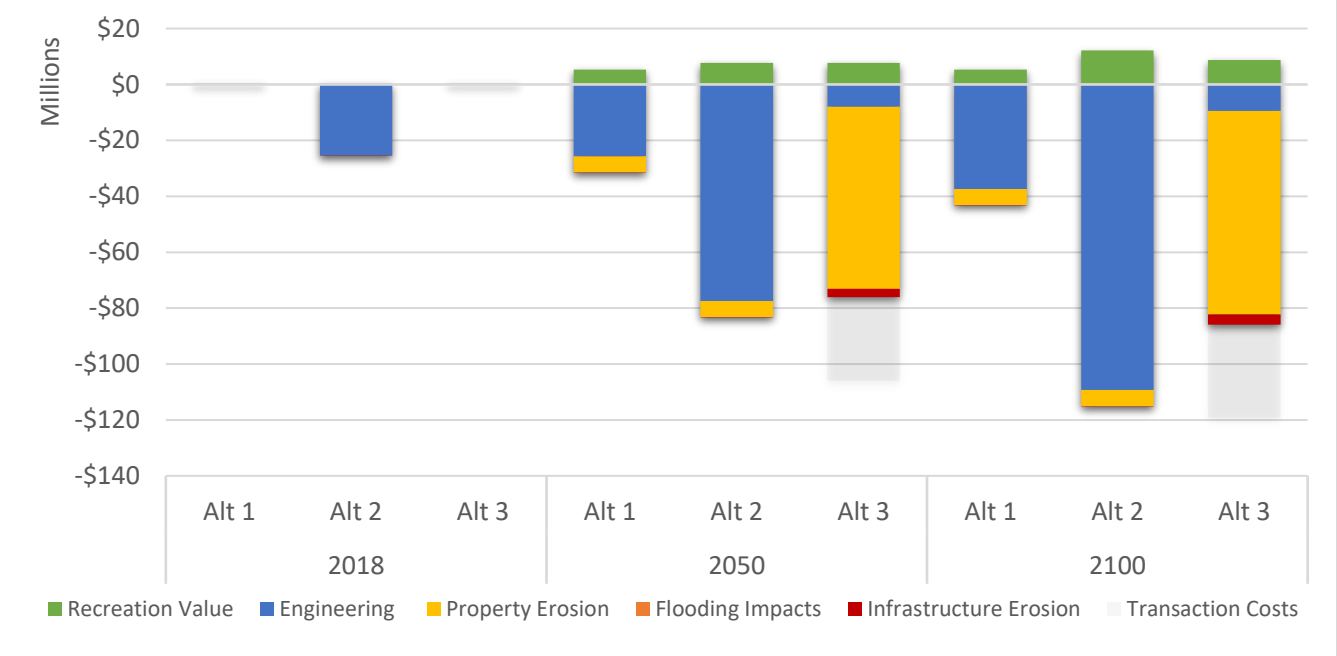
Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 21 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 21 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year) applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 21: Expected Losses in Property Tax Revenue in Fairmont West for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$4,000	$33,000	$62,000
Alt 2	$4,000	$33,000	$61,000
Alt 3	$6,000	$56,000	$104,000

West Edgemar and Pacific Manor

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for this sub-area are compiled in Appendix C of this report. Figure 20 and Table 22 below present the results of the benefit/cost analysis for the West Edgemar/Pacific Manor sub-area. In this sub-area, Alternative 1 provides the lowest costs for both the 2018-2050 and the 2051-2100 planning horizons. Even with Alternative 1, which involves armoring, the consultants estimate that there will be some property (land and infrastructure) losses due to erosion. However, the erosion losses under Alternative 3 include property and structures and are thus significantly higher, such that armoring is the lowest cost alternative. Alternative 2 involves additional nourishment of the beach, with little corresponding increases in recreational value. Flooding during a 1% probability storm is not an issue in this sub-area. Alternative 3 does imply the loss of several apartment complexes, so the City would need to plan for these losses of residences within the community. The transaction cost contingency in Alternative 3 can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Engineering costs shown for Alternative 3 include removing existing coastal armoring and blufftop road/infrastructure realignment. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure.



Pacifica LCP 170663

SOURCE: ESA,

Figure 20
Benefits and Costs of Three Adaptation Alternatives in West Edgemar and Pacific Manor

Table 22: Detailed Breakdown of Benefits and Costs of Three Adaptation Alternatives in West Edgemar, Pacific Manor

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	$0	-$25,400,000	$0
2050	-$25,700,000	-$77,500,000	-$8,000,000
2100	-$37,400,000	-$109,300,000	-$9,500,000
Erosion Losses			
2018	$0	$0	$0
2050	-$5,800,000	-$5,800,000	-$68,100,000
2100	-$5,800,000	-$5,800,000	-$76,400,000
Flooding Damages			
2018	$0	$0	$0
2050	$0	$0	$0
2100	$0	$0	$0
Recreation Value			
2018	$300,000	$300,000	$300,000
2050	$5,400,000	$7,700,000	$7,700,000
2100	$5,400,000	$12,200,000	$8,800,000
Net Benefits (No Additional Transaction Costs)			
2018	$300,000	-$25,100,000	$300,000
2050	-$26,100,000	-$75,600,000	-$68,400,000
2100	-$37,800,000	-$102,900,000	-$77,100,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$29,900,000
2100	$0	$0	-$33,300,000

Potential Property Tax Losses

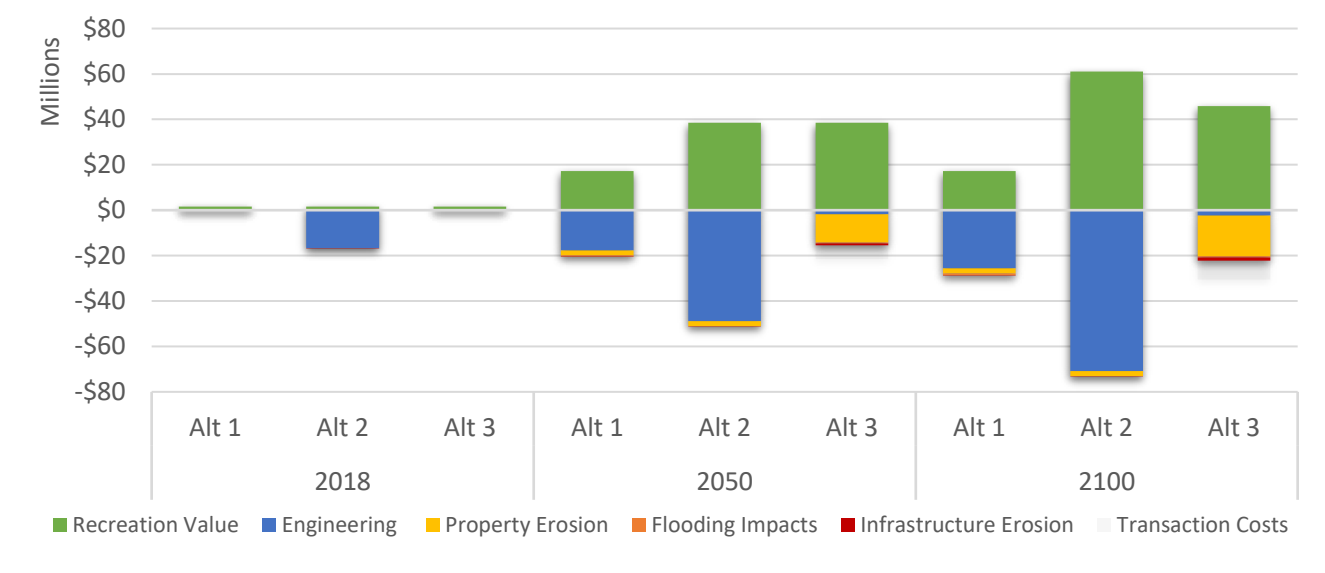
Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 23 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 23 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year) applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 23: Expected Losses in Property Tax Revenue in West Edgemar, Pacific Manor for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$78,000	$693,000	$1,280,000
Alt 2	$78,000	$693,000	$1,280,000
Alt 3	$853,000	$7,619,000	$14,076,000

Northwest Sharp Park

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for this sub-area are compiled in Appendix C of this report. Figure 21 and Table 24 present the benefit/cost analysis for Northwest Sharp Park. For the 2050 and 2100 planning horizons, Alternative 3 provides the highest net benefits in this analysis. One significant factor in this sub-area is the potential erosion of the sandy beach under Alternative 1, which lowers future recreational benefits within this alternative. The transaction cost contingency in Alternative 3 can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Engineering costs shown for Alternative 3 include removing existing coastal armoring and intermediate blufftop road/infrastructure realignment. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure.



Pacifica LCP 170663

SOURCE: ESA,

Figure 21
Benefits and Costs of Three Adaptation Alternatives in Northwest Sharp Park

Table 24: Detailed Breakdown of Benefits and Costs of Three Alternatives in Northwest Sharp Park

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	$0	-$16,700,000	$0
2050	-$17,700,000	-$48,900,000	-$1,700,000
2100	-$25,700,000	-$70,900,000	-$2,400,000
Erosion Losses			
2018	$0	$0	$0
2050	-$2,200,000	-$2,200,000	-$12,500,000
2100	-$2,200,000	-$2,200,000	-$17,800,000
Flooding Damages			
2018	$0	$0	$0
2050	-$500,000	$0	-$400,000
2100	-$800,000	$0	-$600,000
Recreation Value			
2018	$1,700,000	$1,700,000	$1,700,000
2050	$17,200,000	$38,500,000	$38,500,000
2100	$17,200,000	$61,100,000	$45,900,000
Net Benefits (No Additional Transaction Costs)			
2018	$1,700,000	-$15,000,000	$1,700,000
2050	-$3,200,000	-$12,600,000	$23,900,000
2100	-$11,500,000	-$12,000,000	$25,100,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$6,000,000
2100	$0	$0	-$8,300,000

Potential Property Tax Losses

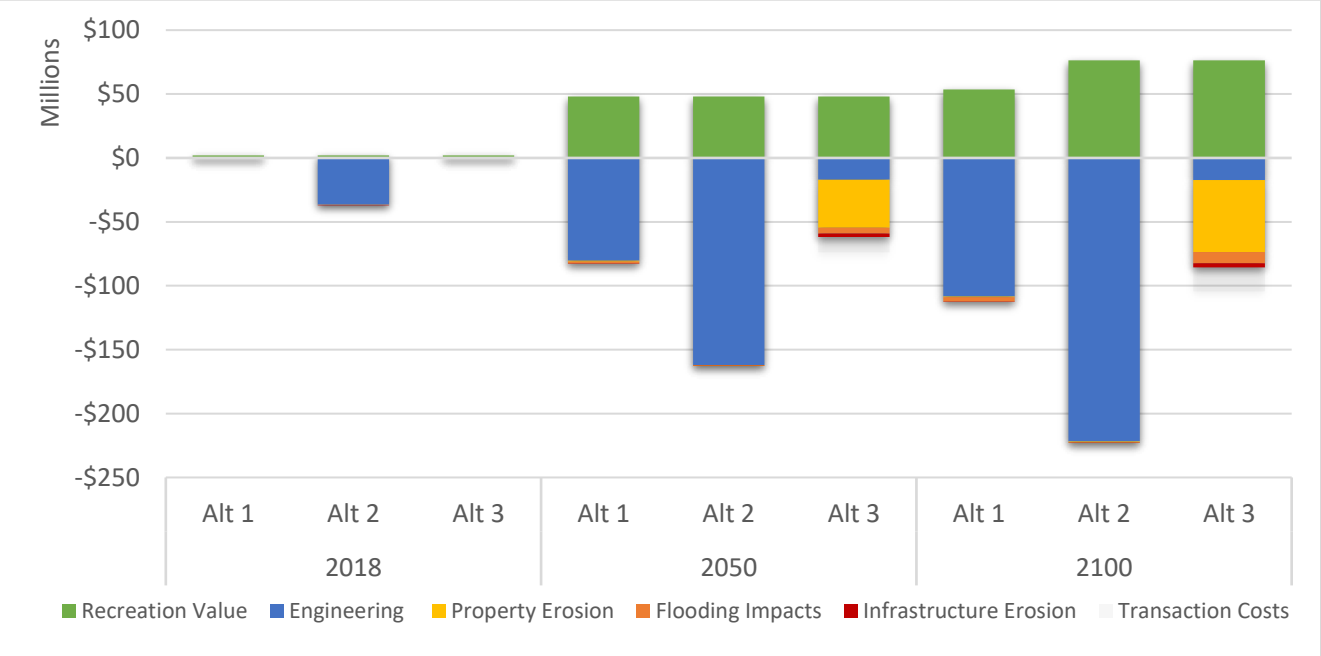
Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 25 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 25 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year) applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 25: Expected Losses in Property Tax Revenue in Northwest Sharp Park for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$30,000	$266,000	$492,000
Alt 2	$30,000	$266,000	$492,000
Alt 3	$208,000	$1,855,000	$3,427,000

Sharp Park, West Fairway Park and Mori Point

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for this sub-area are compiled in Appendix C of this report. Figure 22 and Table 26 below present results for the Sharp Park, West Fairway Park, and Mori Point sub-area. For the 2050 and 2100 planning horizons, Alternative 3 provides the highest net benefits, primarily because the engineering costs associated with armoring, and armoring with nourishment, significantly exceed the benefits (in terms of lowering property vulnerability). Alternative 3 does imply impacts to the Sharp Park sewer pump station and an apartment building as well as other property. The City would need to plan for the loss of residences in the community. Recreational benefits are the same for all alternatives, except in 2100, when Alternative 1 has lower recreational benefits, as the beach erodes. Our estimates do indicate a significant amount of property loss under Alternative 3. The transaction cost contingency in Alternative 3 can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Engineering costs shown for Alternative 3 include removing existing coastal armoring, relocating pump stations and intermediate blufftop road/infrastructure realignment. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure. Managed retreat of the Sharp Park Golf Course Berm to facilitate lateral public access was not included in the cost-benefit analysis, but would entail realignment of a similar earthen berm further landward which could cost approximately $530,000 per realignment (assuming 10-foot wide path with 2:1 side slopes that is constructed 20 feet above the ~10 ft NAVD interior to match existing berm elevations) which is small compared to the overall cost of managed retreat.



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SOURCE: ESA,

Figure 22
Benefits and Costs of Three Adaptation Alternatives in Sharp Park, West Fairway Park and Mori Point

Table 26: Detailed Breakdown of Benefits and Costs of Three Alternatives in Sharp Park, West Fairway Park, and Mori Point

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	-$200,000	-$36,600,000	-$200,000
2050	-$80,500,000	-$161,900,000	-$17,000,000
2100	-$108,300,000	-$221,800,000	-$17,300,000
Erosion Losses			
2018	-$200,000	-$200,000	-$200,000
2050	-$700,000	-$700,000	-$40,200,000
2100	-$800,000	-$800,000	-$59,500,000
Flooding Damages			
2018	-$100,000	-$100,000	-$100,000
2050	-$1,500,000	-$100,000	-$4,600,000
2100	-$3,500,000	-$100,000	-$8,900,000
Recreation Value			
2018	$2,100,000	$2,100,000	$2,100,000
2050	$48,100,000	$48,100,000	$48,100,000
2100	$53,600,000	$76,400,000	$76,400,000
Net Benefits (No Additional Transaction Costs)			
2018	$1,600,000	-$34,800,000	$1,600,000
2050	-$34,600,000	-$114,600,000	-$13,700,000
2100	-$59,000,000	-$146,300,000	-$9,300,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$12,200,000
2100	$0	$0	-$18,800,000

Beach Recreation Valuation

Several comments on the final draft Adaptation Plan questioned whether the valuation of beach visitation, $40/day per person-visit, was too high and whether a lower value might result in a different assessment of alternative net costs. In particular, commenters opined that a lower value should be used because the beach in front of Sharp Park has dangerous waves and other negative conditions, adding that a lower beach valuation would facilitate funding for coastal armoring. These commenters also emphasized that the number of people using the beach was very small, and less than the estimates used in the adaptation study. In response to these concerns, a review of the economic projections was accomplished using the Sharp Park subarea, and a sensitivity analysis was accomplished by using a lower valuation ($10 / day per person-visit). The adaptation analysis did not separately assess pedestrian uses of the berm walkway because we presumed that a shore walking trail would be maintained for all alternatives.

A review of the prior analysis (with $40/ day per person-visit) indicates that the recreational value of the beach was computed to be the same for all options in 2018 and 2050 (in Table 26 above). In this case increasing or reducing the value of a beach day (e.g., from $40 to $10) would make no difference in the ranking. By 2100 under Alternative 1, the beach erodes to the point where recreational value declines relative to other alternatives (Alternative 2 consists of armoring and beach nourishment and Alternative 3 consists of managed retreat).

Using the lower beach valuation ($10/day per person-visit) does not change the rankings, even for year 2100 where the beach is forecast to be greatly reduced for Alternative 1 Shore Armoring (Table 27). Using the $10/day per person-visit, the total recreational benefits are now $13.4 m for Alt 1, and $19.1 m for Alts 2 and 3. The net benefits for Alt 1 are now -$99.4 m, for Alt 2 the net benefits are -$203.8m; for Alt 3 the net benefits are -$57.1m. Consequently, even for a much lower (or even zero) valuation for beach recreation, Alt 3 has the highest net benefits.

In summary, the lowering the value of a beach day, or lowering attendance, will not change the rank ordering of the alternatives economics results as shown by comparison of Table 26 and Table 27. Note that the effect of lowering the beach value by a 75% yields the same result as lowering attendance by 75% or reducing both attendance and unit value by 50%.

Table 27: Alternative Recreation Value and Net Benefits Applying a $10/day Beach Value at Sharp Park, West Fairway Park, and Mori Point sub-area

Year	Alternative 1	Alternative 2	Alternative 3
Recreation Value			
2018	$525,000	$525,000	$525,000
2050	$12,025,000	$12,025,000	$12,025,000
2100	$13,400,000	$19,100,000	$19,100,000
Net Benefits (No Additional Transaction Costs)			
2018	$125,000	-$36,375,000	$125,000
2050	-$70,675,000	-$150,775,000	-$41,375,000
2100	-$99,400,000	-$203,800,000	-$57,100,000

Further, the US Army Corps of Engineers can consider the beach recreation as a factor in assessing a Federal interest in cost-sharing beach nourishment projects. Therefore, valuing a beach lower is not necessarily a valid strategy for attaining funding. Finally, it is the economist's professional opinion that the $10/ day per person visit is too low and we do not recommend using this value.

Wetland Habitat Valuation

In addition, the City of San Francisco, which owns the Sharp Park golf course, as well as a number of Pacifica residents, suggested that a habitat value be applied to land lost due to erosion at the Sharp Park golf course. However, there are potential ecological impacts with all of the alternatives: Beaches also support valuable ecology (Dafeo et. al. 2009; Dugan et. al. 2006) and Alt 1 armoring results in greater beach habitat loss, and there are construction-period impacts with Alt 2 nourishment. Therefore, there are ecological tradeoffs associated with the response to sea-level rise. Economic valuation of ecology (wetland, beach, etc.) is not within the scope of this study, but we agree that Pacifica or other public agency or land owner may wish to consider ecology in their adaptation planning. Wetland habitat dollar values are discussed in Section 5.3 under **Sensitive Habitats**.

Potential Property Tax Losses

Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 28 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 28 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year)

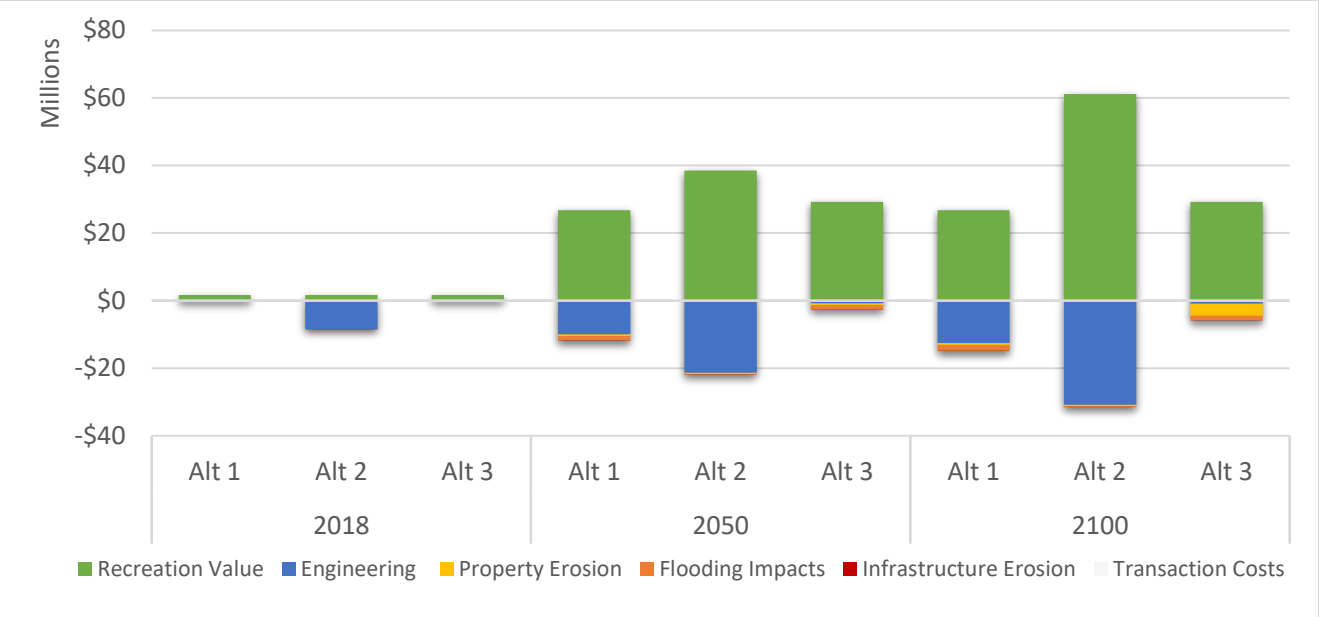
applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 28: Expected Losses in Property Tax Revenue in Sharp Park, West Fairway Park, and Mori Point for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$300	$3,000	$5,000
Alt 2	$300	$3,000	$5,000
Alt 3	$328,000	$2,933,000	$5,419,000

Rockaway Beach, Quarry and Headlands

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for this sub-area are compiled in Appendix C of this report. Figure 23 and Table 29 present the benefit/cost analysis for the Rockaway Beach, Quarry, and Headlands sub-area. For the 2018 and 2050 planning horizons, Alternative 3 provides the highest net benefits. By 2100, Alternative 2 yields the highest net benefits. It should also be noted that the consultants who conducted this study performed a sensitivity analysis for future beach attendance (see below). By 2100, erosion losses are forecasted to reach part of one of the hotel properties—which is why Alternative 2 is preferred by 2100. The main implication here is that once critical businesses are impacted at Rockaway, some kind of protection is warranted by this economic analysis. In addition, if beach demand continues to grow, nourishment may also be a cost-effective method to protect property and provide additional beach recreation. The transaction cost contingency can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure. The transaction cost contingency in Alternative 3 can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Engineering costs shown for Alternative 3 include removing existing coastal armoring, floodproofing a pump station and intermediate blufftop road/infrastructure realignment.



Pacifica LCP 170663

SOURCE:
ESA,

Figure 23

Benefits and Costs of Three Adaptation Alternatives in the Rockaway Beach, Quarry and Headlands

Table 29: Detailed Breakdown of Benefits and Costs of Three Alternatives in Rockaway Beach, Quarry, and Headlands

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	$0	-$8,400,000	$0
2050	-$10,000,000	-$21,300,000	-$800,000
2100	-$12,500,000	-$30,800,000	-$900,000
Erosion Losses			
2018	$0	$0	$0
2050	-$500,000	-$500,000	-$600,000
2100	-$600,000	-$600,000	-$3,600,000
Flooding Damages			
2018	-$100,000	$0	-$100,000
2050	-$1,200,000	$0	-$1,200,000
2100	-$1,700,000	$0	-$1,200,000
Recreation Value			
2018	$1,700,000	$1,700,000	$1,700,000
2050	$26,800,000	$38,500,000	$29,200,000
2100	$26,800,000	$61,100,000	$29,200,000
Net Benefits (No Additional Transaction Costs)			
2018	$1,600,000	-$6,700,000	$1,600,000
2050	$15,100,000	$16,700,000	$26,600,000
2100	$12,000,000	$29,700,000	$23,500,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$200,000
2100	$0	$0	-$1,600,000

Potential Property Tax Losses

Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 30 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 30 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year) applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 30: Expected Losses in Property Tax Revenue in Rockaway Beach, Quarry and Headlands for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$5,000	$46,000	$84,000
Alt 2	$5,000	$46,000	$84,000
Alt 3	$6,000	$50,000	$93,000

Potential Sales and Transient Occupancy Tax Losses

Since Rockaway also includes hotels, this study also estimated potential losses in transient occupancy taxes. As with West Linda Mar, losses due to flooding are more serious in the 2050-2100 time periods. Since the primary losses in sales and transient occupancy taxes are likely due to businesses closing from flooding, this study estimated the potential sales tax and transient occupancy tax losses from one flood event. The City of Pacifica provided high and low estimates for sales and transient occupancy taxes in the Rockaway planning area. The property damages from a (1%) transient occupancy taxes when businesses shut down. Table 31 and Table 32 below present estimates of sales tax and transient occupancy tax losses from one flood event in the Rockaway area. Following another economic study of sea level rise impacts in San Diego County,[26] this study presents losses for a 15-day, 30-day and 60-day period, for one flood event.

Table 31: Potential Sales Tax Losses from Flooding at Rockaway Beach, Quarry and Headlands

	Low	High	Average
Sales Tax	$118,100	$171,674	$144,887
Flooding Losses			
15 day	$4,853	$7,055	$5,954
30 day	$9,706	$14,110	$11,908
60 day	$19,413	$28,220	$23,817

Table 32: Potential Transient Occupancy Tax Losses from Flooding at Rockaway Beach, Quarry and Headlands

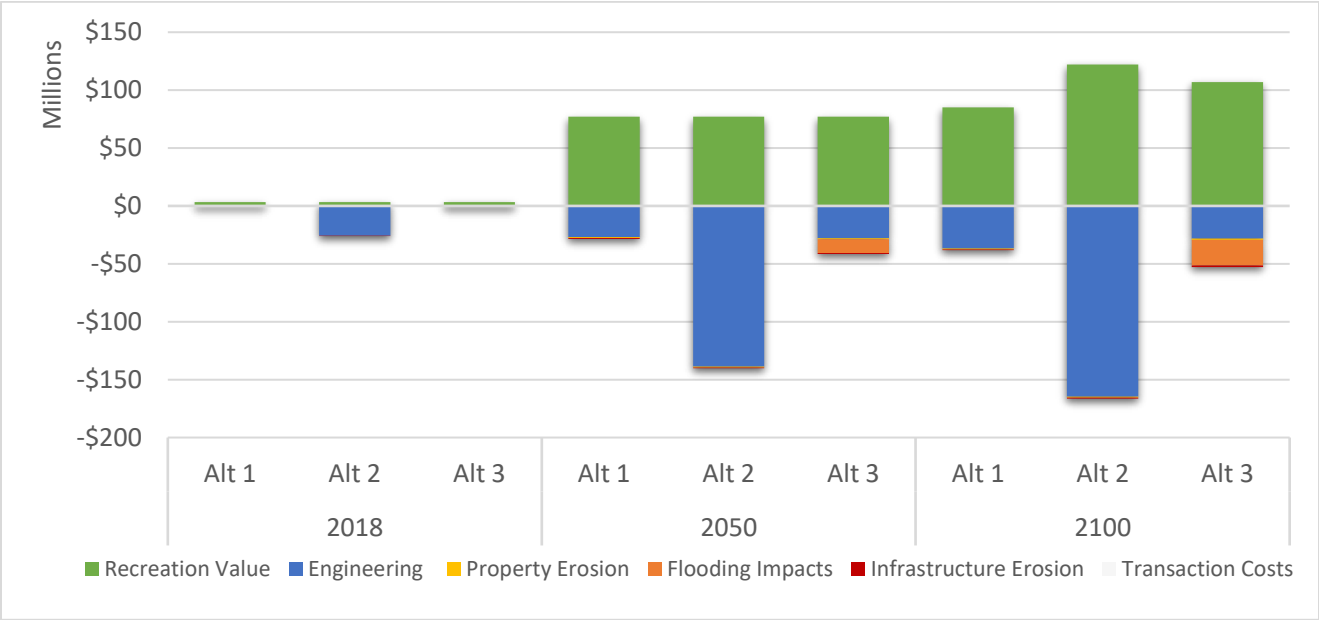
	Low	High	Average
Sales Tax	$739,435	$1,289,839	$1,014,637
Flooding Losses			
15 day	$30,387	$53,007	$41,697
30 day	$60,775	$106,014	$83,394
60 day	$121,550	$212,028	$166,789

Pacifica State Beach & West Linda Mar

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for each of these two sub-areas are compiled in Appendix C of this report. Figure 24 and Table 33 provide benefit/cost estimates for West Linda Mar, Pacifica State Beach sub-areas. In these sub-areas, Alternative 1 provides the highest net benefits for the 2018 and 2050 planning horizons. By 2100, Alternative 3 has somewhat higher net benefits since Alternative 3 allows for a wider beach at Pacifica SB and provides more recreational benefits. The largest property damages involve flooding, including flooding to some shopping areas in West Linda Mar, which may disrupt local businesses as well. The potential tax losses from loss of sales in West Linda Mar are discussed later in this report. The City may want to also consider the potential losses in tax dollars in its assessment. The transaction cost contingency in Alternative 3 can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment. Engineering costs shown for Alternative 3 include removing existing coastal armoring, relocating pump stations and intermediate blufftop

[26] Regional Economic Vulnerability to Seal Level Rise in San Diego County, Center for the Blue Economy, 2018, http://centerfortheblueeconomy.org/wp-content/uploads/2018/04/4.4.18.Final-San-Diego-Vulnerability-Report.pdf.

road/infrastructure realignment. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure.



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SOURCE: ESA,

Figure 24
Benefits and Costs of Three Adaptation Alternatives in West Linda Mar and Pacifica State Beach

Table 33: Detailed Breakdown of Benefits and Costs of Three Alternatives in West Linda Mar and Pacifica State Beach

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	-$100,000	-$25,600,000	-$100,000
2050	-$26,900,000	-$138,700,000	-$27,900,000
2100	-$36,700,000	-$164,700,000	-$28,200,000
Erosion Losses			
2018	$0	$0	$0
2050	-$800,000	-$800,000	-$1,000,000
2100	-$800,000	-$800,000	-$1,100,000
Flooding Damages			
2018	$0	$0	-$400,000
2050	$0	$0	-$11,700,000
2100	$0	$0	-$22,200,000
Recreation Value			
2018	$3,300,000	$3,300,000	$3,300,000
2050	$77,000,000	$77,000,000	$77,000,000
2100	$85,200,000	$122,200,000	$107,000,000
Net Benefits (No Additional Transaction Costs)			
2018	$3,200,000	-$22,300,000	$2,800,000
2050	$49,300,000	-$62,500,000	$36,400,000
2100	$47,700,000	-$43,300,000	$55,500,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$200,000
2100	$0	$0	-$200,000

Potential Property Tax Losses

Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 34 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 34 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year) applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 34: Expected Losses in Property Tax Revenue in in West Linda Mar and Pacifica State Beach for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$200	$2,000	$4,000
Alt 2	$200	$2,000	$4,000
Alt 3	$4,000	$38,000	$71,000

Potential Sales Tax Losses

Since the West Linda Mar sub-area includes one major shopping center and several smaller shopping areas, flooding could substantially disrupt business. Table 35 below present estimates of sales tax losses from one flood event in the West Linda Mar sub-area. The exact amount of time that a business shuts down depends upon a number of factors that are impossible to predict. Following another economic study of sea level rise impacts in San Diego County,27 this study presents losses for a 15-day, 30-day and 60-day period, for one flood event. **Error! Reference source not found.** below presents our estimates of sales tax losses for West Linda Mar sub-a rea. The City of Pacifica provided the consultant with a range for yearly sales taxes, since sales taxes can vary due to economic conditions, store openings and closings, etc. For an average year, this study decided to take the average of range, shown in the last column of **Error! Reference source not found.**. Please note that flood d amages may not be a significant threat to shopping areas in the West Linda Mar sub-area in the 2050-2100 planning horizon if adaptation actions are taken. If no action is taken, an extreme storm event (e.g., El Nino) could cause stores to shut down for 15-60 days, and this threat increases with sea level rise over time.

Table 35: Potential Sales Tax Losses from Flooding at West Linda Mar

	Low	High	Average
Sales Tax	$389,945	$566,836	$478,391
Flooding Losses			
15 day	$16,025	$23,295	$19,660
30 day	$32,050	$46,589	$39,320
60 day	$64,101	$93,179	$78,640

The major shopping center and several smaller shopping areas including grocery stores in the Pacifica State Beach and West Linda Mar sub-areas are vital to the community. If these shopping areas are impeded by flooding or other coastal hazards for a significant time, there could be significant losses to the Pacifica community, both economic and non-economic, beyond those estimated in this study. Any adaptation plan must address these issues. As flooding issues become more chronic, the viability of these centers could be in jeopardy. Any plan for retreat of these shopping areas would need to include the costs of relocating vital shopping within the City. The economic analysis valued these centers at current rates, but these relocation costs could be significantly higher.

Pedro Point and Shelter Cove

An overview figure, sea-level rise vulnerabilities, adaptation strategies considered and cost-benefit results for this sub-area are compiled in Appendix C of this report. This sub-area does include a small portion of narrow beach southwest of San Pedro Creek mouth but it is included with the Pacifica State Beach sub-area, and thus recreational benefits are not shown here (but would be relatively small due to the limited beach area). Approximately 80 parcels and structures are vulnerable. Erosion losses become significant after 2050. Retreat is the lowest cost option. Figure 25 and Table 36 provide benefit/cost estimates for Pedro Point and Shelter Cove. For the 2018 time horizon, all alternatives provide the same net benefits. However, for the 2050 and 2100 planning horizons, alternative 3 provides the highest net benefits (lowest costs). Given the margin of error associated with this type of analysis, Alternative 3 has significantly higher net benefits (lower costs) than either Alternative 1 or Alternative 3 without transaction costs. However, if one includes potential transaction costs, all

[27] Regional Economic Vulnerability to Seal Level Rise in San Diego County, Center for the Blue Economy, 2018, http://centerfortheblueeconomy.org/wp-content/uploads/2018/04/4.4.18.Final-San-Diego-Vulnerability-Report.pdf.

three alternatives provide similar net benefits, well within the margin of error. Erosion impacts are broken down by property (public and private land and buildings) and public infrastructure. The transaction cost contingency can also account for the need to purchase landward parcels as needed in order to make space for road and other infrastructure realignment.

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SOURCE: ESA,

Figure 25

Benefits and Costs of Three Alternatives in Pedro Point and Shelter Cove

Table 36: Detailed Breakdown of Benefits and Costs of Three Alternatives in Pedro Point and Shelter Cove

Year	Alternative 1	Alternative 2	Alternative 3
Engineering Costs			
2018	-$100,000	-$100,000	-$100,000
2050	-$25,400,000	-$25,400,000	-$1,000,000
2100	-$35,500,000	-$35,500,000	-$1,200,000
Erosion Losses			
2018	$0	$0	$0
2050	-$1,900,000	-$1,900,000	-$15,000,000
2100	-$1,900,000	-$1,900,000	-$21,300,000
Flooding Damages			
2018	$0	$0	$0
2050	$0	$0	$0
2100	$0	$0	$0
Recreation Value			
2018	$0	$0	$0
2050	$0	$0	$0
2100	$0	$0	$0
Net Benefits (No Additional Transaction Costs)			
2018	-$100,000	-$100,000	-$100,000
2050	-$27,300,000	-$27,300,000	-$16,000,000
2100	-$37,400,000	-$37,400,000	-$22,500,000
Additional Transaction Costs			
2018	$0	$0	$0
2050	$0	$0	-$7,000,000
2100	$0	$0	-$9,900,000

Potential Property Tax Losses

Gains or losses in taxes to the City of Pacifica or elsewhere are not incorporated into this type of benefit/cost analysis. However, the City of Pacifica or other stakeholders may want to consider these losses when evaluating alternatives. Table 37 below presents estimates of the loss in property taxes at current rates and valuations under the three alternatives. These estimates are per year and cumulative for 2018-2050. In Table 37 below, column 3 presents the cumulative loss in property tax dollars for 2018-2050 applying the same discount rate (3% per year) applied in the benefit costs tables/charts above. Column 4 presents the cumulative loss in tax dollars without any discount rate. Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

Table 37: Expected Losses in Property Tax Revenue in Pedro Point and Shelter Cove for Three Adaptation Alternatives

Alternative	One Year Loss	Cumulative 2018-2050 (Present Value)	Cumulative 2018-2050 (No Discount Rate)
Alt 1	$17,000	$148,000	$273,000
Alt 2	$17,000	$148,000	$273,000
Alt 3	$167,000	$1,488,000	$2,750,000

Additional Economic Considerations

Tax Impacts

Tax impacts are not included in the above benefit cost analysis since they do not fall under the scope of a benefit-cost analysis of this type. However, the City of Pacifica and its stakeholders may wish to consider the tax impacts of various alternatives as well. Three important sources of revenue for the City of Pacifica are sales taxes, transient occupancy taxes (TOTs), and property taxes. The City of Pacifica provided the study consultants with aggregate estimates of yearly sales tax revenues for the West Linda Mar sub-area, which includes numerous stores and shopping areas. In addition, the City provided sales and transient occupancy tax data for the Rockaway sub-area, which includes numerous businesses and two hotels. Flooding has the potential to disrupt businesses in many ways. The benefit cost analysis above estimated the cost of repair for flooded structures as well as generalized estimates of content loss (e.g., inventory, furniture). However, these do not include the loss of business revenue and taxes that result from the closure of these businesses. These losses could be substantial.

Property Taxes

The City of Pacifica may also lose property tax revenues. Table 38 below presents this study's estimates of potential property tax losses due to erosion. The average property tax rate for Pacifica is 1.1112% and was applied to the assessed value of property parcels lost to erosion.[28] (This study assumed flooded property would be repaired.) Note that not all property tax revenue goes to the City of Pacifica. In California; cities receive, on average, only 21% of property tax revenues[29], but since the distribution varies by parcel, a more detailed analysis of each parcel would be required since the exact percentage that goes to the City often varies by parcel. As indicated in Table 38, property tax losses could be substantial by 2050 under alternative 3, particularly in the West Edgemar/Pacific Manor sub-area, ($853,000 under Alternative 3 in 2050) Sharp Park/Fairway Park/Mori Point sub-area, ($328,000 under Alternative 3 in 2050) NW Sharp Park sub-area (208,000 under Alternative 3 in 2050) and Pedro Point sub-area, ($167,000 under Alternative 3 in 2050). This study did not evaluate property tax losses for the 2050-2100 planning horizon since the assessed value of the homes over a long-term horizon depends on a number of other factors not considered in this study (e.g., the turnover of residential and commercial property, which effects the assessed value due to Proposition 13).

Table 38: Potential Loss in Property Taxes by Sub-area and Alternative

Planning Area	Alt 1		Alt 2		Alt 3	
	2018	2050	2018	2050	2018	2050
W. Edgemar, Pac. Manor	$0	$78,000	$0	$78,000	$0	$853,000
Fairmont West	$0	$4,000	$0	$4,000	$0	$6,000
Sharp Park, W. Fairway Park, Mori Pt.	$0	< $1,000	$0	< $1,000	$0	$328,000
Pedro Pt, Shelter Cove	$0	$17,000	$0	$17,000	$0	$167,000
W. Linda Mar, Pacifica St Beach	$0	< $1,000	$0	< $1,000	$0	$4,000
Rockaway Beach, Quarry, Headlands	$0	$5,000	$0	$5,000	$0	$6,000
Northwest Sharp Park	$0	$30,000	$0	$30,000	$0	$208,000
Total	**$0**	**$134,000**	**$0**	**$134,000**	**$0**	**$1,572,000**

[28] Tax Rates and Valuation of Taxable Property of San Mateo County for fiscal year 2014-2015. https://controller.smcgov.org/sites/controller.smcgov.org/files/documents/files/2014-15%20Tax%20Rate%20Book%20Final_3.pdf

[29] Accessible here: http://www.californiacityfinance.com/getandgo_PUB.pdf

Expected losses in property tax revenue are greatest for Alternative 3 because the properties removed are not replaced elsewhere in the City for this analysis; to properly assess the viability of new neighborhoods or densifying current areas is outside of the scope of this study.

It should also be noted that if the transfer of development rights program is implemented, voluntarily transfer of development right off of property less suitable for development (potential due to erosion or flooding) to property that is appropriate to accept more development, then the complete property tax revenues may not be lost.

Chronic (Tidal) Inundation

Chronic inundation, often impacts low-lying areas during high tides and thus is often referred to as "tidal inundation." Currently, there are no standard metrics to apply to tidal flooding, though it is likely that tidal flooding lowers property values and requires resources to mitigate. Given that many of Pacifica's coastal property lies on bluffs well above sea level, tidal inundation is only an issue in certain areas of Pacifica. Table 39 below presents estimates of the value of property subject to tidal inundation by sub-area and alternative. Note that these are NOT estimates of property losses, but rather estimates of property values subject to tidal inundation and/or associated elevated groundwater.

In Table 39 below, the Pedro Point and Shelter Cove sub-areas has $20,000 worth of property exposed to tidal inundation by 2100 and West Linda Mar has a significant amount of property ($11.5 million) exposed to elevated groundwater if no adaptation actions are taken. This exposure includes a number of shopping areas and would also likely impact local business and commerce.

Table 39: Value of Property Subject to Tidal Flooding by Sub-area and Alternative

Region	Alt	2018	2050	2100
Pedro Point and Shelter Cove	Alt 1	$0	$0	$20,000
Pedro Point and Shelter Cove	Alt 2	$0	$0	$20,000
Pedro Point and Shelter Cove	Alt 3	$0	$0	$20,000
West Linda Mar, Pacifica State Beach	Alt 3	$0	$0	$11,550,000

Items not included in the Cost-Benefit Analysis

The scope of work for this cost-benefit analysis was limited by budget and data availability. The following economic benefits/costs were not included in the analysis:

- **Recreational Benefits from Trails**: The engineering consultants, ESA, estimated the loss of trails in feet for each alternative. These are presented in Table 40 below. Some of these alternatives, in particular Alternative 3, involve significant loss of trail. With additional information and resources, these losses could be evaluated in terms of lost recreational value or the cost of replacing these trails. Table 40 below presents the loss in trails by sub-area and alternative.

- **Ecological Functions Goods and Services (EFGS):** Coastal habitat provides significant EFGS not evaluated in this report. Placing a dollar value on EFGS other than recreation (e.g., beach recreation--evaluated in this report) or storm buffering ability (also evaluated in this report) is difficult. Economists and ecologists are just beginning to create standard metrics for EFGS beyond recreation and storm buffering (e.g., see Barbier et. al., 2011 and Costanza et. al., 2006). Consequently, any changes in EFGS

due to sea level rise or the various alternatives evaluated in this study is beyond the scope of this economic study. However, policy makers may wish to consider these potential impacts. Habitat impacts and ecological function are discussed in Section 5.3.

Table 40: Trail Lengths Exposed to Coastal Erosion for Three Adaptation Alternatives

Sub-area	Total in City (ft)		Alternative 1		Alternative 2		Alternative 3	
		2018	2050	2100	2050	2100	2050	2100
Fairmont West	110	0	0	0	0	0	88	109
West Edgemar, Pacific Manor	4,834	33	33	33	33	33	4,721	4,834
Northwest Sharp Park	2,965	0	0	0	0	0	410	1,232
Sharp Park, West Fairway Park, and Mori Point	25,647	33	932	3,026	932	3,026	7,077	9,967
Rockaway Beach, Quarry, and Headlands	7,556	0	0	197	0	0	717	1,677
Pacifica State Beach	4,054	0	873	1,779	0	0	1,594	2,699
West Linda Mar	10,318	0	0	0	0	0	0	0
Pedro Point and Shelter Cove	9,023	0	0	71	0	71	0	98

Summary of Cost Benefit Analysis Results

The economic analysis prepared for the City of Pacifica estimated the benefits and costs of various alternatives for the coastal management at eight planning sub-areas in the City of Pacifica. In a number of sub-areas, Alternative 3 yielded the highest net-benefits (or lowest costs) because the cost of Alternative 1, which involves armoring, were higher than the benefits of protecting the property. Alternative 1 (armoring) may also reduce the width of beaches, which can lower recreational value. However, Alternative 3 is less aligned with the Council adopted goal to Preserve Existing Neighborhoods and Promote Environmental Justice and Local Economic Vitality. When considering policies to incorporate into the LCP Update, the City will need to consider costs/benefits on balance with community goals.

As with any economic study, all of the results are dependent upon the assumptions made. This study used the best available data/science. One area where data was very limited was beach recreation, except for Pacifica State Beach. This study also employed a very conservative assumption about the growth of beach recreation – it assumed that beach visitation would increase at the rate of growth for San Mateo Count, forecasted by the State to be 0.6% per year till 2050. However, if the number of hot sunny days in Pacifica increases, it's very possible that visitation will increase much more rapidly. To understand how an increase in beach visitation might impact this study's projections, this study conducted a sensitivity analysis using all of the same assumptions/data except assuming that beach visitation would increase by 3% a year, instead of 0.6%. The only sub-area where changing the assumption about the rate of growth of beach visitation mattered was Rockaway, where Alternative 2 yielded the highest net benefits. The sensitivity analysis on beach visitation is presented in Appendix F.

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