City of Pismo Beach
Local Coastal Program/General Plan Update

Sea Level Rise Vulnerability Assessment

[DRAFT]

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Acronyms and Abbreviations

CalEPA	California Environmental Protection Agency
CCC	California Coastal Commission
CCSMW	California Coastal Sediment Management Workgroup
CDC	U.S. Center for Disease Control
CDIP	Coastal Data Information Program
City	City of Pismo Beach
cm	centimeter
COAST	Coastal One-line Assimilated Simulation Tool
CoSMoS	Coastal Storm Modeling System
cy	cubic yards
cy/yr	cubic yards per year
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
ft	feet
ft/yr	feet per year
GIS	Geographic Information System
GP	General Plan
H++	Extreme SLR scenario due to rapid Antarctic ice sheet mass loss (Sweet et al, 2017)
H_s	Significant Wave Height
in	inch
IP	Implementation Plan
IPCC	Intergovernmental Panel on Climate Change
LCP	Local Coastal Program
LCPAC	Local Coastal Program Advisory Committee
lf	linear foot
LUP	Land Use Plan
m	meter
M&N	Moffatt & Nichol
MHHW	mean higher high water
MLLW	mean lower low water

MSL	mean sea level
NAVD 88	North American Vertical Datum of 1988
NE	northeast
NOAA	National Oceanic and Atmospheric Administration
OCOF	Our Coast, Our Future
OEHHA	Office of Environmental Health Hazard Assessment
OPC	Ocean Protection Council
PCH	Pacific Coast Highway
RSM	Regional Sediment Management
RV	recreational vehicle
SLR	sea level rise
SOVI	social vulnerability index
SW	southwest
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VA	Vulnerability Assessment
WWTP	Wastewater Treatment Plant
yr	year

Executive Summary

Planning for and adapting to a changing coastline is a critical challenge facing many coastal communities throughout California. This Sea Level Rise (SLR) Vulnerability Assessment, prepared as part of the City of Pismo Beach General Plan and Local Coastal Program Update, aims to determine the potential vulnerability of coastal resources in the Pismo Beach coastal zone. This is accomplished by first compiling an inventory of coastal resources then identifying how these resources will be affected by various increments of SLR, forming the basis for future policy development and adaptation strategies to mitigate potential impacts.

This Study was funded in part by the California Coastal Commission (CCC) grant LCP-17-06 awarded to the City of Pismo Beach. Resources within the coastal zone were identified through sources such as government databases, prior reports, and aerial imagery and include coastal development, recreational assets, coastal access points, residential areas, utilities infrastructure, transportation infrastructure, and ecological assets. A resource's vulnerability to SLR is a product of the following three factors:

- Exposure to coastal hazards (shoreline erosion, flooding and inundation);
- Sensitivity to coastal hazards (potential for damage or loss of function); and,
- Adaptive capacity (ability to restore function or avoid damage).

In order to capture the variety of coastal settings, littoral processes, and coastal resources found within Pismo Beach, the study evaluated SLR vulnerability across three coastal reaches: the bluff-backed beaches northwest of the Downtown waterfront (Bluffs Study Area), Pismo State Beach and the Downtown waterfront itself (Downtown Study Area), and the low-lying areas southeast of Pismo Creek (Low-Lying Study Area). The focus of this study and related findings are based on the following key questions:

What are the hazards associated with sea level rise for Pismo Beach?

The primary storm-related hazards affecting coastal resources in Pismo Beach are bluff erosion and fluvial flooding from Pismo Creek. Bluff erosion is an unpredictable and episodic process and it is therefore difficult to forecast these hazards with any certainty. However, each increment of SLR will result in additional wave energy at the base of the bluffs and therefore increase the potential for bluff collapse. The CoSMoS bluff erosion hazard projections indicate there could be 5-15 feet of bluff-top retreat under a 1.6 ft SLR scenario and 10-30 feet for a 3.3 ft SLR scenario. A variety of coastal protection structures are in place along the Bluffs Study Area that were not factored into these hazard projections, and so the ability of these structures to tolerate increasing wave attack associated with SLR would vary by parcel.

Based on the existing 100-year floodplain extents along Pismo Creek, published in San Luis Obispo County's most recent FEMA flood insurance study (FEMA, 2017), fluvial hazards present the most significant source of flooding in the Downtown Study Area and Low-Lying Study Area over the

next several decades. This type of flood hazard would also be influenced by SLR, especially along the lower reaches of Pismo Creek where SLR will push the beach profile upward and landward, potentially impacting the breaching patterns of Pismo Creek and Meadow Creek.

Non-storm hazards could also result in significant impacts to coastal resources Citywide. Sea level rise will result in a process known as "coastal squeeze," depicted in Figure E-1, in which resources reliant on sandy beach and intertidal areas are squeezed between rising sea levels and a coastal protection structure or erosion resistant bluff formation.

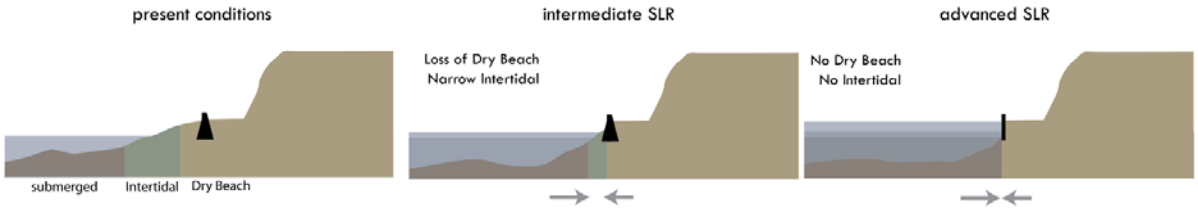


Figure E-1: Illustration of coastal squeeze in front of a non-erodible structure

What magnitudes of sea level rise matter for Pismo Beach and what resources are at risk?

Any amount of sea level rise will increase wave energy at the base of the bluffs, and coastal squeeze could potentially impact coastal access and environmental resources. At 1.6 ft SLR, CoSMoS results predict bluff erosion impacts to infrastructure and recreational resources along Eldwayen Ocean Park Beach and between Margo Dodd Park and Dinosaur Caves Park. Stormwater outfalls throughout the Bluffs Study Area would also be exposed to erosion hazards.

An extreme coastal flood event in combination with 1.6ft SLR could result in temporary flooding of low-lying areas adjacent to Pismo Creek and seaward of Dolliver Street such as the RV resorts and North Beach Campground.

A 3.3 ft rise in sea level represents a significant threshold along the Bluffs Study area as many of the pocket beaches would likely be eroded or submerged, impacting recreation, access, and environmental resources. The loss of protective beaches would also result in regular wave attack along the natural bluffs or shoreline protection structures. Along the Downtown Study Area nearly half of Pismo State Beach width is predicted to be eroded (Figure E-2), reducing the natural storm buffer for Downtown development and potentially impacting beach recreation and coastal access opportunities. The Pier itself could also be at risk of severe damage during a 100-year coastal storm event, especially at the outer end where waves could impact the Pier deck. More frequent coastal flooding during high tide conditions is a more significant concern in this scenario, affecting the low-lying areas adjacent to Pismo Creek.



Figure E-2: Shoreline erosion projections along the Downtown Study Area

The 4.9 ft SLR scenario is another significant threshold due to widespread coastal flooding of low-lying areas adjacent to Pismo Creek. Residential development, infrastructure, and parks within the Downtown Study Area on the northwest bank of Pismo Creek could be exposed to flooding during monthly high tides and 100-year coastal storm conditions under this scenario. Nearly all of the Low-Lying Study Area, Pismo Lake Ecological Reserve, and the North Beach Campground would be vulnerable to coastal flooding in a 100-year storm event. High tides at 4.9 ft SLR combined with significant long-term shoreline retreat could result in limited and seasonal beach access along the Downtown waterfront.

Bluff erosion, shoreline erosion, and coastal flooding hazards within these regions of concern are projected to intensify under SLR scenarios beyond 4.9 ft. The hazard zones in the Downtown and Low-Lying Study Areas only increase incrementally between 6.6 ft and 9.8 ft SLR scenarios, largely impacting the same resources in the 4.9 ft SLR scenario; however, the depth and duration of tidal flooding and extreme storm damage would increase significantly for each SLR scenario above 4.9 ft SLR.

When could these scenarios happen?

SLR projections referenced within this study are based on the Point San Luis projections included in the 2018 California Ocean Protection Council (OPC) SLR guidance, identified by the California Coastal Commission as the best-available science on the subject. The range of probabilistic SLR projections is illustrated in Figure E-3. Climate science is a constantly changing field, often with high degrees of uncertainty. In the case of SLR in California, the OPC has high confidence in estimates for SLR to around year 2050, after which emissions scenarios cause predictions to diverge.

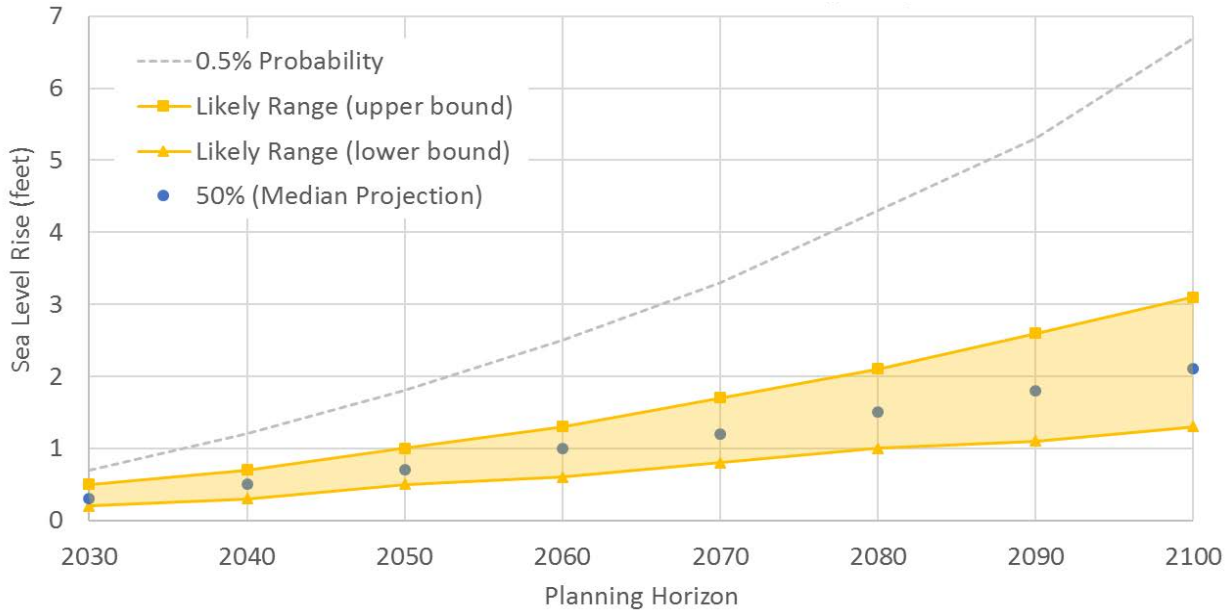


Figure E-3: Probabilistic sea level rise projections (OPC, 2018)

For the 2050 time horizon the likely range of SLR as defined by OPC is between 0.5 to 1.0 feet which means there is a 66% probability that SLR will fall within this range. The guidance document also acknowledges the potential for less probable scenarios that result in higher amounts of SLR. For example, the document indicates there is a 0.5% chance SLR reaches 1.8 feet by 2050. In other words, the 1.6 foot SLR scenario presented within this study represents a conservative projection for the 2050 time horizon. This scenario is more likely to occur in the 2070-2080 timeframe.

The potential vulnerabilities identified for SLR scenarios of 3.3 feet and higher are unlikely to occur before 2100, but there is a slight chance (0.5% probability) that 3.3 ft of SLR could occur by 2070. The likely range of sea level rise in 2100 is 1.3 to 3.1 feet but there is a slight chance (0.5% probability) that SLR could reach 6.7 feet. Under a worst-case scenario, described as the H++ scenario in the OPC guidance, SLR could reach 9.9 feet in 2100. Though this scenario is theoretically possible, the latest update to global SLR projections (IPCC, 2019) specifically excluded this scenario from their projections, citing deep uncertainty and ongoing discussion in the scientific community over the assumptions underlying the H++ scenario.

How do we plan for these potential impacts?

Sea level rise is unique among other natural hazards because it is a slow-moving disaster of uncertain magnitude that will develop over the span of decades, and the impacts will be permanent. The vulnerabilities identified for worst-case sea level rise projections at the end of the century are overwhelming but the likely range of SLR expected over the next 50 years (less than 2 feet) is manageable. There is time to responsibly plan, fund, and implement adaptation strategies to mitigate potential impacts.

This Sea Level Rise (SLR) Vulnerability Assessment is intended to determine the potential vulnerability of coastal resources for a range of potential SLR scenarios that could occur this century to inform adaptation planning efforts and policy development that will be incorporated into the General Plan and Local Coastal Program Update.

The next phase of the project will develop an Adaptation Plan that focuses on adaptation strategies and policy updates to address present day hazards and potential near-term vulnerabilities identified for the 2050 timeframe, represented by the 1.6 ft SLR scenario. A long-term vision for adaptation strategies to address more significant impact thresholds identified for SLR scenarios of 3.3 ft and higher will also be included in the Adaptation Plan.

1. Introduction & Approach

The City of Pismo Beach (City) is a historic beach town in California's central coast. The City coastline is very accessible and offers a wide variety of scenic, cultural, and recreational opportunities for both locals and visitors. Much of the community's identity and tourism draw are due to its vibrant beach culture and variety of coastal environments, ranging from the impressive Pismo State Beach and dune complex to Shell Beach's tidepools in the north part of the City.

Recent sea level rise (SLR) science and coastal hazard projections indicate that valuable coastal resources in the City may become exposed to more intense coastal hazards such as bluff retreat, beach erosion, and coastal flooding in the future. This study is based on SLR projections published in the California Ocean Protection Council (OPC) report *State of California Sea Level Rise Guidance* (OPC, 2018). The potential effects of SLR on existing coastal hazards such as beach and bluff erosion and storm related flooding were evaluated using results of the Coastal Storm Modeling System (CoSMoS), a multi-agency effort led by the United States Geological Survey (USGS).

1.1 Study Approach

The purpose of this SLR Vulnerability Assessment (VA) is to understand how rising seas could impact coastal resources in the City. The term "coastal resource" is used to describe both natural and manmade features that provide a benefit to the City, including its residents, businesses, and visitors. The term "asset" is used to describe a specific resource or facility being evaluated. Key questions that guide the vulnerability assessment are illustrated in Figure 1-1. An initial step of the assessment is to identify how coastal hazards may change with various increments of SLR. By comparing predicted hazards with a baseline of how coastal processes and hazard events have impacted these resources in the past, it is possible to identify which scenarios pose significant thresholds at which the vulnerability of a resource will increase. The vulnerability of an individual asset or resource is dependent on three factors:

- **Exposure**: the type, duration and frequency of coastal hazard a resource is subject to under a given sea level rise scenario. A resource that experiences daily tidal, wave, or water level fluctuations would be considered to have a greater SLR exposure than a resource that only experiences minor flooding during an extreme wave or storm event.
- **Sensitivity**: the degree to which a resource is impaired by exposure to a coastal hazard. For example, a lift station near a bluff edge would be more sensitive to undermining from erosion than a deepened pile supported structure such as the recently renovated City Pier.
- **Adaptive Capacity**: the ability of a resource to adapt to changing coastal hazards. Resources such as beaches may have the ability to adapt due to sand transport if sufficient sand exists in the littoral cell and landward space is available for this migration. Built

infrastructure typically has a low inherent adaptive capacity as increased coastal hazards can exceed the original design capacity, requiring improvements to maintain the asset.

The VA informs the LCP by outlining potential consequences and key SLR thresholds for the City. This information may be used by the City to support policies and adaptation strategy development for the LCP to improve coastal resiliency.

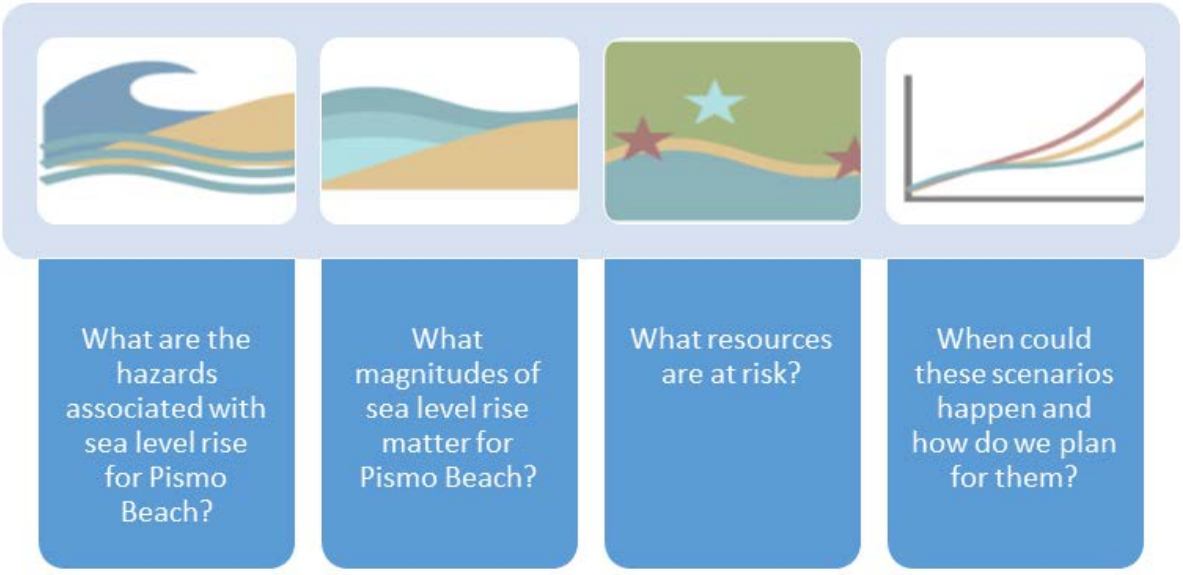


Figure 1-1: Key questions for a Vulnerability Assessment

1.2 Coastal Setting

The City of Pismo Beach is located within the southern portion of San Luis Obispo County. The City is situated on a marine terrace between the coastline and hills of the San Luis Range. Highway 101 intersects the city in a path that runs roughly parallel to the coast. The City is currently exposed to a variety of coastal hazards including beach erosion, bluff erosion, and coastal flooding. Coastal processes are described in more detail in Section 2 of this Study.

City limits, coastal bathymetry, and topography are presented in Figures Figure 1-2 and Figure 1-3. The shoreline in the southern area of the City is characterized by its wide, sandy beach. The southern city limit begins near the terminus of Meadow Creek, which drains into Pismo Lake Ecological Reserve. A diversion channel that drains high flows from Meadow Creek runs along the City's southern boundary closest to the Pacific Ocean. This Meadow Creek diversion channel and Pismo Creek, a larger stream, meet to form a lagoon that backs the beach in this area. The mouth of their confluence is unfixed by manmade structures and varies in size and position. Moving northwest along the coast from Pismo Creek, the dune backed beach transitions to a seawall backed beach followed by bluffs of increasing height north of the City's pier.

Approximately 0.75 miles northwest of Pismo Creek the bluffs shift to a more southern-facing orientation, and the sandy beach rapidly disappears. From this point northwest the coast is defined by intermittent, thin, rocky and sandy beaches backed by steep bluffs ranging from 10 to over 100 feet tall. Most of the bluffs are unprotected, but a variety of shoreline protection and bluff stabilization structures are present at some parcels along this reach. The northwestern city limit lines the bluffs above Pirate's Cove Beach.

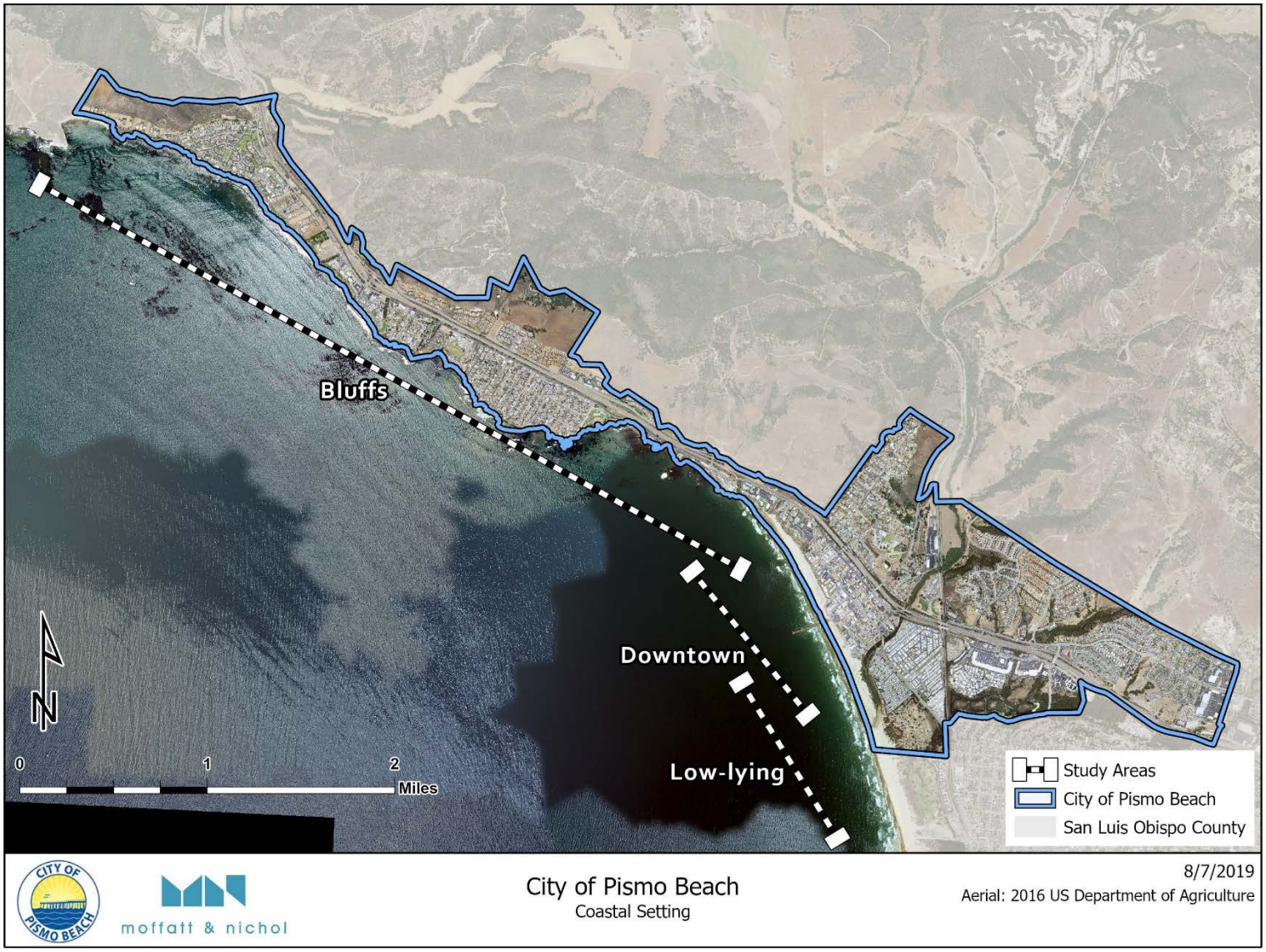


Figure 1-2: City limits and locations of each Study Area included in the Vulnerability Assessment

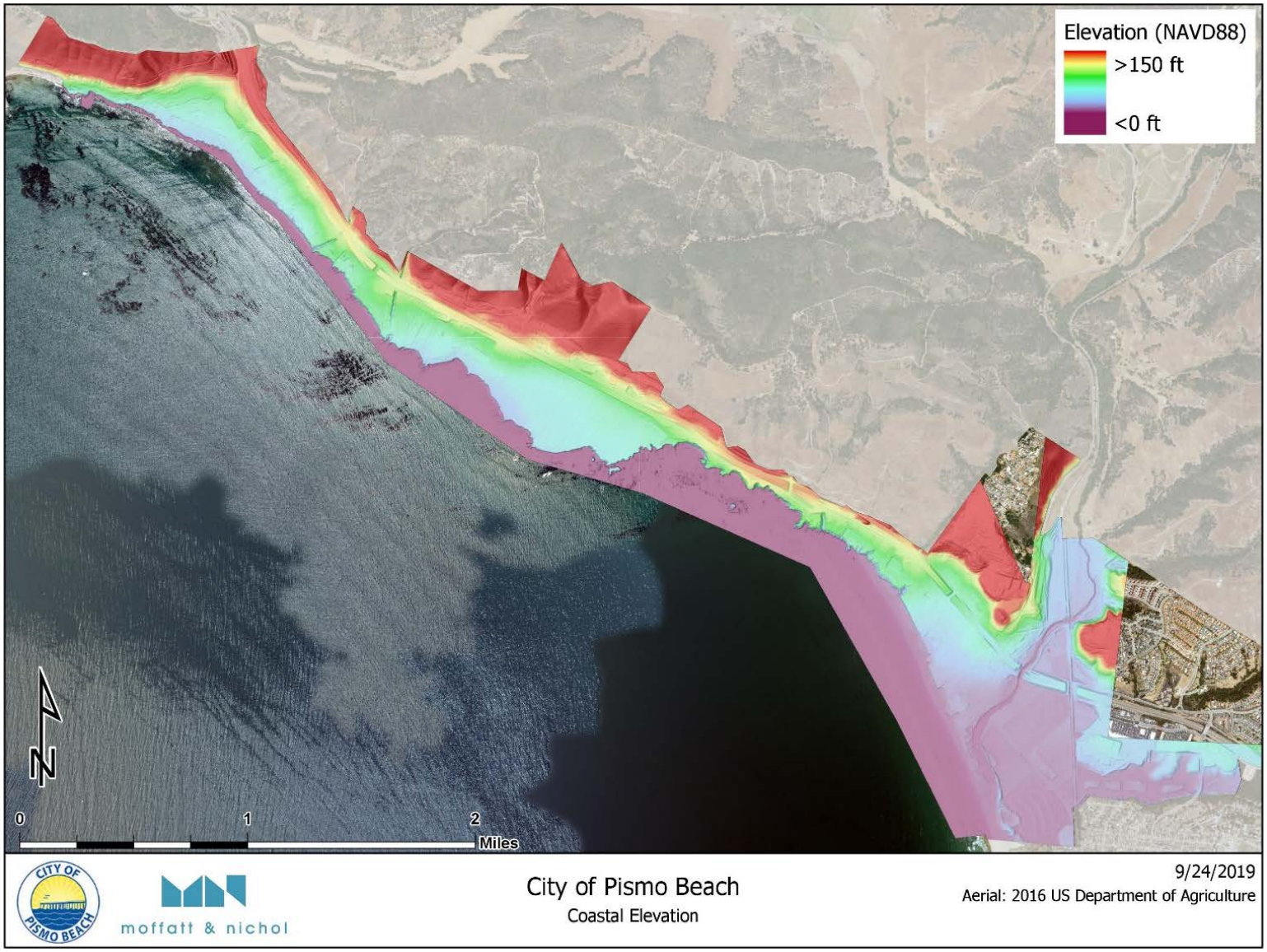


Figure 1-3: Map of coastal elevation within the City of Pismo Beach

1.3 Study Area

The study area for the VA encompasses the full extent of the City of Pismo Beach shoreline and coastal zone. The study area extends landward as necessary to capture the full extent of coastal hazards present under each SLR scenario analyzed. Within this area, there are three distinct regions where SLR hazards could result in differing impacts. These regions are subject to unique hazards as discussed below.

1.3.1 Bluffs

The region of bluffs within City limits stretches from Pirate's Cove in the northwest to the City's downtown northwest of the pier. Development atop the bluffs includes private residences, visitor serving amenities, and public recreation areas. The area is currently exposed to coastal erosion and wave runup, especially during extreme events, which has prompted construction of seawalls and other bluff stabilization measures in some sections (Figure 1-4).

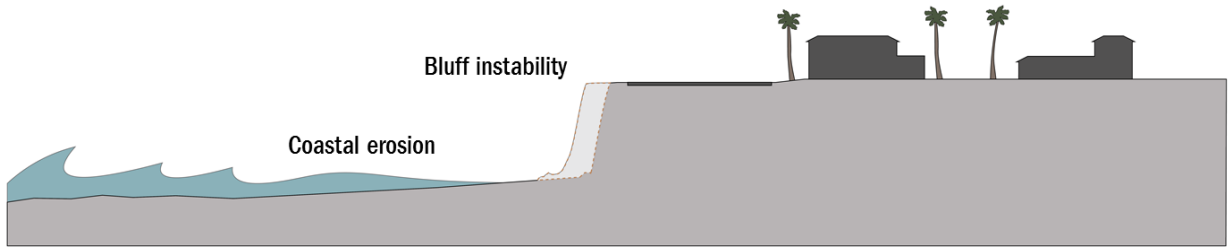


Figure 1-4: Example Bluffs Area shoreline profile

1.3.2 Downtown

Extending approximately from the northwest end of Pismo State Beach to Pismo Creek, the downtown region is the center of beach-related activity in Pismo Beach due to the accessibility and proximity to the City pier, visitor serving amenities, and Pismo State Beach itself. Although most of the developed shoreline is protected by a seawall, the area is currently exposed to coastal erosion, wave runup, and flooding during extreme events (Figure 1-5).

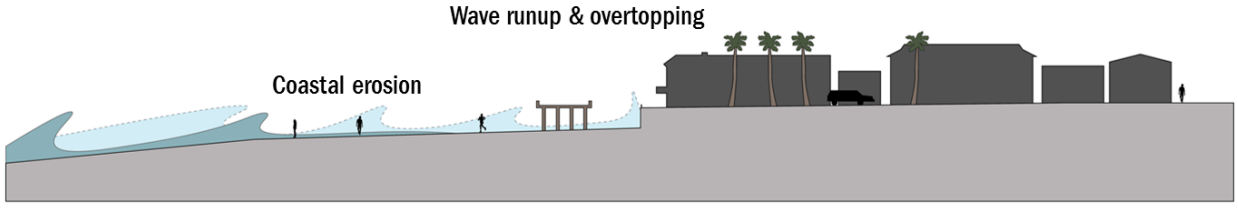


Figure 1-5: Example Downtown Area shoreline profile

1.3.3 Low-lying

The area of the City most prone to coastal and fluvial flooding is between the southern side of its downtown and the southern City boundary, including the banks of Pismo Creek, Pismo Lake, and visitor facilities and attractions between Highway 101 and the coastline. If unmitigated, sea level rise could significantly increase flooding potential in this region (Figure 1-6).

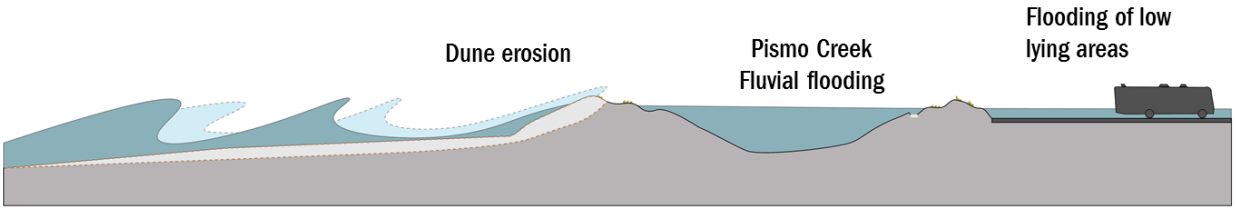


Figure 1-6: Example Low-lying Area shoreline profile

1.4 Coastal Resources Inventory

The coastal resources to be evaluated in the VA were determined through analysis of data provided by the City as well as other regional and federal agencies. This inventory of coastal resources and their managers is summarized in Table 1-1. Section 4 provides an overview of the resources and discusses SLR vulnerabilities by resource category, while maps of selected critical resources and coastal hazards are provided in Appendix A.

Table 1-1: Coastal resources inventory in Pismo Beach

Resource Category	Asset	Managers
Coastal Development	City parcels and associated structures	Private entities, City of Pismo Beach
Beaches & Public Trust Resources	Pismo State Beach	California State Parks, City of Pismo Beach
	Shelter Cove Beach	City of Pismo Beach
	Pier Avenue Beach	City of Pismo Beach
	Eldwayen Ocean Park Beach	City of Pismo Beach
	Memory Park Beach	City of Pismo Beach
	Spyglass Park Beach	City of Pismo Beach
	Cliffs Beach	City of Pismo Beach
	South Palisades Park Beach	City of Pismo Beach
Utilities Infrastructure	Potable water lines and facilities	City of Pismo Beach
	Stormwater lines and facilities	City of Pismo Beach
	Wastewater lines and facilities	City of Pismo Beach
	Pismo Beach WWTP	City of Pismo Beach
Transportation Infrastructure	Roads and highways	City of Pismo Beach, Caltrans
	Dolliver Street Bridge	City of Pismo Beach, Caltrans
	City parking lots	City of Pismo Beach
	Railroad tracks	Union Pacific Railroad

Resource Category	Asset	Managers
	Transit routes	San Luis Obispo Regional Transit Authority, South County Area Transit
Coastal Access & Recreation	Public access points	City of Pismo Beach, private entities
	Ira Lease Park	City of Pismo Beach
	Mary Herrington Park	City of Pismo Beach
	Pismo Beach Pier	City of Pismo Beach
	Dinosaur Caves Park	City of Pismo Beach
	Margo Dodd Park	City of Pismo Beach
	Eldwayen Ocean Park	City of Pismo Beach
	Memory Park	City of Pismo Beach
	Spyglass Park	City of Pismo Beach
	Ebb Tide Park	City of Pismo Beach
	South Palisades Park	City of Pismo Beach
	Pismo State Beach North Beach Campground	California State Parks
Environmental Resources	Pismo State Beach Monarch Butterfly Grove	California State Parks
	Pismo Lake Ecological Reserve	California State Parks
	Intertidal and subtidal habitat	City of Pismo Beach
	Pismo Creek estuary	City of Pismo Beach
	Sandy beach and dune habitat	City of Pismo Beach

2. Coastal Processes

Coastal processes refer to the water levels, waves, and sediment transport patterns that shape the coastline of Pismo Beach. These dynamic processes are largely driven by natural forces but have also been significantly modified by anthropogenic activities such as development, coastal structures, and beach nourishment. This section describes historic coastal processes and how they have affected the shoreline along Pismo Beach. The influence of sea level rise on coastal processes is discussed further in Section 0.

2.1 Water Levels

The tides in Pismo Beach are semidiurnal, with two high tides and two low tides of different magnitude occurring each lunar day (an approximately 25-hour time period). These differences in magnitude vary with longer-term tidal cycles. Astronomical tides account for the most significant amount of variation in the total water level. The Port San Luis tidal station (NOAA #9412110), located approximately 6.5 miles west-northwest of the Pismo Pier, has been collecting data since 1933. The typical diurnal tidal range at this station, ranging from MLLW to MHHW, is 5.3 ft (NOAA, 2019). During spring tides, which occur twice per lunar month, the tidal range increases to approximately 7 ft due to the additive gravitational forces caused by alignment of the sun and moon. During neap tides, which also occur twice per lunar month, the forces of the sun and moon partially cancel out, resulting in a smaller tidal range of approximately 4 ft. The largest tides of the year, occurring in winter and summer, are sometimes referred to as “King” tides and result in high tides of 6.5 ft or more above MLLW and tidal ranges of more than 8 ft. The existing range of water levels, including daily and extreme values, is illustrated in Figure 2-1. When considering the effects of SLR on coastal hazards, it is important to consider that SLR increases the entire range of existing water levels.

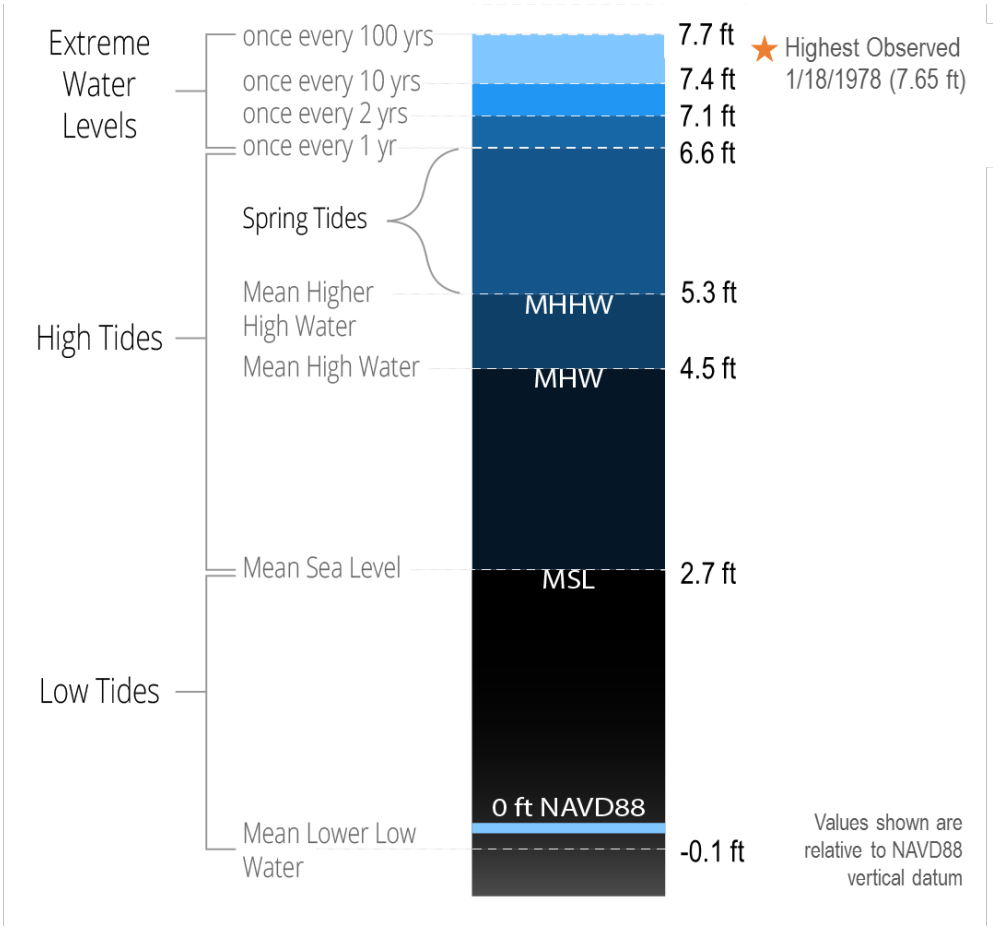


Figure 2-1: Water levels for Port San Luis, CA (NOAA, 2019)

Unless otherwise noted, water level elevations shown in Figure 2-1 and throughout this study are referenced to the North American Vertical Datum of 1988 (NAVD88). This datum is consistent with the effective FEMA Flood Insurance Rate Map (FIRM) and Coastal Storm Modeling System (CoSMoS) hazard data published by the United States Geological Survey (USGS). Another commonly used datum in coastal and marine engineering applications is Mean Lower Low Water (MLLW), which is very close to the NAVD88 datum at this location (NAVD88 = MLLW + 0.08 ft).

In addition to astronomical tides, sea level anomalies such as El Niño-Southern Oscillation cycles and storm surge also contribute to changes in relative water levels along the Pismo Beach shoreline. These factors can increase the predicted tides over timescales ranging from hours to months. An example of this occurred on November 25, 2015 when a king tide of about 6.63 ft above MLLW was predicted, but a water level of 7.18 ft was measured at the Port San Luis tide station. The tide series from this event is shown in Figure 2-2. The predicted astronomical tide was elevated by 0.54 feet due to a sea level anomaly associated with the strong El Niño and high ocean temperatures during the 2015-2016 winter season.

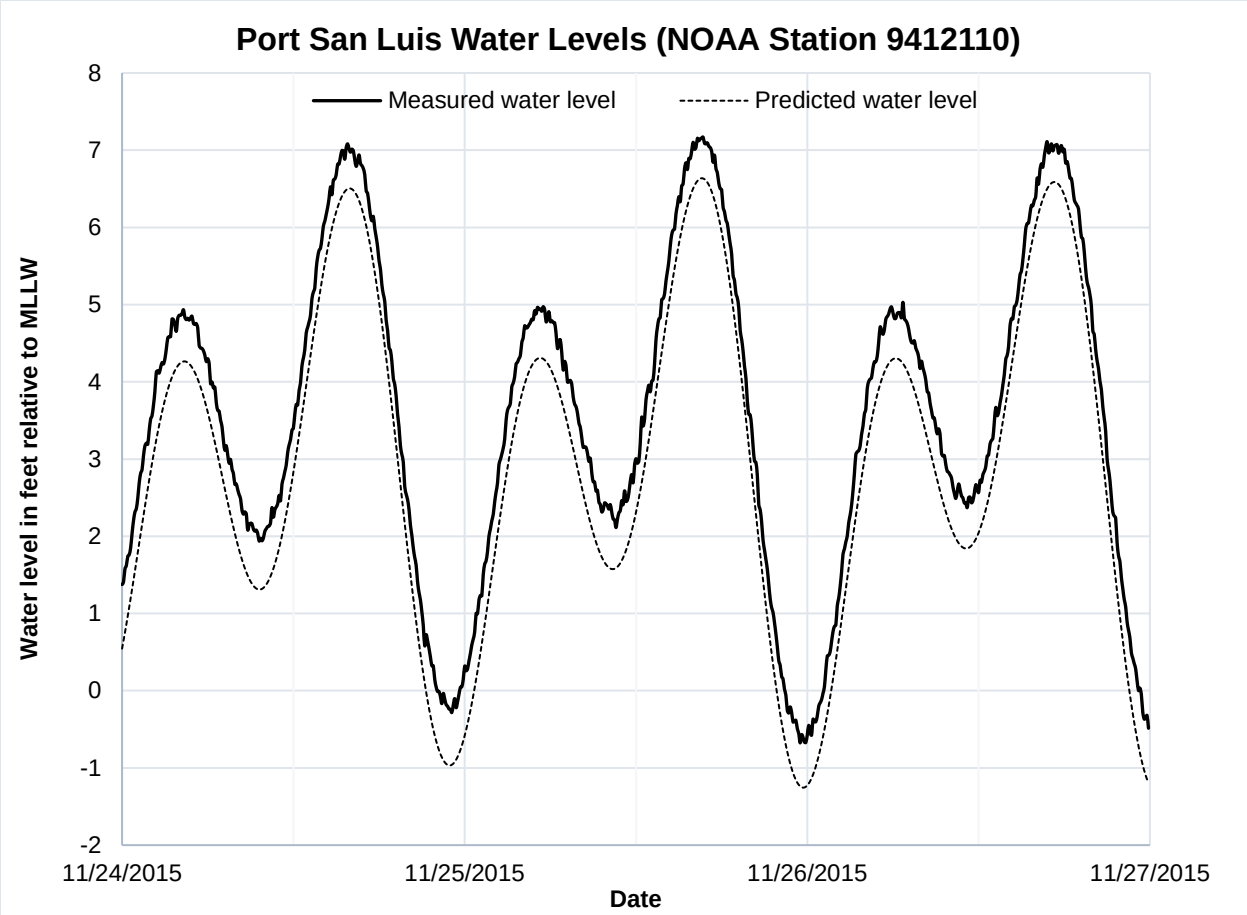


Figure 2-2: November 2015 water levels at Port San Luis (NOAA, 2019)

2.2 Wave Climate

Waves act to carry sand in both the cross-shore and longshore directions and can also cause short-duration flooding events due to dynamic increases in water levels. Both the long-term exposure of a coastline to incoming waves and episodic extreme wave events are important in understanding future SLR vulnerabilities.

The best identified source for wave data for Pismo Beach is the Coastal Data Information Program (CDIP) wave buoy at Diablo Canyon, approximately 13 miles west-northwest of the City. This buoy is installed around 1200 ft offshore in 90 ft of water and has been in service since 1983. As seen in Figure 2-3, the region is generally most exposed to west and northwest swell generated by extratropical cyclones and cold fronts in the North Pacific (CCSMW, 2016). This type of swell tends to peak in size and period in the winter. The highest significant wave height measured by CDIP Station 076 was 21.3 ft with a peak period of 16.7 seconds on January 11th, 2001 (CDIP, 2019). The significant wave height is defined as the average of the highest one-third of waves in a wave spectrum. The theoretical maximum wave height in a given spectrum can be two times the significant wave height. In the summer, the California high-pressure system generates additional

northwestern swell. Other wind and storm generated waves approach from the south and southwest, although this occurs less frequently (CCSMW, 2016). Pismo Beach's shoreline orientation is generally perpendicular to the dominant (westerly) wave approach direction.

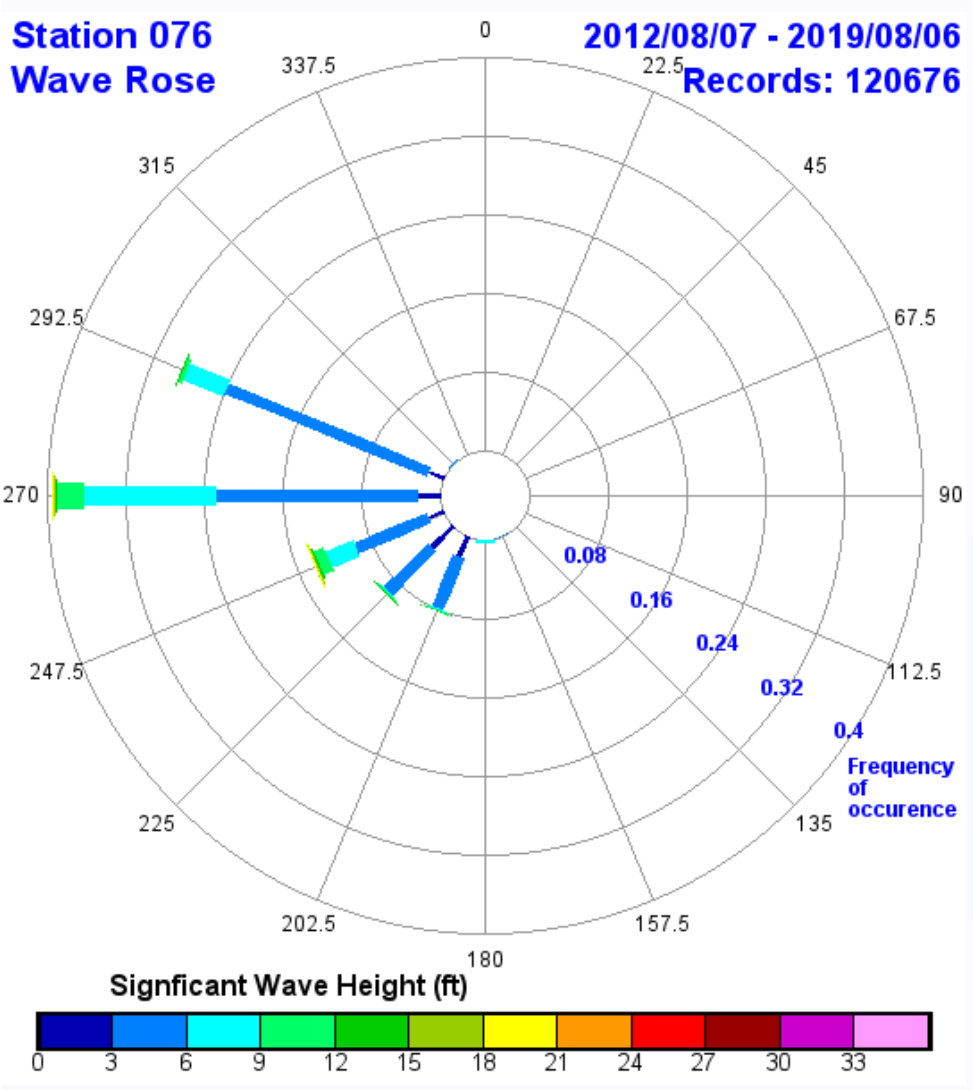


Figure 2-3: Wave orientation and significant height at CDIP Station 076 Diablo Canyon, 2012-2019

2.3 Littoral Processes

A littoral cell is a coastal compartment or physiographic unit that contains sediment sources, transport paths, and sediment sinks (Patsch & Griggs, 2007). The City's shoreline is within the Santa Maria littoral cell, named for its primary sediment source: the Santa Maria River (CCSMW, 2016).

2.3.1 Littoral Cell Extent

A previous, broadly cited study (Bowen & Inman, 1966) used a regional sediment budget, including what is now considered the Santa Barbara littoral cell, to determine that significant sand transport occurs from Point Buchon to the Santa Barbara area. Recent efforts (Patsch & Griggs, 2007) have also employed similar methods to define the Santa Maria littoral cell as a sub-cell of the greater Santa Barbara littoral cell.

Other studies incorporating more detailed analyses of local geomorphology have identified several probable partial or total littoral barriers present from Point San Luis to Point Sal. In the north, Point San Luis and the associated breakwater for Port San Luis likely prevent sediment transport from the direction of Point Buchon (Everts Coastal, 2000). Studies also show that Fossil Point and the headlands of Shell Beach either form another complete sediment transport barrier or reduce longshore transport to negligible amounts (Everts Coastal, 2000; Everts, June 2001; Everts, November 2001). In the south, Mussel Point and Point Sal to a lesser extent exist as significant impediments to sediment transport (Everts, June 2001; Moffatt & Nichol, 2001).

Although some littoral transport may occur beyond Mussel Point and Point Sal, the headlands of Shell Beach in the north and of Mussel Point and Point Sal in the south are used as cell limits within this study. The cell extent and its primary sediment sources are illustrated in Figure 2-4.

2.3.2 Sediment Sources

Santa Maria River represents the largest source of sediment for the littoral cell which encompasses Pismo Beach. The mouth of the Santa Maria River is located 10 to 15 miles south of the City. Before construction of Twitchell Dam on the Cuyama River, a tributary of the Santa Maria River, in 1958, approximately 500,000 cubic yards per year (cy/yr) of sand was introduced to the Santa Maria littoral cell at this river mouth (Moffatt & Nichol, 2001). This volume has since been reduced to approximately 175,000 cy/yr (Fugro West, Moffatt & Nichol, 2002; Willis & Griggs, 2003).

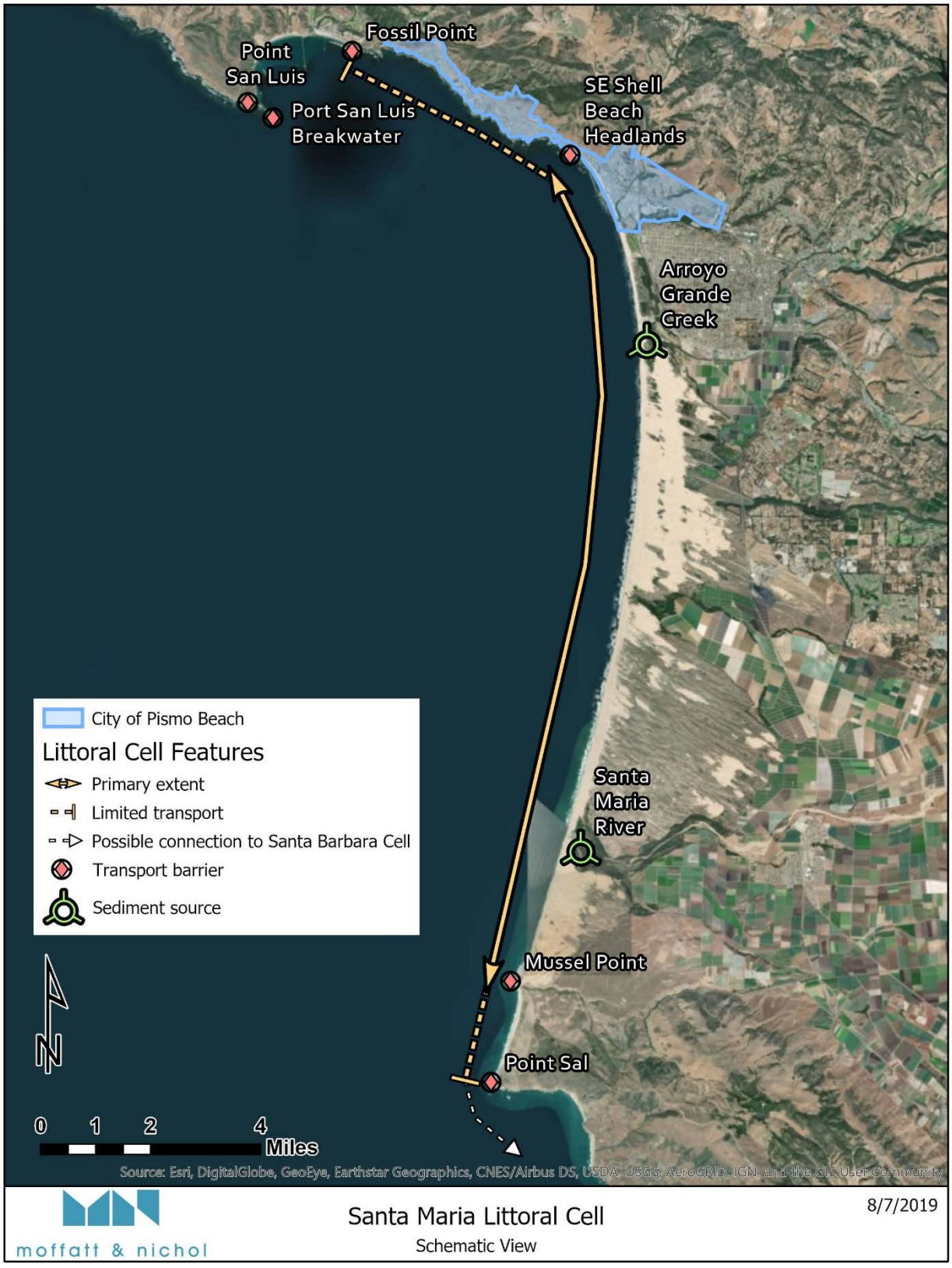


Figure 2-4: Map illustrating the Santa Maria Littoral Cell and major features

Other sources of sediment include Arroyo Grande Creek and San Luis Obispo Creek. Several other smaller creeks also contribute sediment to the littoral cell but were not evaluated in previous studies which estimated sediment delivery from the larger rivers and creeks. Before damming in the 1950s and 1960s, Arroyo Grande Creek supplied approximately 80,000 cy/yr of beach-grade sediment to the cell as well (Swanson Hydrology + Geomorphology, 2006; Willis & Griggs, 2003). This volume has since dropped to approximately 25,000 cy/yr (Bowen & Inman, 1966; Willis & Griggs, 2003). San Luis Obispo Creek provides a source of sediment for Avila Beach but is not a significant source of sediment for Pismo Beach since Point San Luis and the harbor breakwater prevent longshore transport of this material beyond the Fossil Point headland.

Bluff erosion in the vicinity of Shell Beach is relatively insignificant for the cell as a whole and likely only furnishes sediment for beach formation at the base of a given bluff (Fugro West, Moffatt & Nichol, 2002). Therefore, most sediment in the cell has historically been supplied by fluvial sources that currently have impaired sediment supply capabilities. This reduced sediment supply is potentially problematic and could result in a long-term trend of shoreline erosion that would be amplified by an increased rate of sea level rise.

2.3.3 Sediment Sinks

The primary sink in the Santa Maria littoral cell is aeolian, or wind-blown, transport to the Oceano Dunes and Guadalupe-Nipomo Dunes, both located south of Pismo Beach. This process has not been subject to detailed study for quantification, but estimates near 150,000 cy/yr have been used in multiple littoral cell sediment budget analyses (Bowen & Inman, 1966; Moffatt & Nichol, 2001). Most other sediment loss from the cell is assumed to be cross-shore transport offshore beyond the depth of closure or longshore sediment transport out of the cell.

2.3.4 Longshore Transport

Longshore transport refers to the movement of sediment parallel to the shore and, in the absence of littoral barriers, primarily varies with wave orientation. Sediment may be transported in one direction for some time, then transported in the reverse direction in a season with an opposing wave climate. On a yearly timescale, gross transport refers to the total volume moved in a given direction, while net transport is the difference between north and south transport rates and represents the annual amount of sediment moving in the dominant direction.

Early studies identified the magnitude and predominant direction of net longshore sediment transport as approximately 60,000 cy/yr to the south, exiting the cell at Point Sal (Bowen & Inman, 1966). The same studies postulate that net transport is much smaller in magnitude than the gross transport to the north and south, which are estimated at 200,000 to 300,000 cy/yr respectively (CCSMW, 2016). Further work based upon these early studies has asserted that net southward transport occurs throughout the cell, resulting in net transport out of the cell to the south similar to early estimates (USACE, Los Angeles District, 1986).

An alternate theory exists that construction of the Port San Luis breakwater in 1913 altered littoral dynamics to increase northward sediment transport within the cell (Everts Coastal, 2002). Although some net transport out of the cell to the south may occur, nearly all sediment that reaches Pismo Beach is distributed via an effective northward transport of approximately 150,000 cy/yr from the Santa Maria River mouth (Moffatt & Nichol, 2001). This transported sediment exits the cell primarily through aeolian transport, and a small portion either causes shoreline accretion or exits the cell offshore.

2.4 Shoreline Change

California's beaches are subject to regular seasonal changes that must be separated from long-term erosion or accretion. The stormy winter months temporarily move sand offshore causing narrowing or near-complete disappearance of beaches in severe cases. Sediment returns during the relatively calm summer, widening the beaches (Figure 2-5). Long-term shoreline change refers to trends of shoreline movement over multiple yearly cycles.

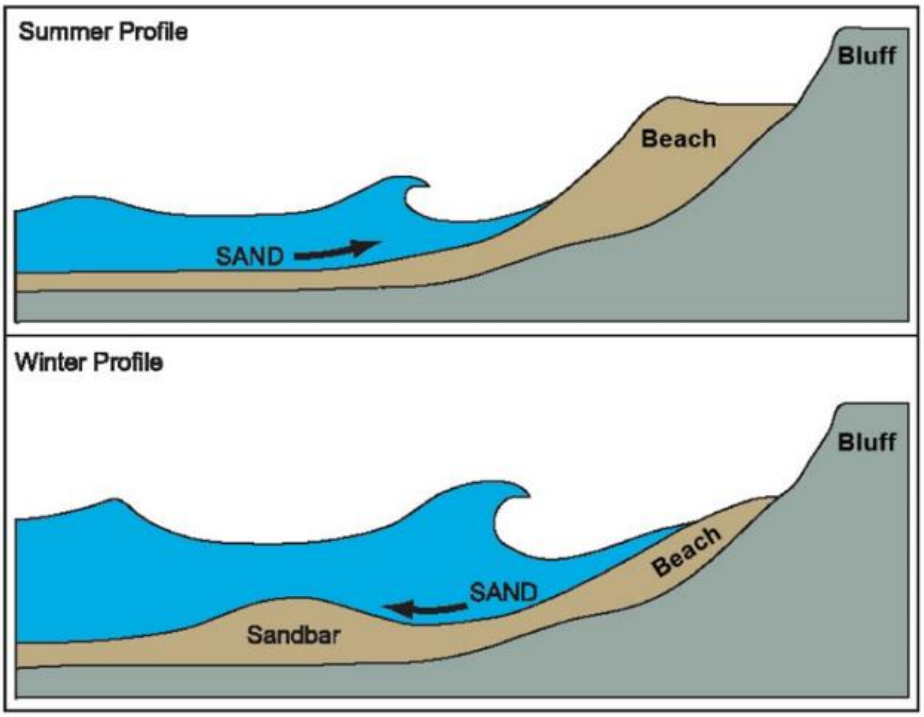


Figure 2-5: Schematic of typical seasonal shoreline change (Patsch & Griggs, 2006)

2.4.1 Sandy Beaches

Unlike many other areas in Central and Southern California, the sandy beaches of the Santa Maria littoral cell within San Luis Obispo County do not show a history of significant shoreline retreat over the last century (CCSMW, 2016). Instead, as seen in Figure 2-6 the sandy beaches in the vicinity of the City advanced through the first half of the 20th century (Moffatt & Nichol, 2001).

Since the reduction in sediment supply from damming the Santa Maria River shoreline positions within the study area have remained primarily static, while the more southerly area near the river mouth has shown significant retreat. Figure 2-6 only evaluates shoreline change through 1976, but USGS research found sandy shoreline positions in the vicinity of Pismo Beach in the early 2000s to be similar to those in the 1970s (Hapke, Reid, Richmond, Ruggiero, & List, 2006). Looking forward on the multi-decadal timescale of SLR, the pattern of shoreline retreat occurring in the southern area of the cell is likely to spread north towards Pismo Beach (Fugro West, Moffatt & Nichol, 2002).

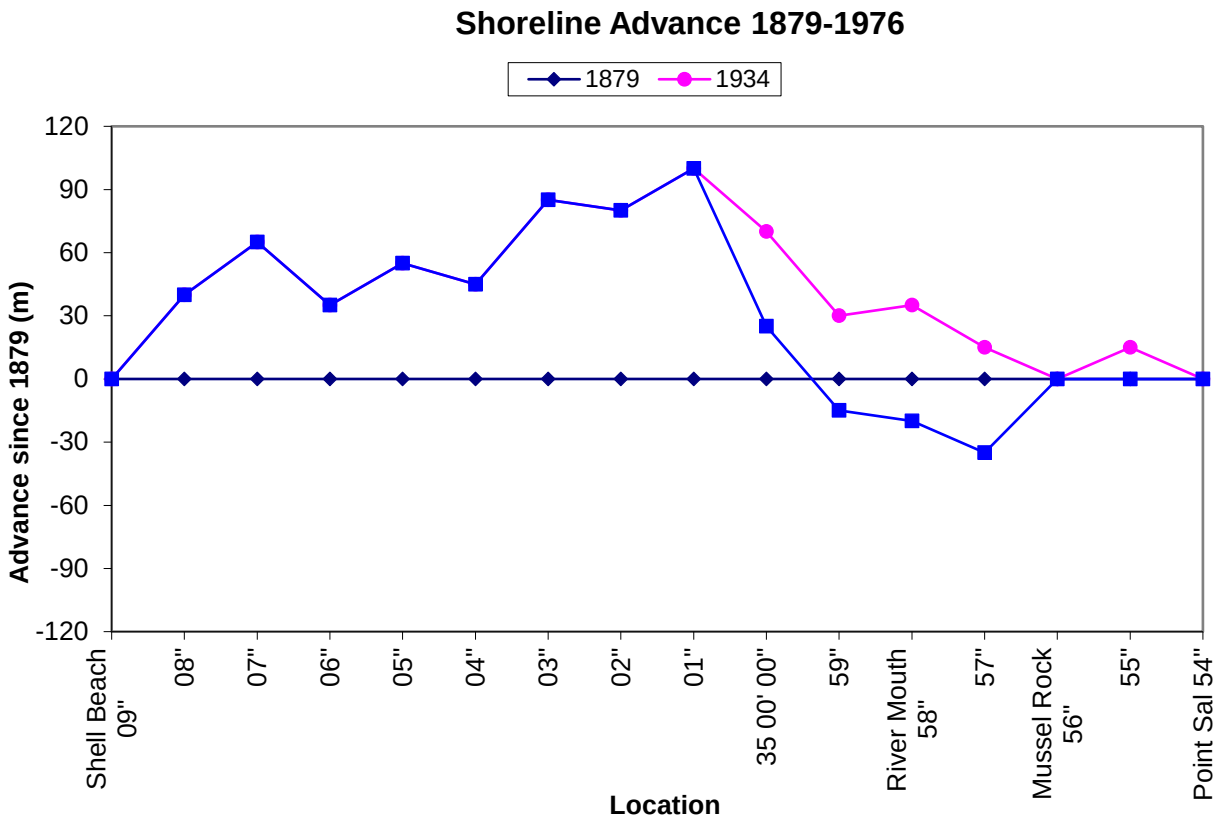


Figure 2-6: Shoreline advance history between Shell Beach and Point Sal (Moffatt & Nichol, 2001)

2.4.2 Bluff-Backed Beaches

The bluff-backed beaches between Fossil Point and the northern end of Pismo State Beach are primarily composed of sand and gravel sourced from the actively eroding bluffs of this area as well as sediment carried in small streams and gullies (Everts, June 2001; Fugro West, Moffatt & Nichol, 2002). These beaches are typically shallow, steeply sloping layers of coarse sediment overlaying bedrock within embayments (USACE, Los Angeles District, 2008).

The limited width of many of the bluff-backed beaches causes normal seasonal effects to be particularly apparent. These beaches provide little protection from intense winter storms, exposing the bluffs to direct wave impact and potentially significant erosion. Some of the City's bluff-backed beaches show a minor long-term trend of erosion (Hapke, Reid, Richmond, Ruggiero, & List, 2006). Although the overall bluff retreat rate in Pismo Beach is approximately 4 inches per year, erosion typically occurs episodically, with greater than ten of feet of bluff top erosion possible in a single season or storm event (Fugro West, Moffatt & Nichol, 2002). These are general magnitudes, as the localized bluff erosion rate depends on a multitude of factors including geologic and hydrologic variation.

2.5 History of Coastal Storm Damage

Coastal assets in Pismo Beach are susceptible to damage from extreme storm hazards like wave attack and high-volume surface runoff. On the Central and Southern California coast significant storms occur more frequently during strong El Niño-Southern Oscillation events. The City has requested FEMA disaster recovery funding for coastal storm damages for at least 3 storm seasons since 1970.

The 1982-1983 El Niño season was particularly damaging throughout coastal California, causing over $35 million in damage to public recreational facilities alone (Dean, Armstrong, & Sitar, 1984). A sequence of eight major storms struck the state's coast between November 1982 and mid-March 1983. Resulting hazards included significant wave heights greater than 20 ft, extreme water levels, and high precipitation. Pismo Beach suffered heavy damages, including a collapse of the last 400 ft of the City's pier, significant bluff failures, and considerable structural losses along the downtown waterfront (City of Pismo Beach, 1983-1985). Figure 2-7 displays scour damage from overtopping of the seawall north of the base of the City pier. Figure 2-8 and Figure 2-9 further illustrate the extent of damages despite shoreline protection installed along the downtown waterfront. The storm caused approximately $2.5 million in damages to the City's public resources, including at least $2 million for reconstruction of the pier.



Figure 2-7: 1982-83 storm damage between Pomeroy Ave and City Pier (Nix)

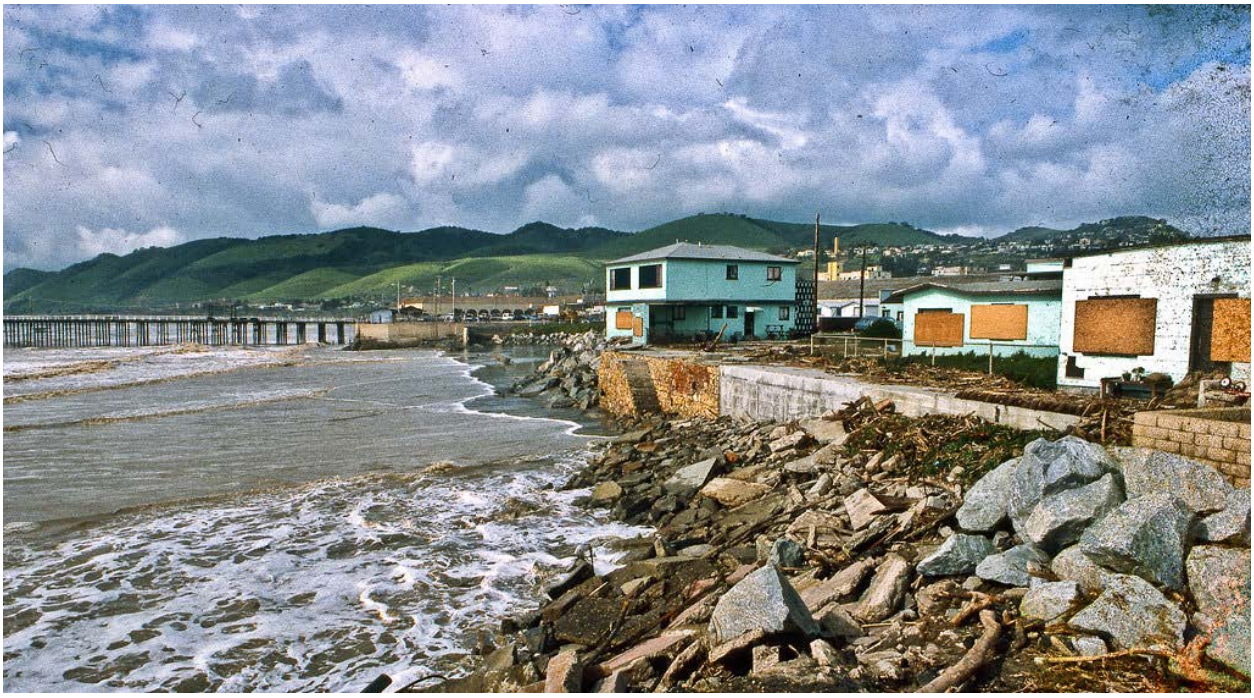


Figure 2-8: 1982-83 storm damage between Stimson Ave and Hinds Ave (Nix)



Figure 2-9: 1982-83 storm damage between Park Ave and Ocean View Ave (Nix)

2.6 Existing Shoreline Protection

In response to erosive and storm-related hazards, a variety of shoreline protection structures have been constructed along the City's coastline. Concrete seawalls have lined areas near the pier since the 1970s and continue to be used in addition to steel sheet pile seawalls today (Adelman & Adelman, n.d.). By 2002, portions of the City's bluffs were lined with riprap and multiple types of seawalls including concrete, shotcrete, terrace, and wooden pile (Fugro West, Moffatt & Nichol, 2002). Constructed sand berms have also been utilized as a temporary bluff protection measure at the northwest limit of Pismo State Beach. (USACE, Los Angeles District, 2008).

2.7 Fluvial Hazards

The low-lying portions of Pismo Beach adjacent to Pismo Creek are exposed to fluvial flooding in extreme events. Pismo Creek drains a 37.9 square mile watershed and has a 100-year peak discharge of 14,700 cubic feet per second (FEMA, 2017). Much of the development along Pismo Creek, south of Highway 101, falls within hazard zone AE, which means the area falls within the computed base flood extent and elevation for the 100-year (0.1% annual chance) event. The floodplain extents are mapped on the effective flood insurance rate map shown in Figure 2-10 and can be viewed online at the FEMA Map Service Center (https://msc.fema.gov/portal/search).

The hydraulic analysis conducted by FEMA on Pismo Creek was completed in 1983 and 1989 and indicates the lower reach of Pismo Creek is limited in capacity and unable to convey the base flood within the main channel, resulting in widespread flooding downstream of Highway 101. The RV parks and mobile home communities south of the creek are within this overland flood zone with a base flood elevation of 18 feet (NAVD88) east of Dolliver Street. The residential community north of the creek is also subject to overbank flooding that extends up to Ocean View Avenue. The base flood elevation drops to 13 feet (NAVD88) downstream (west) of Cypress Street. The flood insurance study for San Luis Obispo County does not mention any specific historic flood events along Pismo Creek although the January and February flood events in 1969 resulted in an estimated $4.5 million of damage throughout the county (FEMA, 2017).

Water surface elevations in the lower reach of Pismo Creek are controlled by the beach berm elevation and ocean water levels during large storm events. A photograph looking downstream from Cypress Street Bridge (Figure 2-10) illustrates the barrier beach at the mouth of Pismo Creek. A review of the water surface profiles for the 100-year event in the flood insurance study (FEMA, 2017) indicate several of the bridges do not have capacity for the base flood event, resulting in higher water surface elevations upstream of each crossing. The base flood elevations increase from 13 feet (NAVD88) downstream of Cypress Street Bridge to 18 feet (NAVD88) upstream of the Dolliver Street Bridge, shown in Figure 2-10.



Figure 2-10: FEMA Flood Insurance Rate Map (No. 06079C1344H), Pismo Beach, CA

3. Evaluation of Sea Level Rise and Related Hazards

3.1 What is Sea Level Rise?

Sea level rise science involves both global and local physical processes, as illustrated in Figure 3-1. Models are created based on the current best scientific understanding of these processes from global to local scales and, therefore, are dynamic and periodically updated to reflect these changes. On a global level, the most recent predictions come from the Intergovernmental Panel on Climate Change's 5th assessment report released in 2013. The 5th assessment projections for sea level rise were 50% higher than the previous assessment released in 2007 due to the addition of melting ice sheet dynamics on sea level rise. At the state level, the California Coastal Commission presently recommends using SLR projections published in the *State of California Sea Level Rise Guidance* (Ocean Protection Council, 2018) that was released in March 2018.

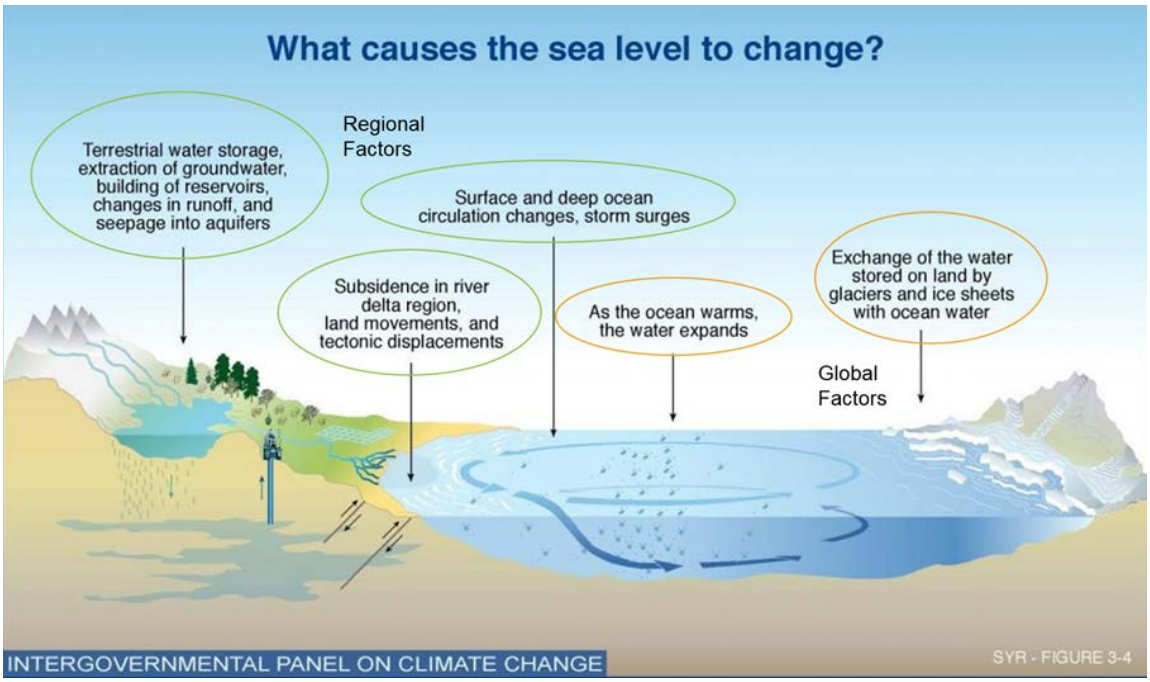


Figure 3-1: Regional and global factors that can contribute to changes in sea level (IPCC, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013)

3.2 Projections and Probability

The OPC (2018) Guidance projects SLR for multiple emissions scenarios and uses a probabilistic approach based on Kopp et al., 2014 to generate a range of projections at a given time horizon for 12 tide gauges along the California coast. The projections for the Port San Luis tide gauge are referenced in this section. CCC SLR Policy Guidance recommends using projections associated

with a high emissions future given that worldwide emissions are currently following the high emissions trajectory.

Climate science is a constantly changing field, often with high degrees of uncertainty. In the case of California, the OPC has high confidence in estimates for sea level rise to 2050, after which greenhouse gas emissions scenarios cause predictions to diverge. For the 2050 time horizon the "likely range" of SLR is between 0.5 feet and 1.0 feet. There is a 66% probability that SLR will fall within this "likely range" at a given time horizon according to OPC projections. The likely range of SLR at the 2100 time horizon is 1.3 feet to 3.1 feet for a high emissions scenario.

The 2018 OPC Guidance lays out a risk decision framework that relates SLR projections to low or high-risk aversion cases based on probability of occurrence. The upper end of the "likely range" of SLR projections is recommended for low risk aversion situations where impacts from SLR greater than this amount would be insignificant or easily mitigated. The state recommends this high-risk tolerance or low risk-aversion case be used when considering resources where the consequences of SLR are limited in scale and scope with minimum disruption or where there is low potential impact on communities, infrastructure, or natural systems. This "low risk aversion" curve is shown in orange in Figure 3-2. At any given time horizon there is a 17% chance that SLR will exceed this curve.

For medium-high risk aversion situations more conservative, lower probability projections for SLR are recommended by the OPC Guidance. These projections have a 1-in-200 chance (0.5% probability) of occurring at a given time horizon and would be appropriate for use on projects where damage from coastal hazards would carry a higher consequence and/or a lower ability to adapt, such as residential and commercial structures with a longer design life (75-100 years). For these lower-probability cases SLR of 1.8 feet is projected at the 2050 time horizon, 3.3 feet is projected at the 2070 time horizon, and 6.7 feet is projected at the 2100 time horizon. The "medium-high risk aversion" curve is shown in red in Figure 3-2.

The OPC guidance also includes a specific singular scenario, called H++, based on projections by Sweet et al., 2017 which incorporate findings of Pollard & Deconto, 2016 that predict Antarctic ice sheet instability could make extreme sea-level outcomes more likely than indicated by Kopp et al. 2014 (Griggs, et al., 2017). Because the H++ scenario is not a result of probabilistic modeling the likelihood of this scenario cannot be determined. Due to the extreme and uncertain nature of the H++ scenario, it is most appropriate to consider when planning for development that poses a high risk to public health and safety, natural resources and critical infrastructure (Ocean Protection Council, 2018). The H++ extreme risk aversion curve is shown in purple in Figure 3-2.

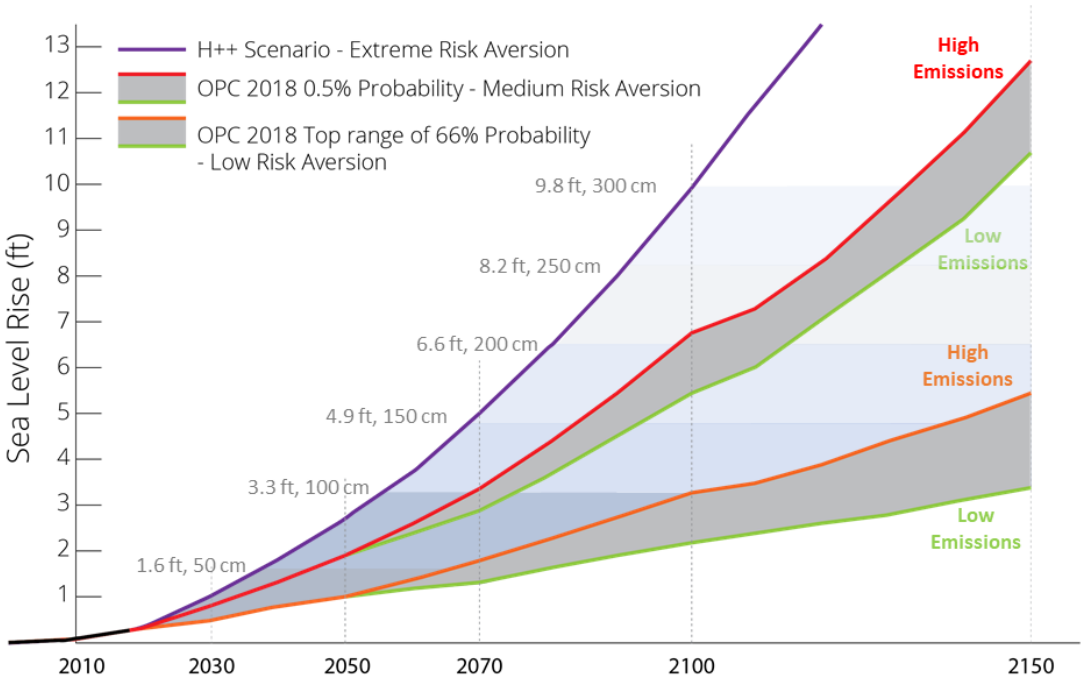


Figure 3-2: Approximate sea level rise projections for three risk aversion levels

3.3 Selected SLR Scenarios

In accordance with CCC Sea Level Rise Policy Guidance and coordination with CCC staff, five sea level rise scenarios were selected for use in this Study. Due to the high degree of uncertainty associated with predicting when and at what rate SLR will occur, this study evaluates even increments of SLR between 1.6 ft and 6.6 ft and also evaluates the impacts from extreme SLR, represented by an 8.2 ft and 9.8 ft SLR scenario. These SLR scenarios are identified in Figure 3-2 and illustrate how each scenario could be applicable at different time horizons. For example, the 1.6 ft SLR scenario could occur as soon as 2040 under an extreme SLR scenario (H++) but is more likely to occur in the 2070-2080 time frame. The specific scenarios described below will provide a basis for understanding how hazards and vulnerabilities change with each increment of SLR that could potentially occur this century.

1. SLR of 1.6 ft (50 cm) is representative of the low risk aversion projection for 2070, which means there is an 83% probability SLR will not exceed this amount over the next 50 years. There is less than a 5% probability that this amount of SLR will occur before 2060. Under a worst-case extreme SLR scenario (H++) this amount of SLR could occur by 2040.
2. SLR of 3.3 ft (100 cm) is representative of the medium-high risk aversion projection for 2070 which means there is a 99.5% probability SLR will not exceed this amount over the next 50 years. This scenario also represents the upper end of the likely range of SLR predicted for 2100. Under a worst-case extreme SLR scenario (H++) this amount of SLR could occur by 2060.

3. SLR of 4.9 ft (150 cm) represents the medium-high risk aversion projection for the 2080-2090 time horizon. There is a 95% probability that 4.9 ft of SLR does not occur until after 2100. However, under a worst-case extreme SLR scenario (H++) this amount of SLR could occur by 2070.
4. SLR of 6.6 ft (200 cm) is representative of the medium-high risk aversion projection for 2100 which means there is a 99.5% probability SLR of this magnitude will not occur this century. This scenario provides a conservative projection for SLR to be applied on projects with a longer design life (75-100 years) and subject to medium-high consequences if SLR is underestimated.
5. SLR of 8.2-9.8 ft (250-300 cm) is representative of the worst-case extreme SLR scenario (H++) for the 2090-2100 time horizon. This scenario does not have an associated likelihood of occurrence but is recommended to be applied on critical projects which would have considerable public health, safety, or environmental impacts if damaged.

3.4 Coastal Hazard Evaluation

The effects of SLR on storm and non-storm related flooding were evaluated using results of the Coastal Storm Modeling System (CoSMoS) Version 3.1, a multi-agency effort led by the United States Geological Survey (USGS) to make detailed predictions of coastal flooding and erosion based on existing and future climate scenarios for Central California. Other SLR hazard viewers such as the NOAA Sea Level Rise Viewer are also available, but these tools lack the regional focus and depth of information provided in CoSMoS modeling efforts.

The CoSMoS modeling system incorporates state-of-the-art physical process models to enable prediction of currents, wave height, and total water levels (Barnard, et al., 2019). A total of 8 SLR scenarios are available, increasing in 0.8 ft (25 cm) increments from 0 to 3.3 ft (0 to 100 cm) and 1.6 ft (50cm) increments from 3.3 ft to 9.9 ft (100 to 300 cm), also including an extreme SLR scenario of 16.4 ft (500 cm). CoSMoS modeling results provide predictions of shoreline erosion, cliff erosion, and coastal flooding under both average conditions and extreme events.

Hazard analyses for the City of Pismo Beach incorporate shoreline erosion, bluff erosion, and coastal flood modeling results given the variety of environments within the City coastal zone. The hazards depicted in this report are presented solely based on the assumptions and limitations accompanying the CoSMoS data available at the time of this study. No additional numerical modeling or independent verification of the CoSMoS data was performed.

3.4.1 SLR-Related Shoreline and Bluff Erosion Projections

CoSMoS shoreline erosion projections include long-term erosion resulting from SLR and projected wave conditions. Shoreline erosion projections are modeled with the CoSMoS Coastal One-line Assimilated Simulation Tool (COAST), which includes a suite of models that consider historic erosion trends, long- shore and cross-shore sediment transport, and shoreline changes

due to increased water levels. These models were tuned with historic data to account for unresolved sediment transport processes and inputs such as sediment loading from rivers and streams, regional sediment supply including beach nourishment and bypassing, and long-term erosion. The CoSMoS-COAST shoreline projections are developed from an initial shoreline mapped from a 2009-2011 LIDAR data set (Erikson, et al., 2017). CoSMoS Version 3.1 also provides cliff erosion projections based on a range of SLR scenarios. Similar to shoreline erosion modeling, historic rates of cliff retreat were used to inform future rates of bluff erosion, including the effects of SLR.

CoSMoS shoreline and bluff erosion projections for each level of SLR are based on four management scenarios. Management scenarios are defined by the presence or absence of shoreline armoring and beach nourishment. The use of shoreline and bluff armoring is referred to as a "Hold-the-Line" scenario, and shoreline erosion modeling under this scenario assumes that the existing boundary between sandy beach areas and development is maintained with coastal structures. The "No Hold-the-Line" scenario assumes no such armoring is in place and allows shoreline erosion projections to propagate inland to the maximum potential extent based solely on topography. In a similar manner to the shoreline armoring scenarios, the "Beach Nourishment" management scenario assumes that historical beach nourishment practices are continued into the future, whereas the "No Beach Nourishment" scenario assumes the beach is left in its current state. The No Hold-the-Line, No Beach Nourishment scenario is used for hazard analyses within this study in order to document the full suite of potential SLR hazards. Bluff erosion hazards are detailed in Figures Figure A-1, Figure A-2, Figure A-3, and Figure A-4 within the hazard map appendix.

3.4.2 Wave Hazard Projections

Future storm conditions are downscaled from winds, sea-level pressures, and sea surface temperatures of an established global climate model (Erikson et al., 2017). Additional modeling was performed to translate projected deep-water waves during modeled storm scenarios to shore, simulating additional regional and local wave growth. Due to the large geographical extent of CoSMoS modeling efforts, the same representative storm events are used across central and southern California to model wave impacts. Each of the modeled representative storm events produces waves from a W-NW direction typical of winter storms (Table 3-1). Figure 3-3 shows significant wave heights projected for a 100-year coastal storm event at current sea levels. Wave exposure is expected to be generally uniform along Pismo State Beach. Local bathymetry affects wave exposure to a greater degree in the Bluffs Study Area due to the non-linear orientation of bluffs and the presence of various offshore rocky outcrops.

Table 3-1: Boundary conditions associated with each CoSMoS modeled storm scenario

Scenario	Hs (ft)	Tp (s)	Dp (degrees)	Maximum wind speed (m/s)
Background	5.7	12	286	N/A
1-year storm #1	14.4	16	284	22.8
20-year storm #1	19.2	18	281	22.3
20-year storm #2	20.1	18	292	28.7
100-year storm #1	20.3	16	264	26.6
100-year storm #2	22.3	18	287	30.3

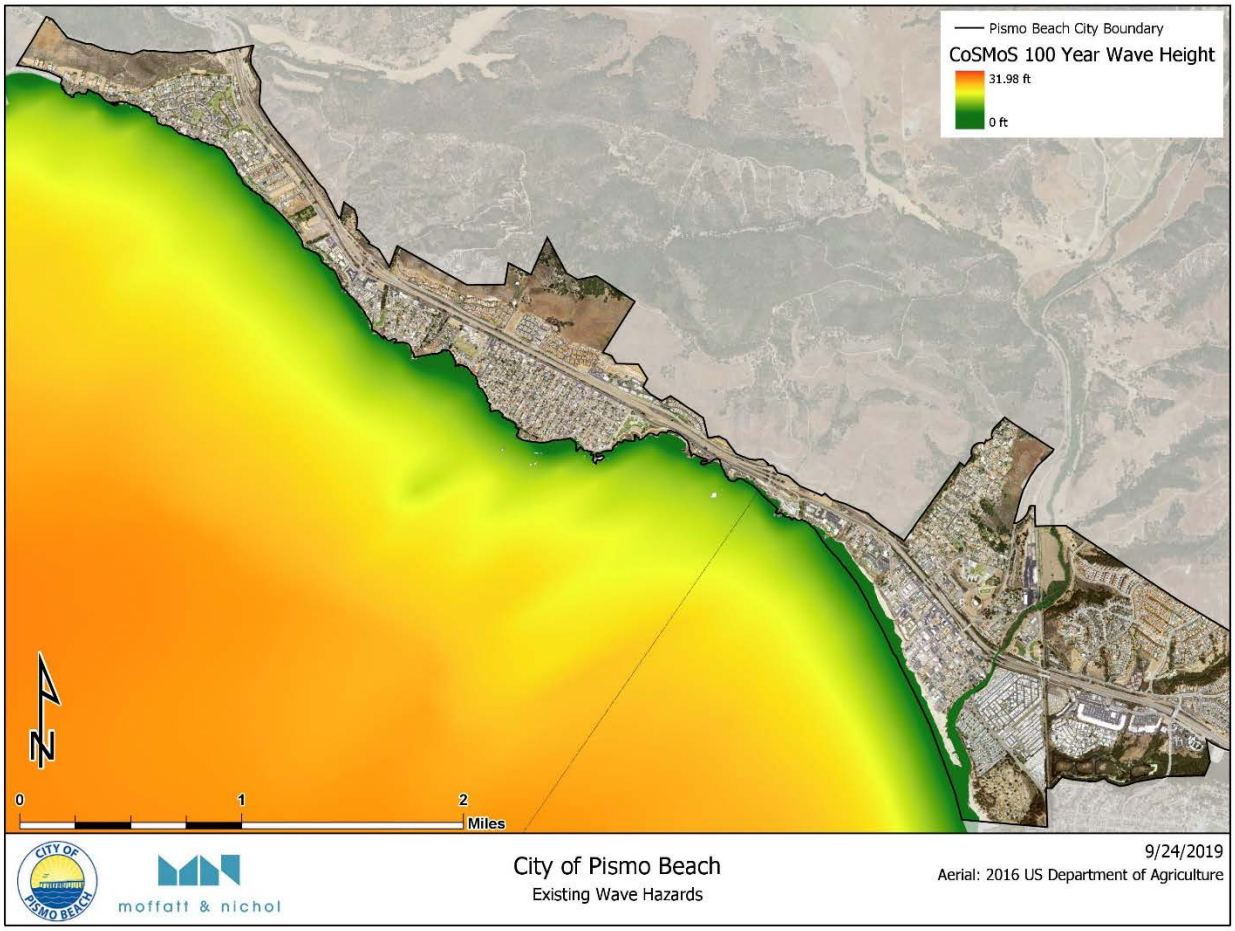


Figure 3-3: Map of CoSMoS 100-year wave heights in the Pismo Beach area

3.4.3 Coastal SLR-Related Flood Projections

CoSMoS coastal flooding projections simulate the effects of erosion, wave runup, and overtopping during storm events. Coastal flood extents are calculated and mapped at profiles spaced approximately 300 ft along the shoreline. The projected coastal water levels used in flood mapping consider future shoreline change, tides, sea level anomalies like El Niño, storm surge,

and SLR. Future wave conditions used in the model are based on forecasted conditions out to year 2100. All flood events are modeled in conjunction with a high spring tide, a tide height that occurs approximately twice a month, to represent a near worst-case scenario (Erikson, et al., 2017).

In this Study, 'tidal flooding' and 'non-storm flooding' both refer to coastal flooding based on the CoSMoS results for average, non-storm conditions at a spring high tide. Figure 3-4 shows projected tidal flooding hazards for SLR scenarios between 1.6 ft and 6.6 ft SLR. The other CoSMoS event scenario analyzed in this Study is the 100-year return period, or 1% annual chance, coastal storm. Coastal flooding hazards during such an extreme coastal storm are expected to be substantially greater than flooding hazards during normal conditions for each SLR scenario, as can be seen by comparing Figure 3-5 to Figure 3-4. CoSMoS flood projections under storm and non-storm conditions are detailed in Figures Figure A-5, Figure A-6, Figure A-7, and Figure A-8.

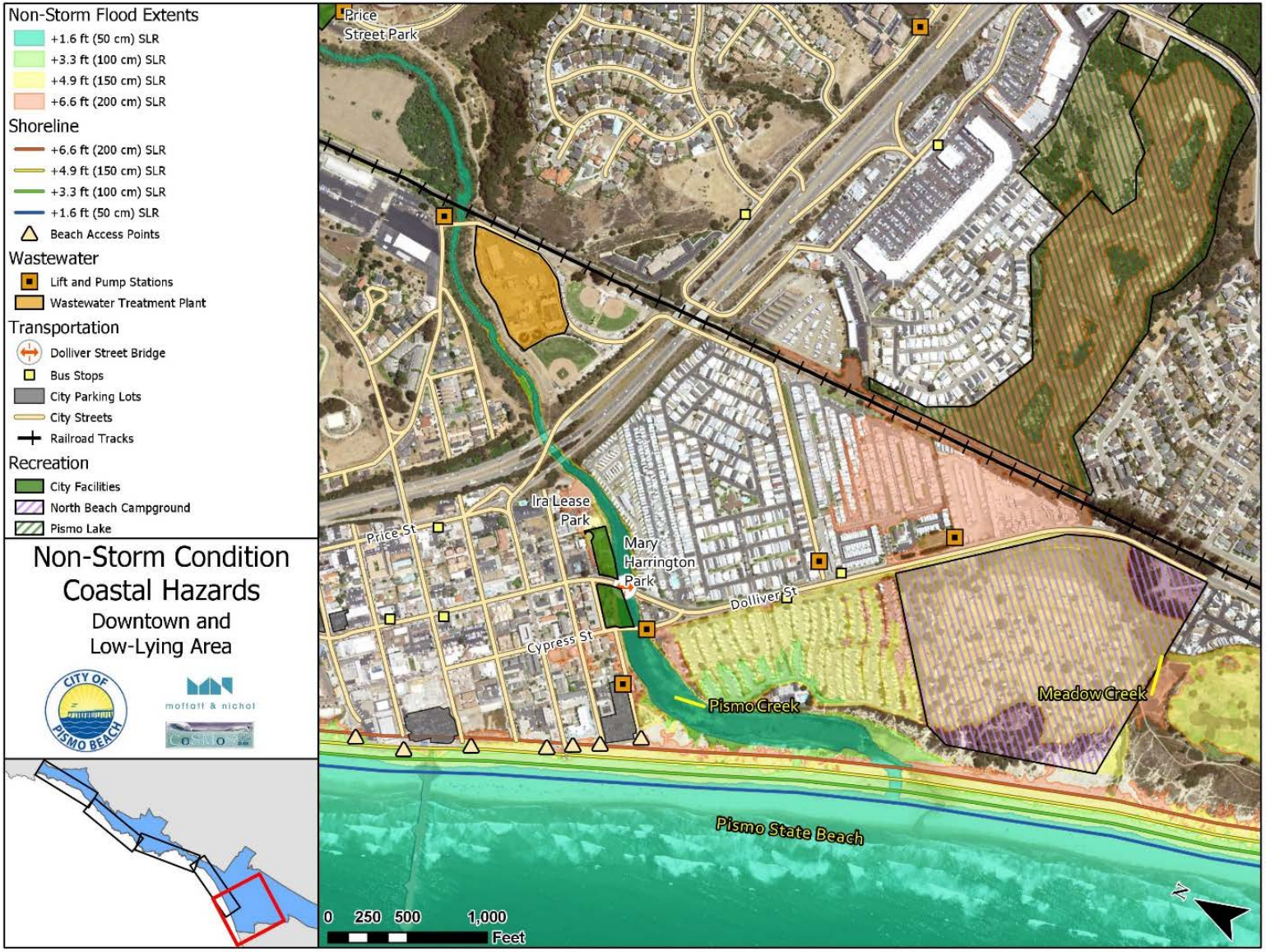


Figure 3-4: Map of tidal flooding hazards



Figure 3-5: Map of 100-year event flooding hazards

3.4.4 Limitations of CoSMoS Projections

The regional focus of the CoSMoS modeling effort results in certain limitations when applied at smaller scales or specific locations. The limitations are particularly evident at locations where wave action and littoral processes are heavily influenced by coastal structures and sediment management activities. Limitations of the CoSMoS model and how they may influence the projected exposure of resources in Pismo Beach are discussed below. An independent verification of their model was not within the scope of this Study.

CoSMoS bluff erosion hazards are reported at transects located at intervals of approximately 500 to 700 feet along the coastline, and linear interpolation is used to approximate hazards in between transects. Due to the highly non-linear shape of the bluffs and coastline within the City this assumption can result in over-estimation or under-estimation of erosion hazards at a specific parcel. An example of these inaccuracies is evident in the vicinity of the Pier Avenue and Ocean Avenue intersection in Shell Beach, where bluff erosion hazards are under-predicted since the transect spacing does not reflect the actual blufftop position, illustrated in the top image of Figure 4-2. Just upcoast at the Chapman Estate, the bluff erosion hazards are significantly over-estimated because the transect spacing does not reflect the bluff position at this particular headland.

CoSMoS coastal flood modeling results assume that future shoreline retreat will be halted at the existing development line. These assumptions may have potential impacts on flood modeling results within the City of Pismo Beach due to the various elevated walkway and armoring structures present in the Downtown Study Area. Projected coastal flood extents, unlike shoreline erosion, are permitted to extend beyond the line of development. The specific type, height, and shoreline profile of existing coastal protection structures that vary by parcel are typically not fully represented by large-scale modeling efforts such as CoSMoS. These parameters are key in providing precise evaluations of the wave runup height and potential for inundation and erosive damage landward of specific structures, and thus it may be prudent to verify CoSMoS findings with more detailed, site specific coastal modeling to evaluate the effectiveness of any potential adaptation strategies that involve existing or new shoreline protection structures.

It is also important to distinguish between the flooding from a coastal storm in combination with SLR as modeled by CoSMoS and other potential sources of flooding that were not evaluated in this study, such as fluvial hazards. The potential flood hazards identified by the CoSMoS model may not represent the worst case flooding scenario for resources in Pismo Beach. Based on the existing 100-year floodplain extents along Pismo Creek, published in San Luis Obispo County's most recent FEMA flood insurance study (FEMA, 2017), fluvial hazards present the most significant source of flooding in the Downtown Study Area and Low-Lying Study Area. This type of flood hazard would also be influenced by SLR, especially along the lower reaches of Pismo Creek where SLR will be pushing the beach profile upward and landward, potentially impacting the breaching patterns of Pismo Creek and Meadow Creek. The interaction between moderate

to extreme fluvial events on Pismo Creek and evolving coastal hazards is beyond the scope of this Study but is recommended as part of any adaptation efforts aimed at reducing the vulnerability of resources in these areas.

During dry weather and even small storms the natural processes which govern water levels in the Pismo Creek estuary are complex and depend on many factors such as dry weather flows, groundwater levels, and barrier beach dynamics that are beyond the scope of this study; however, some general conclusions can be drawn regarding the influence of sea level rise on these processes. It can be assumed that sea level rise will increase the elevation of the beach berm at the mouth of Pismo Creek, increasing the potential for overland flooding during smaller storm events under closed beach berm conditions. Rising sea levels will also increase the downstream controlling water surface elevation of the creek, reducing the storage volume in the creek channel and establishing a higher water surface profile for a certain distance upstream of the ocean. These impacts would combine to result in more frequent flooding of low-lying development adjacent to lower Pismo Creek.

4. Vulnerability Assessment

This vulnerability assessment provides a qualitative evaluation of coastal resources that could be impacted by future hazards associated with increasing static and dynamic water levels under the selected SLR scenarios. The purpose of this assessment is to identify what resources are vulnerable at each increment of SLR to inform City planning efforts.

A Geographic Information System (GIS) was used to compare hazard zones and coastal resources in the City. The overall vulnerability was then assessed as a function of a resource's exposure, sensitivity, and adaptive capacity. These terms are defined as follows in the context of how they were used to develop this vulnerability assessment:

- **Exposure**: the degree to which a system or asset is exposed to SLR. In this Study, asset exposure to projected SLR was determined through numerical modeling and mapping and is defined in terms of flooding and inundation.
- **Sensitivity**: the degree an asset would be impaired by the impacts of SLR. Systems that are greatly impaired by small changes in SLR have a high sensitivity, while systems that are minimally impaired by the same small change in SLR have a low sensitivity.
- **Adaptive capacity**: the ability of an asset to respond to SLR, to moderate potential damages, to take advantage of opportunities, and to cope with the consequences. This does not mean that the system must look the same as before the impact, but it must provide comparable services and functions with minimum disruption or additional cost.

The vulnerability of an asset increases as the hazard exposure and sensitivity increase. Adaptive capacity is inversely related to vulnerability in that as the adaptive capacity increases, the vulnerability decreases. For example, Price Street has a high sensitivity because even minor damage from erosion can cause significant disruption in transportation between Shell Beach and other areas of the City. The roadway has a low adaptive capacity to SLR in that it cannot be easily relocated or raised to cope with consequences; thus, it would be classified as a highly vulnerable asset.

4.1 Coastal Development

Coastal development refers to private and publicly owned properties and buildings within the coastal zone. City parcel and zoning data was used to assess potential SLR impacts to these resources. Existing vulnerabilities to coastal development vary depending on the coastal setting of each study area. Blufftop development has been under sufficient threat from bluff erosion to prompt construction of shoreline protection and bluff stabilization structures since at least the 1970s (Adelman & Adelman, n.d.). Seawalls lining downtown behind Pismo State Beach have been overtopped during notable storm events in the past half century, exposing developed parcels to flood and erosion damage. Low-lying areas near Pismo Creek are already vulnerable to

both fluvial and coastal flooding as indicated by the FEMA flood insurance rate map (Figure 2-10). Parcels closest to bluff edges already vulnerable to bluff erosion will increase in vulnerability with increasing sea level rise.

4.1.1 Bluffs Study Area

The City of Pismo Beach's bluffs are extensively developed, including both residential and tourist-serving development. Residential parcels vary in nature from single family homes to medium-density townhome development. Some parcels contain relatively unimproved areas between structures and the blufftop edge that offer some buffer to erosion impacts, but structures directly adjacent to the blufftop edge are most vulnerable to bluff erosion hazards. Blufftop development is highly sensitive to bluff erosion as undermining can cause building foundations to fail, compromising entire structures. This existing combination of exposure and sensitivity has motivated the construction of numerous coastal armoring structures and bluff stabilization measures. As described in Section 3.4.4, protection from erosion hazards offered by such armoring may not be fully captured in CoSMoS bluff erosion projections.

Figure 4-1 and Figure 4-2 show how CoSMoS modeling generally predicts only the first row of development from bluff edges to be vulnerable to bluff erosion hazards until extreme (8.2 ft to 9.8 ft) SLR scenarios. Given the limitations in trying to project future cliff edge positions and the stochastic nature of cliff erosion, as described in Section 2.4.2, it is difficult to estimate precise SLR thresholds at which cliff erosion would impact existing development. Moreover, these thresholds could vary from parcel to parcel. The subject of cliff erosion and influence of SLR along the California coast is a topic of active academic research. As this research advances and monitoring data continues to be collected by the City's ongoing monitoring programs, the City will be able to better evaluate long-term hazards to blufftop development.

While overall vulnerability to bluff erosion increases with increasing SLR, the impact timelines are challenging to predict. In general, the CoSMoS modeling results suggest the number of parcels vulnerable to erosion hazards does not significantly increase from current levels through 6.6 ft SLR. Though additional parcels are not projected to be exposed until severe to extreme SLR, any existing hazards affecting the first row of development will be exacerbated under any additional increment of SLR. The CoSMoS projections indicate there could be 10-30 feet of bluff erosion for a 3.3 ft SLR scenario and 30-70 feet of bluff erosion for a 6.6 ft SLR scenario.

The hazard projections under extreme SLR scenarios of 8.2 ft and 9.8 ft indicate a significant increase in bluff erosion hazards that could threaten resources landward of the first row of development. The CoSMoS projections become increasingly uncertain for the extreme SLR scenarios, and development on parcels not immediately adjacent to bluff edges may be subject to significant erosion hazards if erosion progresses inland of current development and setbacks.

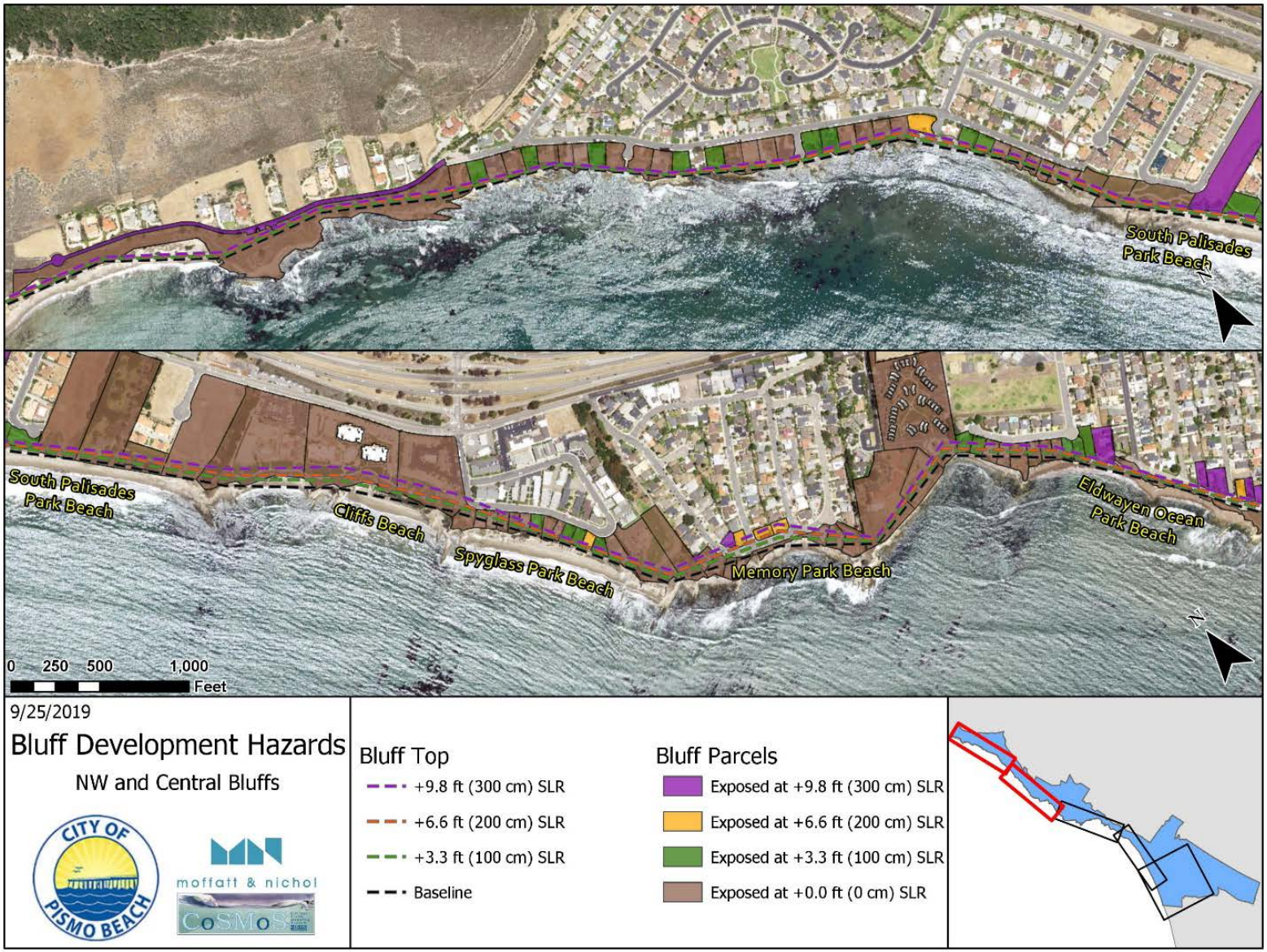


Figure 4-1: Map of coastal development exposure to bluff erosion hazards (NW & Central Bluffs Study Area)

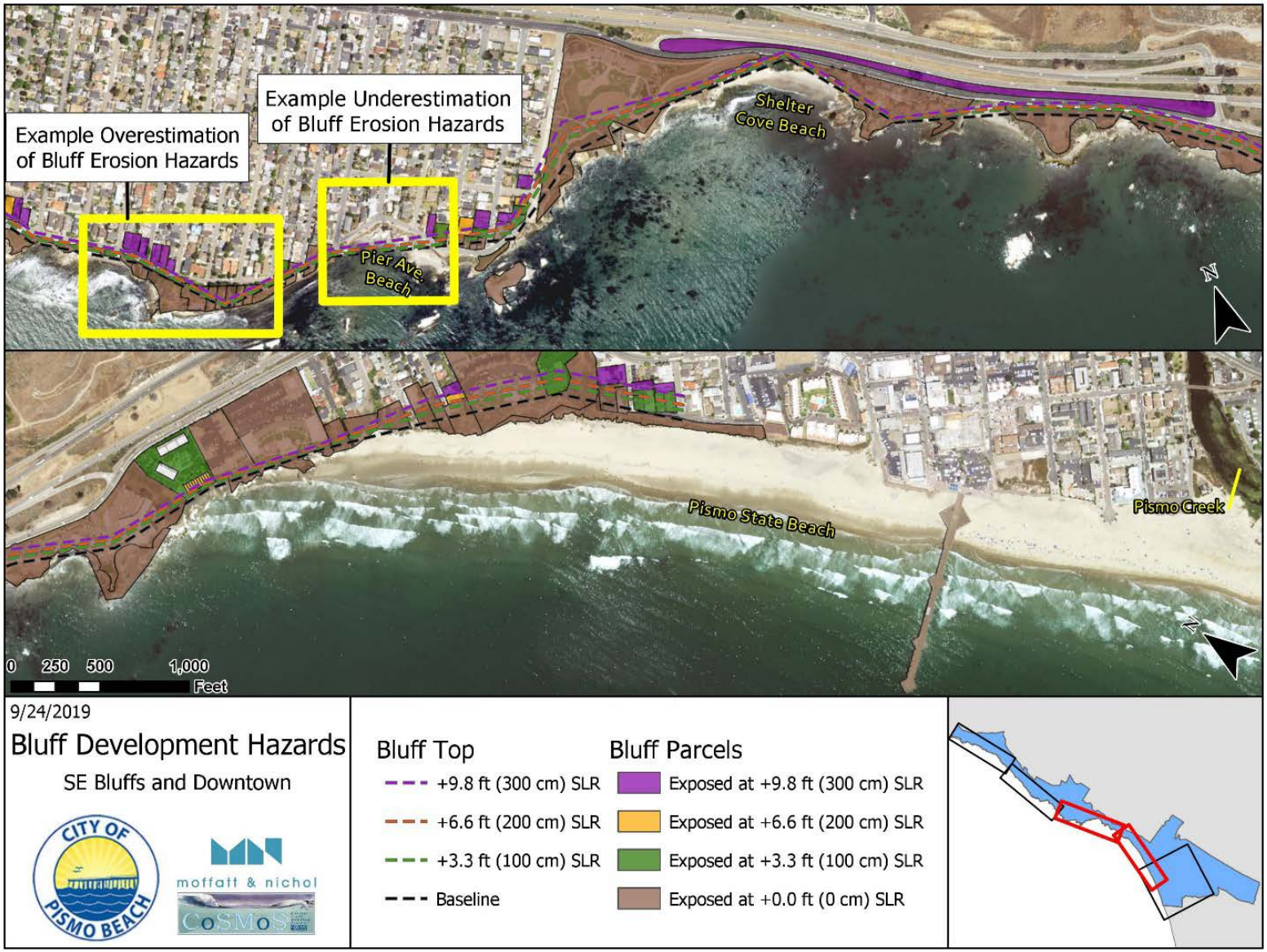


Figure 4-2: Map of coastal development exposure to bluff erosion hazards (SE Bluffs & Downtown Study Areas)

4.1.2 Downtown Study Area

Shoreline erosion along Pismo State Beach will reduce the natural buffer from wave attack provided by the existing beach to beachfront development in the Downtown area, potentially leading to increased overtopping and damage to shoreline armoring. With 4.9 ft SLR the shoreline is predicted to reach portions of the beachfront armoring even during non-storm conditions. With 6.6 ft SLR long-term shoreline retreat is predicted to have reached the back beach line of development, leaving little or no dry beach remaining along Pismo State Beach (Figure A-5).

Sensitivity of development in this area to increased wave hazards associated with shoreline erosion varies depending on the specifications of armoring or other protection present in front of a given structure, though wave runup and overtopping can be expected during extreme events. Adaptive capacity for this area is low due to the intensity and local importance of development in this area, including the pier promenade and multiple large hotels. Predicted SLR-related wave hazards may exceed design specifications for currently installed protection requiring upgrades to mitigate these hazards and preserve existing development.

Increased coastal flooding will also affect the southeast portion of Downtown. The quantity of parcels in both the Downtown Study Area and the Low-Lying Study Area exposed to coastal flooding at each SLR scenario are illustrated in Figure 4-3. Tidal flooding is predicted from Pismo Creek past Addie Street at 6.6 ft SLR (Figure A-5). 100-year storm flooding is predicted to a similar extent at 4.9 ft SLR, extending past Park Avenue at 6.6 ft SLR (Figure A-7). The current FEMA 100-year floodplain already includes this extent, illustrating how non-storm high tide events combined with future SLR may resemble flooding from an extreme fluvial event. In the extreme SLR scenarios (8-10 ft SLR), non-storm flooding adjacent to Pismo Creek will impact most of the development SW of Dolliver Street up to and past Stimson Avenue (Figure A-6).

The projected hazard exposure of Downtown development is limited to temporary flooding during extreme storm events until relatively unlikely, extreme SLR scenarios. Temporary flooding hazards are still of concern due to the high sensitivity of affected development. If flood mitigation measures are not in place, even minor flooding of the developed zone beyond the immediate northern bank of Pismo Creek could lead to extensive structural damages. Several reliable options exist to mitigate temporary, storm-driven flood hazards. Potential adaptation measures include both wet and dry flood-proofing of threatened structures as well as incremental improvements to any existing flood protection mechanisms.

4.1.3 Low-Lying Study Area

Shoreline erosion and increased water surface elevations in Pismo Creek will significantly increase coastal flooding risks to development southeast of Pismo Creek. Tidal flooding of RV facilities SW of Dolliver Street during normal conditions is predicted by 3.3 ft SLR, increasing to nearly the entirety of these facilities by 4.9 ft SLR. Tidal flooding will affect some development NE of Dolliver Street by 6.6 ft SLR (Figure A-5).

Flood exposure of this low-lying area will also increase due to the potential for barrier beach flooding during relatively minor fluvial events on Pismo Creek. The dry beach fronting Pismo Creek can sometimes form a barrier at the creek mouth causing water to pond behind the beach berm during a fluvial event until the berm is breached. As sea level rise pushes the beach berm landward and upward, the elevation at which breaching occurs will also increase. This flood hazard was not specifically evaluated in this Study, but it has the potential to increase the risk of flooding from a fluvial event for resources adjacent to Pismo Creek.

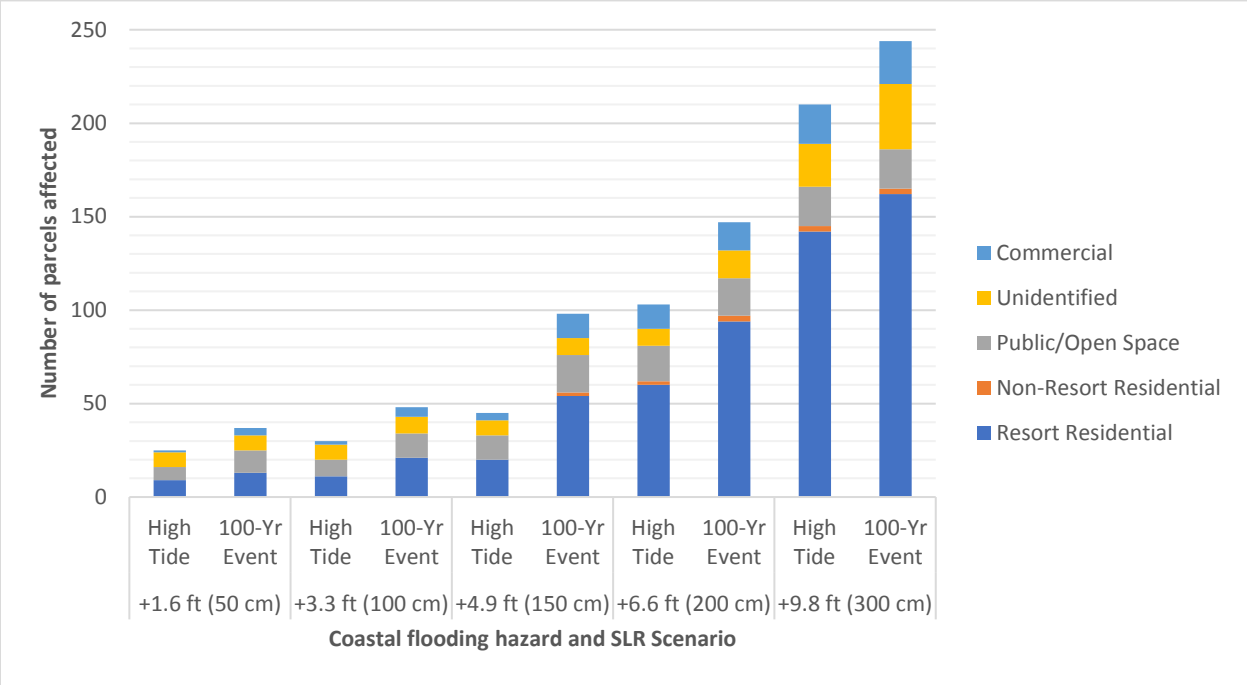


Figure 4-3: Coastal development parcel exposure to coastal flooding hazards (by land use category)

100-year coastal storm flooding elevations are roughly 1.6 feet higher than non-storm flood elevations. The RV resort adjacent to Pismo Creek would be partially vulnerable to severe coastal storm flooding by 1.6 ft SLR and entirely affected by 3.3 ft. An extreme coastal storm combined with 4.9 ft SLR represents an impact threshold that would result in flooding past Dolliver Street to the railroad corridor, impacting critical transportation infrastructure, mobile home communities, and RV resorts in these low-lying areas (Figure A-7). In extreme SLR scenarios (8-10 ft SLR) the extent of flooding changes only incrementally, but the depth of flooding would be much greater during both non-storm and 100-year storm conditions (Figure A-6, Figure A-8).

Coastal development is generally highly sensitive to flood hazards projected under higher SLR scenarios. While it is possible for limited structural damage due to temporary inundation to be repaired in a reasonable timeframe, the recurrent and widespread non-storm flooding projected under 3.3 ft, 4.9 ft, 6.6 ft, and extreme SLR scenarios will likely prevent use of these areas due to ongoing damages and frequent loss of access if no adaptation measures are implemented.

Many traditional flood mitigation practices such as structural elevation or retrofitting are not designed for the frequent flooding expected under SLR scenarios higher than 4.9 feet; however, much of the development within the Low-Lying Study Area (south of Pismo Creek) is relatively adaptive in comparison to the Downtown Study Area (north of Pismo Creek) due to the nature of the development in the former area. Much of the land area in this region is occupied by RV resorts and mobile home parks which can generally accommodate structure relocation and retrofitting with less cost and difficulty than permanent structures. Unfortunately, this area is also the most socioeconomically disadvantaged within the City, as discussed in Section 4.11, and therefore adaptation measures to reduce sensitivity may still impose prohibitive financial burdens. Relocation of these vulnerable communities could result in significant impacts to affordable coastal access and lodging.

4.2 Beaches & Public Trust Resources

Beaches are critical to the City's identity and economy. Pismo State Beach above the present-day high tide line is managed by the State; however, the City is generally responsible for the various pocket beaches amongst the bluffs northwest of Downtown. Pismo State Beach is typically only currently vulnerable to temporary erosion and flooding from extreme coastal storms, but the narrow beaches along the bluffs experience coastal hazard impacts on a more regular basis.

4.2.1 Exposure

The beaches in the Bluffs Study Area are already narrow in comparison to Pismo State Beach. All beaches are projected to be exposed to significant erosion by 1.6 ft SLR, including the current extents of Spyglass Park, Memory Park, Eldwayen Ocean Park, and Pier Avenue. Under this scenario beaches are projected to be completely submerged at higher tides. Assuming little or no landward migration due to erosion resistant bluffs and development, by 3.3 ft SLR all beaches north of Pismo State Beach are predicted to be completely eroded.

As Pismo State Beach is wide and gently sloping, it is predicted to erode at a roughly constant rate with SLR. CoSMoS results, illustrated in Figure 4-4, predict the shoreline near Downtown will advance inland approximately 70 ft for each increment of SLR evaluated in this Study. At the north end of the beach, the shoreline is predicted to move to the base of the Sea Crest Hotel bluff by 1.6ft SLR, to the base of the Wilmar Avenue bluffs by 3.3ft SLR, and to the base of the Kon Tiki Inn bluff by 4.9ft SLR. In these scenarios, CoSMoS modeling predicts the shoreline will continue its advance inland of the current dune structures fronting Pismo Creek. However, barrier beach dynamics near the creek's inlet are critical to beach movement in this area and may not be fully captured in the modeling used for this Study. At 6.6ft SLR the shoreline is projected be near the base of the Cypress Avenue bluffs and against Downtown development SE of Main Street. Extreme SLR scenarios predict near complete erosion of Pismo State Beach within City limits by 9.8ft SLR, assuming the beach is not allowed to migrate inland.



Figure 4-4: Map showing Pismo State Beach CoSMoS erosion projections

4.2.2 Sensitivity & Adaptive Capacity

The beaches in the Bluffs Study Area are significantly more sensitive to SLR-induced shoreline erosion due to their generally narrow nature. The first SLR impacts along the narrow cliff-backed beaches of the Bluffs Study Area (Figure 4-5) can be characterized as "coastal squeeze", the process by which sea level dependent physical, cultural, or biological areas are pushed landwards with SLR but are prevented from natural landward migration due to a protected or non-erodible structure. Along the City's northern coastline, the dry beach and intertidal zone are at risk of permanent loss due to coastal squeeze.



Figure 4-5: Photo of Eldwayen Ocean Park Beach showing narrow beach backed by armored and unarmored bluffs (March 2019)

Erosion of these narrow beaches will also increase wave energy at the bluff toe, increasing potential erosion of unarmored bluffs and wave hazards to armored extents. As the limited sediment transport in this area suggests much of the material for a given beach originates from its backing bluff (Fugro West, Moffatt & Nichol, 2002), sediment supplied from bluff erosion could benefit the beach profile, maintaining the presence of the beach. Bluff erosion is a natural process and could help maintain a natural buffer from rising seas as material eroded form the

bluff face is deposited along the rocky, thin beaches. Therefore, natural adaptive capacity is dependent on the presence and extent of armoring behind specific beaches. The natural adaptive capacity of the bluff backed pocket beaches decreases with armoring that may protect other assets. The recent bluff stabilization project installed at Memory Park Beach is an example of the trade-offs that exist for bluff adaptation strategies (Figure 4-6). While the stabilized bluff protects Street Andrews Lift Station, Seacliff Drive, and improves coastal access, the project has reduced the natural supply of sediment from the bluff, limiting the adaptive capacity of the fronting beach to respond to rising sea levels.



Figure 4-6: Photo of Memory Park Beach showing narrow beach backed by armored bluffs (March 2019)

Comparatively, Pismo State Beach in the Downtown and Low-Lying Study Areas is less sensitive than the northern beaches. The beach is typically hundreds of feet wide between the shoreline at MSL and any backing structures or bluffs, providing better adaptive capacity to accommodate the likely range of SLR projections over the next 50 years. Approximate percentages of lost Pismo State Beach area and estimated economic value losses for each SLR scenario are presented in Section 4.2.3. Partially vegetated dunes exist between the beach and Pismo Creek south of Addie Street, which offer further protection from increasing wave impacts and erosion so long as the

mouth of Pismo Creek does not significantly shift. In addition, Pismo State Beach is well interconnected to the remainder of the Santa Maria littoral cell and does not show general historical erosive trends as discussed in Section 2.4.1. Restoration of sediment to the wider littoral budget may have the potential to cause accretion of Pismo State Beach to offset SLR-related erosion, as the beach extent in the northern area of the littoral cell accreted in the early 20th century before reductions in sediment supplied to the cell (Moffatt & Nichol, 2001).

4.2.3 Non-Market Value Loss

Non-market value refers to those goods and services that cannot be directly measured through a market price when bought or sold. The non-market value of coastal resources is defined in terms of recreation value and ecosystem services such as water quality improvements in wetlands or the provision of ecological diversity within nearshore reefs. Non-market value loss within the City of Pismo Beach is likely due to loss of sandy beach area throughout the City, resulting in significant impacts to recreational resources as sea levels rise.

Beaches such as Pismo State Beach provide non-market value in a number of ways, including recreation and storm buffering capacity (California Department of Boating and Waterways, 2011). These values can be quantified in terms of willingness to pay, or the amount that an individual consumer would be willing to spend to consume the good or use the associated service (Raheem, et al., 2009).

Determination and quantification of non-market values associated with beaches remains challenging due to the inherent variability between locations. Value can be expressed in a spatially explicit manner, such as a per-acre basis, and in terms of consumer surplus per activity day, which provides an estimate of the economic value of each beach attendee.

U.S. Environmental Protection Agency (EPA) estimates of the economic value of coastal ecosystems were used in this analysis to define beach value loss from Pismo State Beach in a spatially explicit manner. U.S. EPA economic value estimates are based on a comprehensive review of past studies by economists, conservation biologists, and California Ocean Protection Council staff to provide policy-relevant ecosystem service values for the California coastline. The study considered over 30 categories of ecosystem services in total and provides quantitative estimates of erosion regulation, recreation and ecotourism, and cultural heritage values associated with beach ecosystems (Table 4-1).

Table 4-1: Non-market values of California beach ecosystems in 2008 $US (Raheem, et al., 2009)

Non-Market Service Category	Service Flow Per Acre Per Year (2008 $US)
Recreation and Ecotourism	$ 16,946
Erosion Regulation	$ 31,131
Cultural Heritage Values	$ 27
Total Value	$ 48,104

The City of Pismo Beach contains approximately 9.2 acres of recreational sandy beach considered part of Pismo State Beach, resulting in a total annual value of approximately $525,000 based on EPA non-market service valuations and adjustments to 2019 dollars using Consumer Price Index values. SLR is projected to progressively reduce this sandy beach area over time. Estimate of beach loss based on CoSMoS shoreline projections under a no-hold-the-line, no-nourishment scenario along with resulting loss in service flow per year are presented in Table 4-2.

Table 4-2: SLR impacts on non-market values for Pismo State Beach within City limits

SLR Scenario	Percent Loss of Beach Area	Service Flow Per Year (2019 $US)	Loss in Non-Market Value Per Year (2019 $US)
+0 ft	0%	$ 525,000	$ 0
+1.6 ft	12.8%	$ 458,000	$ 67,000
+3.3 ft	30.4%	$ 366,000	$ 159,000
+4.9 ft	45.0%	$ 289,000	$ 236,000
+6.6 ft	62.7%	$ 201,000	$ 324,000
Extreme (+9.8 ft)	100%	$ 0	$ 525,000

4.3 Coastal Access

Coastal access points are a key resource for future adaptation planning, as their siting often necessitates exposure to coastal hazards. A multitude of access points including short stairs and ramps exist near the Pier which are subject to wave attack in extreme events. Access points for bluff-backed beaches north of Pismo State Beach are of greater concern due to the actively eroding bluffs and the fact that only one landward access point exists for some beaches. Certain beaches are only accessible from land via unmaintained trails that may have high sensitivity to storm damage. In contrast, many very accessible entries are available to Pismo State Beach. In particular, Main Street, Hinds Avenue, and Addie Street offer vehicular access to Pismo State Beach for emergency services.

4.3.1 Exposure

The Bluffs Study Area contains 10 identified access stairs or paths that descend from developed blufftops to the beaches. Although all access points north of Pismo State Beach are already exposed to erosion hazards, these hazards and wave runup will only increase as sea level increases. Even if access structures remain undamaged, access will be affected by shoreline retreat projected for 1.6 ft SLR. In this scenario, the shoreline at MSL will reach access points at Memory Park, Eldwayen Ocean Park, and Pier Avenue, causing beach access to only be available at lower tide levels or not at all. By 3.3 ft SLR, all beaches north of Pismo State Beach are predicted to be nearly completely eroded or submerged, leaving undamaged access points only to elevated rocky outcrops or directly to the ocean itself.

Beach access points to Pismo State Beach have inherently different exposure to SLR-related erosion hazards than access points to northern beaches. Some are not yet frequently exposed to direct erosion hazards except during extreme storm conditions due to Pismo State Beach providing protection from direct wave attack. These access points show an increase in anticipated exposure with proximity to the northern end of Pismo State Beach, shown in Table 4-3, as the beach width decreases until the bluffs meet the ocean at the beach's northern end.

Table 4-3: Coastal access points exposure (north to south)

Asset	SLR-Related Hazards	SLR Scenario				
		1.6 ft	3.3 ft	4.9 ft	6.6 ft	8-10 ft
Bluffs Study Area						
Cottage Inn, Pismo Lighthouse Suites, Seacrest Hotel Stairs	Shoreline & Bluff Erosion	S	S	S	S	S
Ocean Way Stairs	Shoreline & Bluff Erosion	H	S	S	S	S
Wilmar Avenue Stairs	Shoreline & Bluff Erosion	M	H	S	S	S
Kon Tiki Inn Stairs	Shoreline & Bluff Erosion	M	H	H	S	S
Downtown Study Area						
Wadsworth Avenue Stairs	Shoreline & Bluff Erosion	M	H	H	H	S
Main Street Ramp	Shoreline Erosion	M	H	H	S	S
Pomeroy Avenue Stairs	Shoreline Erosion	M	H	S	S	S
Hinds Avenue Access and Stairs	Shoreline Erosion	M	H	S	S	S
Ocean View Ramp N	Shoreline Erosion	M	H	H	S	S
Ocean View Ramp S	Shoreline Erosion	M	M	H	S	S
Park Avenue Access	Shoreline Erosion	M	M	H	S	S
Addie Street Access and Stairs	Shoreline Erosion	M	M	M	H	S

Moderate: subject to wave attack during storm conditions

High: subject to wave attack during normal conditions

Severe: seaward of projected shoreline

The Downtown Study Area contains eight access structures that descend from elevated City streets to the beach. All access structures will be affected by increasing erosion hazards and wave runup as sea level increases, but these access points are subject to lower SLR-related hazard exposure than access points in the Bluffs Study Area due to the shielding effects of Pismo State Beach.

By 3.3 ft SLR, access points north of Ocean View Avenue will be under regular wave attack due to shoreline erosion, exposing them to increasing risk of damage and significant impacts to accessibility during non-storm conditions. By 4.9 ft SLR these impacts will spread to nearly the entire extent of the Downtown area, and access points in the immediate proximity of the pier will be at particular risk due to the relative prominence of the pier promenade. In higher SLR scenarios high tide lines and, eventually, the shoreline are projected to reach some access points, causing beach access to only be available at lower tide levels or not at all. By the extreme SLR scenarios (8-10 ft SLR) all current access points will be seaward of the shoreline.

Some access points like the Wadsworth Avenue Stairs and Addie Street Stairs have armoring in their direct vicinity that may not be fully accounted for in CoSMoS modeling results, but such details would not be expected to significantly impact exposure as reported in this Study.

4.3.2 Sensitivity & Adaptive Capacity

Erosion-induced damage necessitating repair to access structures or paths could result in extended loss of access to beaches in the Bluffs Study Area. High cost and limited space due to other development could pose difficulties for construction of alternative access.

There is less sensitivity for coastal access to Pismo State beach because of the number of access points and setback from the non-storm shoreline for most SLR scenarios. It is important for the City to maintain a variety of access points from Downtown, a popular tourism area and key economic center. Access points in this area are integrated into the coastal armoring installations protecting Downtown development, and repair or relocation of access points can be considered with and integrated into repairs or modifications to armored segments.

4.4 Recreation Facilities

The City owns and maintains a variety of recreational facilities in the coastal zone, such as parks and the Chapman Estate. The State also owns and operates facilities for Pismo State Beach within the city, including the Pismo State Beach North Campground. These State facilities in the Low-Lying Study Area and multiple City parks in the Downtown Study Area are currently exposed to coastal and fluvial flooding due to their proximity to Pismo State Beach and Pismo Creek. Recreation assets in the Bluffs Study Area, such as Eldwayen Ocean Park and Memory Park, extend up to the edge of actively eroding bluffs.

4.4.1 Exposure

The Bluffs Study Area contains seven City-owned parks and one additional recreation facility, the Chapman Estate, currently subject to erosion hazards. Like other resources located in this region of the City, these erosion hazards will only increase as sea level increases. Exposure by asset varies by local bluff erosion rates and the presence and extent of armoring protecting a given asset. Reviews of City planning documents and satellite imagery were used to produce Table 4-4.

Table 4-4: Armoring of Bluffs Study Area recreation facilities (north to south)

Asset	Identified Armoring
South Palisades Park	Unarmored
Ebb Tide Park	Unarmored
Spyglass Park	Unarmored
Memory Park	Partially Armored
Eldwayen Ocean Park	Partially Armored
Chapman Estate	Partially Armored
Margo Dodd Park	Unarmored
Dinosaur Caves Park	Unarmored

Over half the recreation assets in this area are unprotected and exposed to bluff erosion hazards. Exposure for the partially armored assets is site dependent on site-specific armoring detailed below:

- Armoring in the southern vicinity of Memory Park was recently completed, and the remainder of the park's bluffs are somewhat sheltered from wave action by nearshore rocky outcrops. However, increasing sea levels will reduce this natural shelter and increase exposure by increasing water depths over the rocky reef.
- Eldwayen Ocean Park is a particularly long and narrow park, stretching along approximately 0.25 miles (1300 ft) of coastline. 100-200 ft long armored segments are present at its northern and southern extremities. Rocky outcrops and reefs offer some protection for its central area, but this protection will be diminished with increasing magnitudes of sea level rise.
- The Chapman Estate is located on a corner-like blufftop with both west-facing and south-facing bluff faces. The west-facing bluff is heavily armored as the bluff edge is feet from the primary structure on the property. The south-facing bluff is unarmored and exposed to bluff erosion that will increase with rising sea level. Significant undercutting of the south-facing bluff has already occurred, and bluff collapse is an evident risk.

Recreation assets in the Downtown and Low-Lying Study Areas are not currently exposed nor predicted to be exposed to shoreline erosion hazards in the SLR scenarios evaluated. Instead, several of the parks are exposed to existing flood hazards from Pismo Creek that are likely to increase with each increment of SLR.

Ira Lease Park and Mary Harrington Park are located on the north and south sides respectively of Dolliver Street along the north bank of Pismo Creek. Their location in close proximity to the creek causes them to be currently vulnerable to fluvial flooding and erosion, while coastal flooding due to sea level rise is not expected for SLR scenarios of 1.6 ft and 3.3 ft. Exposure to coastal flooding increases for higher SLR scenarios, with significant tidal flooding of Ira Lease Park predicted with 4.9 ft SLR and Mary Harrington Park prone to tidal flooding by 6.6 ft SLR.

California State Parks operates Pismo State Beach North Beach Campground near the beach at the City's southeastern boundary. Its location just behind the beach and between Pismo Creek and Meadow Creek leads to heightened flood vulnerability due to its exposure to extreme fluvial and potential coastal flooding combined with SLR of 4.9 ft or more. The campground's setback from the active shoreline behind a dune system offers some protection against coastal erosion and flooding for SLR scenarios of 1.6 ft and 3.3 ft. The primary source of flooding under the higher SLR scenarios appears to be from overland flooding from Pismo Creek and Meadow Creek. In the extreme SLR scenarios (8-10 feet), Ira Lease Park, Mary Harrington Park and the North Beach Campground are projected to be subject to frequent tidal flooding absent any form of adaptation to mitigate this widespread flooding.

The CoSMoS modeling results used in this Study likely underrepresent projected fluvial flood exposure to this entire area, as CoSMoS does not reflect how sea level rise and coastal processes could increase the risk of flooding from an extreme fluvial event throughout the low-lying areas adjacent to Pismo Creek and Meadow Creek.

4.4.2 Sensitivity & Adaptive Capacity

Sensitivity and adaptive capacity of recreation assets within the City to bluff erosion is site dependent. Some parks, like Memory Park, Eldwayen Ocean Park, and Margo Dodd Park, are relatively narrow and therefore more sensitive to bluff erosion. Any erosion is likely to significantly reduce the recreation area safely accessible to the public. Others, like Spyglass Park and Dinosaur Caves Park, have larger areas and erosion may not significantly reduce their value to the community for some time. The additional adaptive capacity of these parks includes the potential to shift facilities to less exposed landward areas to retain and prolong recreation benefits. Consideration of potential bluff failure is apparent in the resilient design of Dinosaur Caves Park, with parking, playground, and bathroom facilities placed well inland of the current bluff edge. The parks predominantly lack major structures, so their adaptive capacity for total relocation or creation of alternate recreation is relatively high as well. In contrast, the Chapman Estate has both high sensitivity to bluff erosion hazards and low adaptive capacity. The property is highly developed with little erosion that can occur before structures are threatened by undermining. The large, historic structures on the estate would be prohibitively expensive to relocate even if suitable space could be acquired.

Sensitivity and adaptive capacity of recreation assets to flooding hazards is dependent upon the nature of the flooding. Recreation asset sensitivity within the City to temporary flooding in an

extreme storm event is relatively low and adaptive capacity is high. The weather conditions expected during such an extreme event would also prohibit outdoor recreational activities at these parks. Ira Lease and Mary Harrington Parks are unlikely to suffer more than moderate repairable damage in an extreme coastal storm event so long as the banks of Pismo Creek do not significantly erode, permanently reducing the area of the parks. Park infrastructure can be designed to accommodate flood flows as an adaptation measure. Similarly, permanent facilities at North Beach Campground can be flood-proofed by elevation or retrofitting to withstand temporary inundation.

Reoccurring tidal floods present a much greater hazard to recreation assets. Recreation facility sensitivity to tidal inundation is very high, as such impacts inherently reduce or eliminate accessibility and usability, even during normal weather. It is possible to redesign the parks to be more compatible with increasing water levels for SLR scenarios up to 3.3 ft. However, the usability of parks and campground under extreme SLR conditions will be very difficult to preserve without significant adaptation measures aimed at reducing the exposure to flooding and sensitivity to flooding from both fluvial and coastal events.

4.5 Pismo Beach Pier

As described in Section 2.5, the Pier has experienced significant damage due to past extreme storm events such as those in 1983. The pier was rebuilt in 1984-1985 with a landing deck elevation of 20.9 ft NAVD88 with a slope to 26 ft NAVD88 over its first 200 ft. The deck then follows a more gradual slope to 28.5 ft NAVD88 at its end, approximately 1270 ft from the landing. A more recent rehabilitation in 2016-2017 included structural improvements by replacing wooden piles seaward of the first 200 ft segment with steel piles.

Water levels and wave heights from CoSMoS were utilized to evaluate the exposure of the Pier to damage from large wave events in combination with sea level rise. The pier is considered to be vulnerable to storm damage when the maximum wave crest elevation reaches the deck elevation. Most timber pier structures are sensitive to the dynamic loads resulting from a wave crest impacting the pier deck structure. Major damage experienced during the 1983 events can be attributed to some combination of wave crests exceeding the pier deck, scour at the seabed, excessive wave-induced forces on aging piles, and debris from broken piles impacting other piles.

The significant wave height from the CoSMoS 100-year coastal storm event was used in this analysis to calculate a maximum wave crest elevation profile for each SLR scenario. The wave crest elevation profiles (solid lines) and water level profiles (dashed lines) are provided in Figure 4-7 in relation to the existing pier deck elevation. This analysis indicates that, while any amount of SLR will increase the potential for damage during an extreme event, the vulnerability of the pier deck increases substantially in SLR scenarios of 3.3 feet and higher.

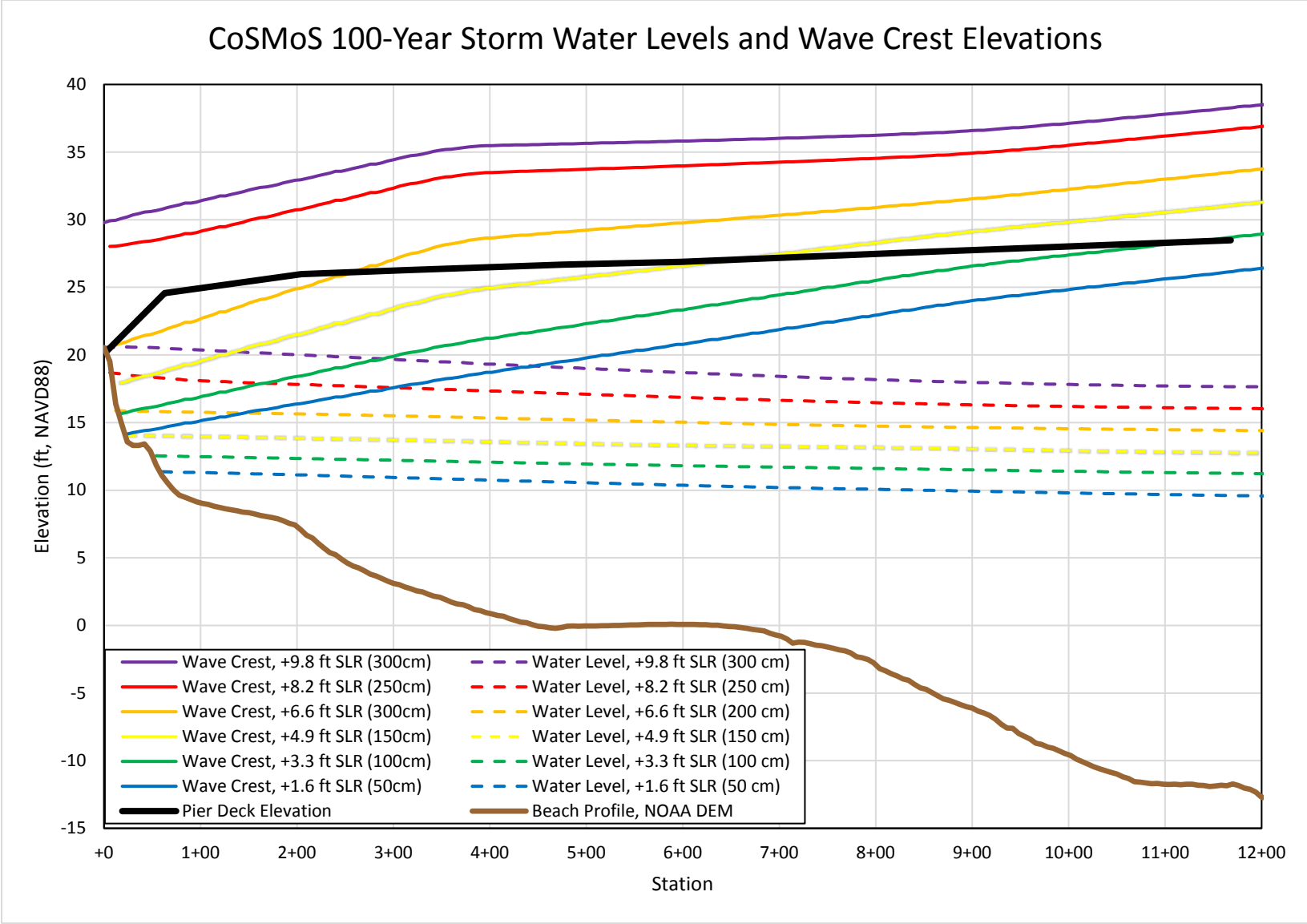


Figure 4-7: Wave crest profiles at Pismo Beach Pier based on CoSMoS 100-year event

4.6 Utilities Infrastructure

The loss of potable water, wastewater, or stormwater services could significantly impact public health and safety. Critical infrastructure within the City includes the Pismo Beach Wastewater Treatment Plant (WWTP), wastewater collection system, water distribution facilities, and stormwater drainage systems. The WWTP is located near Pismo Creek and partially situated within the FEMA regulatory floodway. Distribution pipelines and facilities extend throughout the city, and some key facilities like sewer pump stations have recently necessitated the armoring of bluffs for their protection.

4.6.1 Lift and Pump Stations

The City owns and operates multiple wastewater lift stations already affected by bluff erosion hazards in the Bluffs Study Area. To address erosion threats Street Andrews Lift Station near Memory Park, Vista del Mar Lift Station near Eldwayen Ocean Park, and Cypress Street Lift Station have all been recently protected via bluff armoring.

Multiple pump and lift stations in the Downtown and Low-Lying Study Areas are already exposed to flooding hazards during extreme fluvial storm events. The FEMA 100-year floodplain in this area includes the Addie Street Pump Station at the northeast corner of the beach parking lot, a buried lift station near the southern landing of the Cypress Street Bridge, and two other lift stations in the Low-Lying Study Area northeast of Dolliver Street. Tidal flooding is not expected to reach these pump stations until SLR exceeds 6.6 ft SLR. However, this type of infrastructure can also be affected by higher groundwater levels, which can increase the uplift forces on below ground infrastructure like vaults and lift stations. The impact of SLR on groundwater hazards in the area has not been quantified, but it is expected that the typical groundwater levels will increase with each increment of SLR.

Pump and lift stations are very sensitive to SLR hazards evaluated in this Study. Adaptive capacity is low regarding potential undermining from bluff erosion as acceptable responses typically require expensive relocation of the station or armoring of the bluff face. Pump and lift stations may be able to accommodate and recover from localized, infrequent structural damage or system disruption due to temporary flooding during extreme storm events, but it is unlikely that systems will remain functional if a large portion of utilities resources become subject to recurring non-storm inundation. Elevation or floodproofing may be feasible adaptation measures to address temporary flooding during extreme storm events, but recurring tidal flooding likely necessitates expensive retrofits or reconfiguration of a pump station and its associated utility network.

4.6.2 Stormwater, Wastewater, and Potable Water Lines

Approximately 50 storm drain outlets throughout the Bluffs Study Area terminate at the bluff face and are subject to erosion hazards that are expected to increase with SLR. Since most of these outfalls are gravity systems draining bluff top development, the increased ocean water

levels are not expected to significantly impact drainage capacity. Undermining of these outfalls due to erosion of the bluff face is a more likely hazard due to SLR and will require site specific measures to inspect, maintain, and repair these outfalls as needed.

Most other utility infrastructure is buried beneath roads throughout the City. Several of these roads, such as Ocean Boulevard and Price Street, have little or no setback from bluff erosion hazards, and these utility infrastructure corridors would also be vulnerable to these hazards. Armoring is currently present along some bluff segments but is not reflected in the hazard projections. Figure 4-8 illustrates the length of utility infrastructure potentially vulnerable to erosion hazards predicted by CoSMoS at increasing magnitudes of SLR.

Specific areas where bluff erosion is predicted to threaten both potable water and wastewater lines in different SLR scenarios include:

- Lines underlying the area between the ocean-facing ends of Ocean Boulevard and Boeker Avenue are currently threatened by active erosion.
- Lines buried below Cypress Street between Harloe Avenue and the Sea Gypsy Motel, already vulnerable to erosion, will increase in exposure with each successive SLR scenario.
- Mains near Eldwayen Ocean Park are predicted to be threatened before 1.6ft SLR.
- Lines underlying Ocean Boulevard between Margo Dodd Park and Dinosaur Caves Park are predicted to be threatened by 1.6ft SLR.
- Although CoSMoS modeling may not account for recently installed armoring, results show lines below Price Street inland of Shelter Cove and NE of the Price Street-Mattie Road intersection will be threatened by 3.3ft SLR.
- Mains near Memory Park are predicted to be threatened between 3.3ft and 4.9ft of SLR.

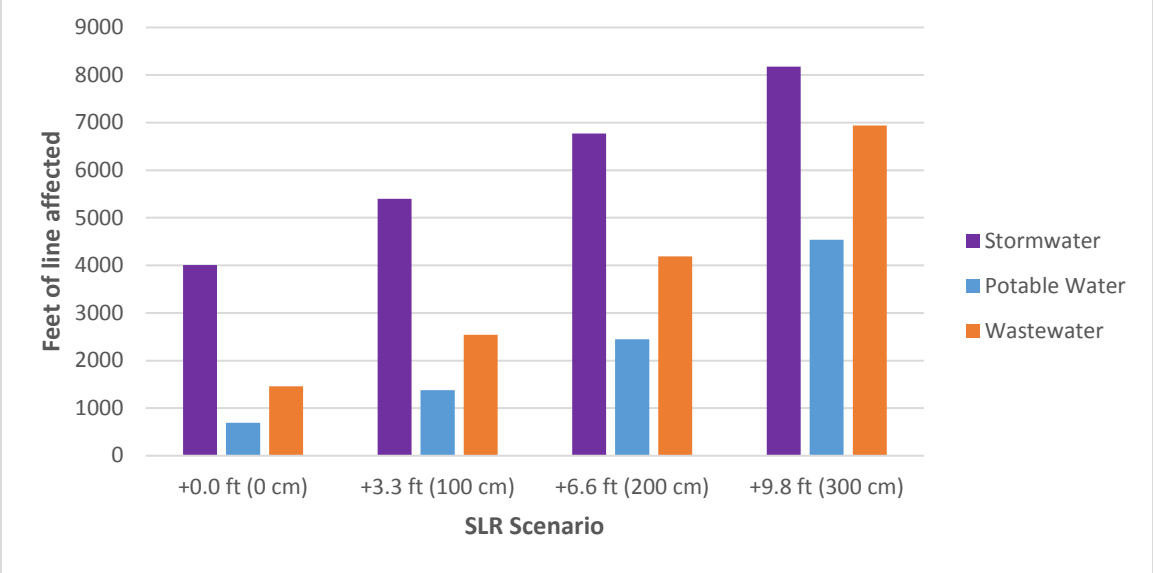


Figure 4-8: Utilities pipelines exposure to bluff erosion hazards

As shoreline erosion is projected to reach the Downtown waterfront between 4.9 ft and 6.6 ft SLR, potable water and wastewater lines serving development in the area could be exposed to erosion hazards if armoring installations are overtopped or damaged. Some buried storm drains serving the Downtown area extend under the beach and have been exposed by severe storms in the past. The potential for similar damage will increase with progressive SLR. At some point, water levels will rise to the elevation of these storm drains, potentially crippling their ability to drain storm flows. As SLR pushes sand higher up on the beach profile any storm drain outlets at the back of the beach may require more frequent maintenance to clear drains in advance of a storm event.

The low-lying areas in the vicinity of Pismo Creek, and utilities which service this area, are exposed to fluvial flooding in an extreme event currently and could be subject to coastal flooding with SLR of 3.3 ft or more. Major force mains which convey wastewater from Addie Street Pump Station to the City's WWTP would be exposed to tidal flooding with 4.9 ft SLR. These utilities already lie within the 100-year FEMA floodplain and CoSMoS results indicate they would be exposed to a 100-year coastal storm with 3.3ft SLR. Other potable water and wastewater lines at the southern end of the Downtown Study Area will be inundated by tidal flooding in scenarios that affect the roadways above them, as detailed in Section 4.7.1.

Total feet of public stormwater, potable water, and wastewater lines throughout the City exposed to each type of flooding evaluated in this Study during different SLR scenarios are illustrated in Figure 4-9. In the Low-Lying Study Area, private potable water networks underlying development southwest of Dolliver Street are projected to be impacted by tidal flooding by 3.3 ft SLR. Broader wastewater lines southeast of Pismo Creek are projected to be impacted by tidal flooding by 4.9 ft SLR. Inundation of public and private potable water lines in the area northeast of Dolliver Street and southeast of Frady Lane are projected to be exposed to tidal flooding by 6.6 ft SLR, and all lines northeast of Dolliver Street area predicted to be inundated by tidal flooding in the extreme SLR scenarios. CoSMoS results show potential 100-year storm impacts to all water networks in this area by 3.3 ft SLR, but the 100-year FEMA floodplain shows they are already exposed to such flooding.

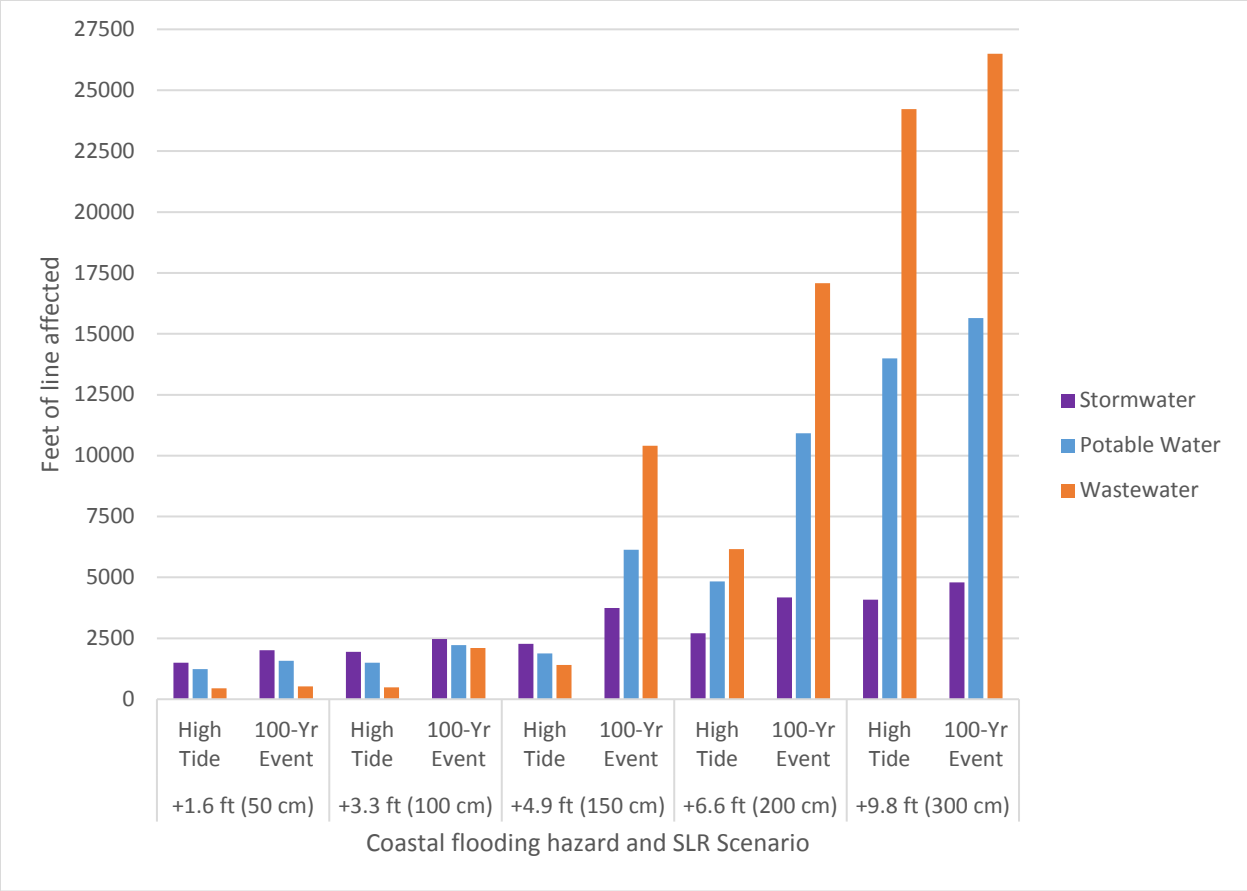


Figure 4-9: Utilities pipelines exposure to coastal flood hazards

Sensitivity of water lines to coastal hazards varies widely. Stormwater drains can be fairly insensitive to bluff or shoreline erosion if effective functionality is not impaired by loss of seaward segments of pipe. Conversely, potable water and wastewater mains are typically highly sensitive to undermining from erosion, as damage to a single pipe can disrupt an interconnected system and cause impacts over a larger area of the pipe network. Sensitivity to flooding is dependent on pipe characteristics and nature of the flooding. Unpressurized stormwater and wastewater lines are typically more sensitive to inundation and flooding as these events can exceed the conveyance capacity of some systems. On the other hand, pressurized potable water lines are typically less sensitive to temporary surface flooding.

Storm flooding will likely reduce the capacity of stormwater and wastewater infrastructure, but these effects would only be temporary. Exposure to reoccurring tidal flooding would likely require some form of adaptation for this infrastructure due to frequent impairment or loss of functionality.

The adaptive capacity of stormwater, potable water, and wastewater lines varies depending on the specific asset and the function it performs as part of the overall system. Adaptive capacity for small-scale isolated utilities infrastructure can be relatively high where opportunities for elevation or relocation are feasible. Adaptive capacity is much lower for assets that play a key

role as part of a larger utility network, such as lift stations which typically collect wastewater from a large pipeline network and convey to the wastewater treatment plant.

4.6.3 Pismo Beach Wastewater Treatment Plant

The City of Pismo Beach Wastewater Treatment Plant was originally constructed in the 1950s and now provides wastewater treatment services to Pismo Beach and several neighboring communities to the south (Carollo Engineers, 2000). A substantial amount of the plant area is located within the current FEMA Regulatory Floodway (FEMA, 2017). Flood control specifications for the WWTP were not reviewed as part of this Study, but the plant appears to be protected from the current main channel of Pismo Creek northeast of Highway 101 by a large levee. CoSMoS modeling does not predict tidal or extreme storm flooding on the protected side of this levee in any SLR scenario, including extreme SLR scenarios. However, there may be indirect impacts to the WWTP from SLR such as increased inflow and infiltration due to widespread flooding that could potentially result in capacity issues at the plant.

4.7 Transportation Infrastructure

The City's transportation network is vital for normal circulation and access as well as emergency services and evacuation. Highway 101, Dolliver Street, and Price Street are major elements of this network. Highway 101 and Dolliver Street both cross Pismo Creek and may be currently vulnerable to extreme flood impacts, particularly Dolliver Street. The vulnerability of Price Street, situated between Highway 101 and eroding bluffs, has motivated an in-progress bluff armoring and stabilization project. Additionally, City-owned parking lots, the region's primary railway, and County regional transit stops are within erosion and flood risk zones from downtown to near the City's southern boundary.

4.7.1 Exposure

Roads atop the City's bluffs are primarily exposed to erosion hazards where there is currently little setback or development between the roadway and bluff edge. Armoring is currently present in some sections, but SLR-influenced erosion hazards will intensify in unarmored extents. Figure 4-10 illustrates the increase in feet of roadway predicted by CoSMoS modeling to be exposed to erosion impacts at increasing magnitudes of SLR.

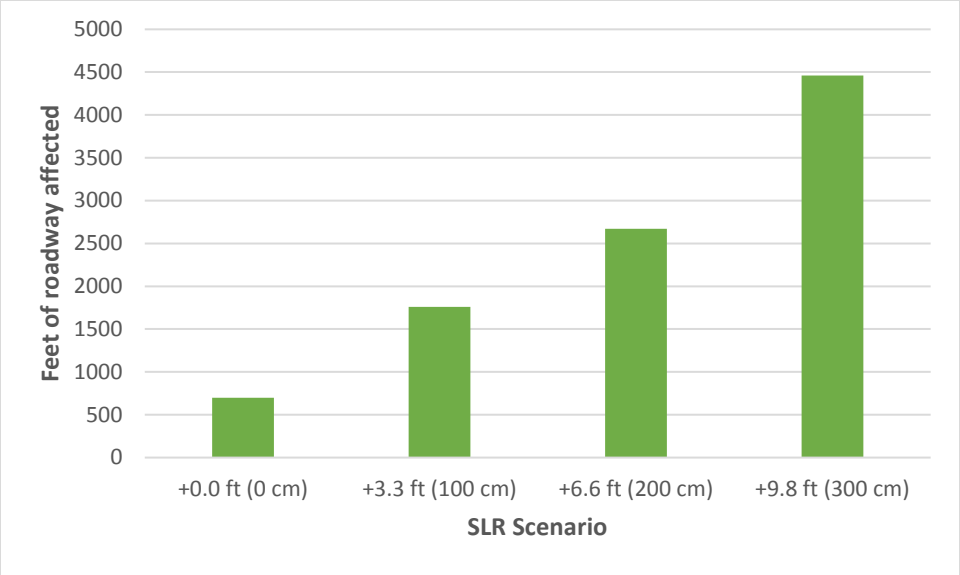


Figure 4-10: Roadway exposure to bluff erosion hazards

Specific areas where bluff erosion is predicted to threaten transportation infrastructure in different SLR scenarios include:

- Portions of Price Street above Shelter Cove and NE of the Price Street-Mattie Road intersection are predicted to be threatened before 1.6 ft SLR.
- The ocean-facing end of Boeker Avenue and the end of Ocean Boulevard immediately to the west of Boeker Avenue are predicted to be threatened as early as 1.6 ft SLR.
- Cypress Street, while already experiencing erosion impacts, will increase in vulnerability with each successive SLR scenario. If erosion progresses inland of Cypress Street, impacts to Harloe Avenue and San Luis Avenue are predicted between 1.6 ft and 3.3 ft SLR.
- Ocean Boulevard in the vicinity of Margo Dodd Park is predicted to be threatened between 1.6 ft and 3.3 ft SLR.
- Seacliff Drive inland of Memory Park and north of recently constructed armoring is predicted to be threatened between 3.3 ft and 4.9 ft SLR.
- Similarly, Ocean Boulevard inland of Eldwayen Ocean Park is predicted to be threatened by the same SLR scenarios of 3.3 ft and 4.9 ft SLR.
- The ocean-facing end of Harbor View Avenue is predicted to be threatened between 4.9ft and 6.6 ft SLR.

As seen in Figure 4-10, bluff erosion predicted from a 9.8 ft SLR scenario greatly increases anticipated exposure in this area. In these scenarios, erosion threats exist to streets perpendicular to the coast inland of Seacliff Avenue near Memory Park. Similarly, nearly the entire extent of Ocean Boulevard from Eldwayen Ocean Park to Dinosaur Caves Park is predicted to be threatened. Unarmored areas of Price Street from Shelter Cove to the Price Street-Mattie Road intersection will also be subject to erosion risks.

Shoreline erosion hazards to transportation infrastructure are of most concern within the Downtown Study Area. While the shoreline is not predicted to reach the end of streets terminating at the beach within Downtown until 3.3 ft to 4.9 ft SLR, exposure to normal and storm condition wave attack will increase at lesser magnitudes of SLR for some streets, especially the unarmored Hinds Avenue and the relatively prominent cul-de-sac of Ocean View Avenue The armored Ocean View Avenue cul-de-sac is predicted to have extremities seaward of the shoreline by 4.9ft SLR. Beyond 6.6ft SLR, shoreline erosion is predicted to continue past the current ends of Hinds Avenue, Stimson Avenue, Ocean View Avenue, Park Avenue, and Addie Street

Coastal flooding hazards to transportation infrastructure are predicted to occur in both the Downtown Study Area and Low-Lying Study Area. As discussed in Sections 0, CoSMoS hazard projections may not capture the full extent of fluvial flood hazards for each SLR increment, which have the potential to impact resources adjacent to Pismo Creek. Figure 4-11 illustrates the length of roadway predicted by CoSMoS modeling to be exposed to tidal and extreme coastal flood hazards at increasing magnitudes of SLR. Similar to other resources in this area, roadways have a low exposure to coastal hazards for the 1.6 ft and 3.3 ft SLR scenarios. The exposure increases significantly for an extreme coastal storm in combination with 4.9 ft SLR and 6.6 ft SLR.

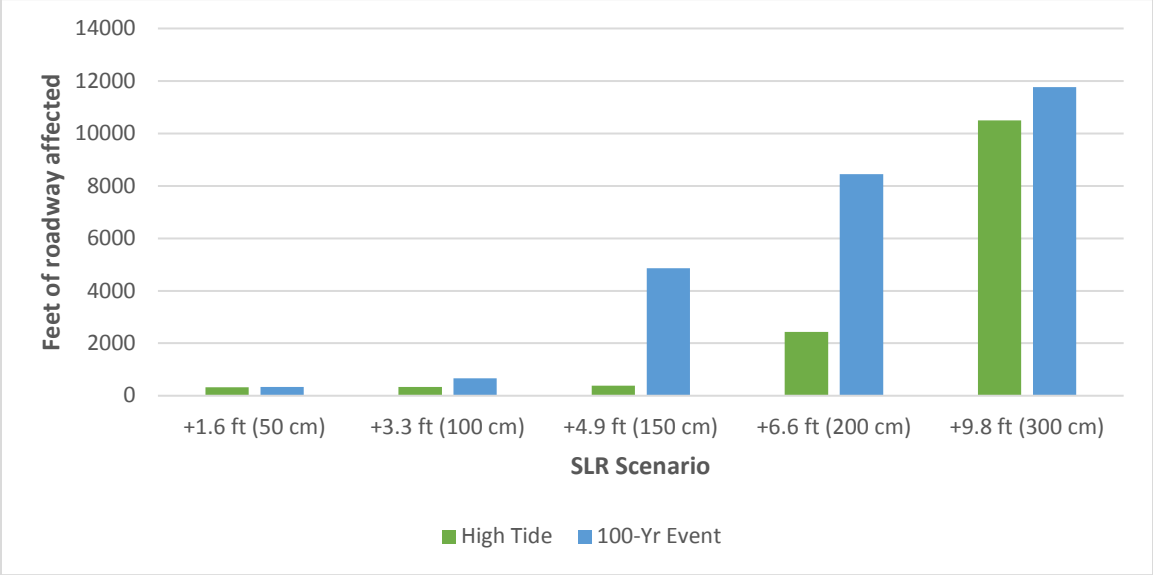


Figure 4-11: Roadway exposure to coastal flooding hazards (from CoSMoS modeling)

Tidal flooding of transportation assets on the northern side of Pismo Creek such as Addie Street, the Addie Street parking lot, and the general area along Cypress Street from Pismo Creek to the Cypress Street-Park Avenue intersection is anticipated by 6.6 ft SLR. In extreme SLR scenarios, tidal flooding of Stimson Avenue and Cypress Street from the beach and Pismo Creek respectively is predicted up to their intersection. In the same scenarios, Park Avenue will experience tidal flooding from the beach to Dolliver Street.

Within the Low-Lying Study Area, transportation assets including Dolliver Street (Cabrillo Highway), Cypress Street, the Dolliver Street Bridge, the Cypress Street Bridge and bus stops

serving this area will be exposed to increased coastal flooding hazards. Dolliver Street will be subject to tidal flooding by 6.6 ft SLR. Dolliver Street is within the FEMA 100-year floodplain and already exposed to flooding in extreme storm events. This Study does not incorporate bridge hydraulics in its modeling, but land elevations on either side of a bridge will be used as a best-available approximation until further study can provide more accurate conclusions. Flood exposure near the bridges is significantly higher under 100-year conditions than non-storm conditions. During non-storm conditions, inundation of either bridge is not predicted until the 8.2ft SLR scenario. In contrast, FEMA floodplain elevations indicate that the Cypress Street Bridge and Dolliver Street Bridges are already exposed to 100-year storm flooding.

The Southern Pacific Railway owns railroad tracks that pass between development in the Low-Lying Study Area and Pismo Lake Ecological Reserve. The area of the railway directly adjacent to Pismo Lake already lies within the FEMA 100-year floodplain and can be considered the segment most exposed to flooding hazards now and in future SLR scenarios. Tidal flooding is predicted to impact the railway in this area by 6.6 ft SLR. In extreme SLR scenarios, nearly the entire railway segment from Highway 101 to the southern City limit is predicted to be subject to tidal flooding. Figure 4-12 shows length of railway affected by flooding hazards in different SLR scenarios based on the CoSMoS modeling results.

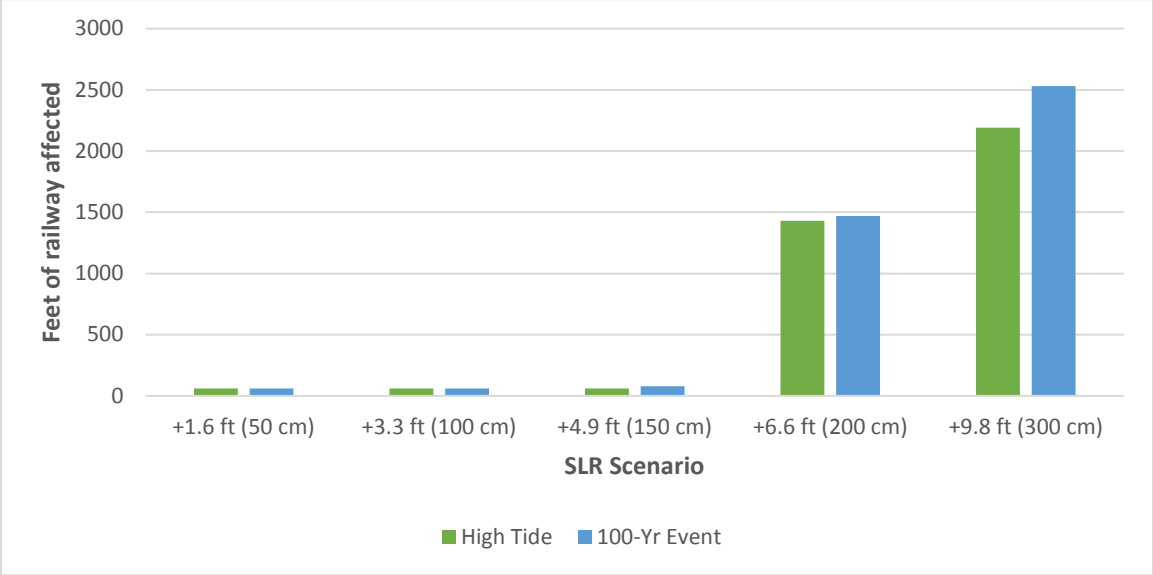


Figure 4-12: Railway exposure to coastal flooding hazards

4.7.2 Sensitivity & Adaptive Capacity

Transportation assets within the City are generally highly sensitive to bluff erosion hazards. Roads such as Seacliff Drive and Ocean Boulevard in the Bluffs Study Area are locally important for general transportation and coastal access, as the relatively inland Shell Beach Road is the nearest alternate thoroughfare for movement parallel to the coastline. Adaptive capacity of these roads is limited due to their narrow width and limited space for relocation.

Transportation infrastructure in the Downtown Study Area is somewhat less sensitive to erosion hazards. Armoring in the area offers protection to many assets, and, as the exposed roads within this area are roughly perpendicular to the shoreline, they are less critical to movement in the coastal zone.

Sensitivity of transportation infrastructure within the City to flood hazards is high. While temporary flooding during extreme storm conditions nay not cause extensive structural damage, the disruption of Dolliver Street as the primary link between the Downtown and Low-Lying Study Areas, even on a limited basis, has the potential to impact critical services throughout the City and surrounding areas. This sensitivity is compounded by the likely need for emergency services in the Low-Lying Study Area during major storm events when flooding will be most severe. Elevation, protection, or floodproofing of critical access routes could be viable adaptation strategies to address these hazards but would require a substantial investment along with consideration of the impacts on the wider transportation network and other coastal resources.

Transportation infrastructure is significantly more sensitive to flood hazards projected under SLR scenarios of 6.6 feet or more. Extensive structural damage is more likely if transportation infrastructure is subject to repeated non-storm inundation, and frequent disruptions of use within non-storm flood areas is likely to significantly reduce the utility of any affected resources. Widespread inundation during extreme storm events is also likely to significantly disrupt transportation patterns throughout the City and surrounding areas until floodwaters subside. The adaptive capacity of transportation infrastructure is also diminished in higher SLR scenarios. Mitigation beyond localized measures for critical infrastructure will likely be necessary to address the extensive nature of non-storm and storm flood projections in the Low-Lying Study Area and associated impacts to the Dolliver Street (Cabrillo Highway) transportation corridor expected by 6.6 ft SLR.

4.8 Cultural Resources

The City and surrounding Central Coast region is the historic home of the Chumash people. As stated in the City's General Plan and Local Coastal Program, preservation of cultural and archaeological resources in coordination with State and relevant Native American representatives is both legally mandated and a priority for the City. City staff reviewed maps of projected SLR-related erosion and flooding extents and concluded that significant known cultural resources would be subject to increased hazard exposure in every SLR scenario. Any sites located at the base or near the top edge of bluffs may experience erosion hazards, while coastal flooding may impact sites in the Downtown and Low-Lying study areas. Due to their sensitive nature, cultural resources were not mapped or quantified, but appropriate adaptation measures will be developed as part of the City's General Plan and Local Coastal Program Update.

4.9 Environmental Resources

Environmental resources include coastal habitats such as those outlined in the City General Plan and Local Coastal Program as well as ecologically sensitive areas managed by the State such as Pismo State Beach Monarch Butterfly Grove and Pismo Lake Ecological Reserve. Many of these resources are already subject to flood hazards, while areas like Pismo Lake may have some natural capacity for flooding.

4.9.1 Coastal Habitat

Detailed assessment of the various coastal habitats and biological resources present in the City is not within the scope of this study; however, the concept of coastal squeeze presents an issue for the coastal habitats of the area. Without the ability for a potential migration of the shore due to armoring such as bluff stabilization and seawalls, the gradient of subtidal, intertidal, and bluff habitats will become squeezed. This indicates a potential loss of the ecologically important intertidal habitat. Subtidal habitats, such as kelp beds present seaward of the rocky bluffs in the City's northern half, could also be vulnerable to changes in substrate and depth.

4.9.2 Pismo Creek Estuary

At high tide, saltwater flows into Pismo Creek for nearly a half mile upstream, forming estuarine habitat. However, minimal wildlife inhabits the reach south of Highway 101 due to impacts from development (City of Pismo Beach, 2013). SLR will increase the upstream distance of saltwater intrusion, but impacts to specific marine and freshwater species known to inhabit the creek are beyond the scope of this Study.

4.9.3 Pismo Lake Ecological Reserve

Pismo Lake Ecological Reserve, managed by California State Parks since 2007 (Charlton, 2011) is identified in the City's General Plan & Local Coastal Program as an extremely valuable resource due to the presence of excellent salt marsh, fresh water marsh, and riparian habitat. As expected of this habitat type and proximity to Pismo Creek and Meadow Creek, most of the preserve is contained within the current FEMA 100-year floodplain, as shown in Figure 4-13.

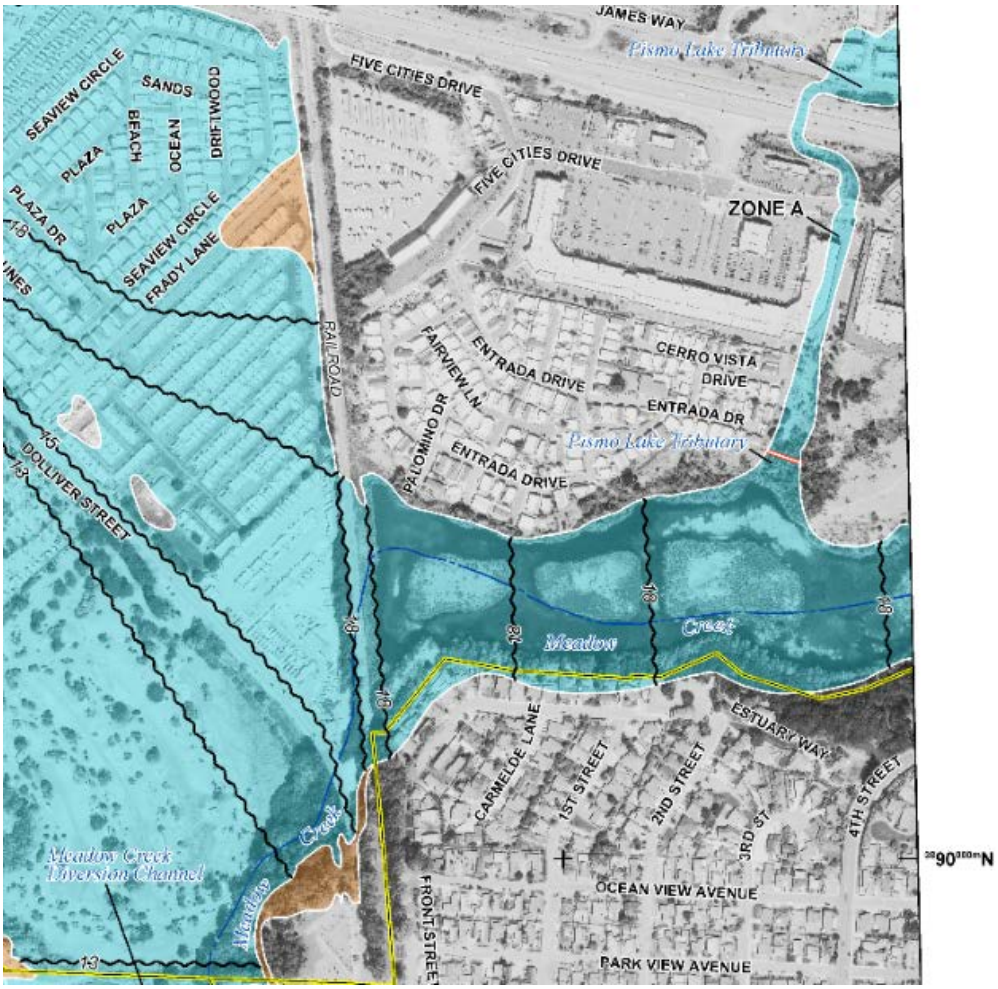


Figure 4-13: FEMA Flood Insurance Rate Map (No. 06079C1344H), Pismo Beach, CA

Meadow Creek is the preserve's primary source of water, and it is unclear how accurately CoSMoS results used within this Study capture future anticipated runoff from Meadow Creek. Nonetheless, saltwater tidal flooding is predicted to affect the reserve up to N 4th Street with 4.9ft SLR.

4.9.4 Pismo State Beach Monarch Butterfly Grove

Although Monarch Butterfly populations overwintering at the City's grove adjacent to the Pismo State Beach North Campground have decreased in recent decades (Leslie, 2019), the habitat remains a conservation priority for the City as directed in its General Plan & Local Coastal Program. The grove is less vulnerable to flooding than the nearby campground due to elevation and flood control infrastructure, supported by the grove's location outside the current FEMA 100-year floodplain and limited exposure to coastal hazards for the range of SLR scenarios evaluated.

4.10 Groundwater Intrusion

As sea levels rise, subsurface elevations along the natural gradient between freshwater and saltwater are pushed upwards. This causes the lighter freshwater lens, which floats on top of any intruded seawater, to rise in elevation. The top surface of this lens, the beginning of the saturated zone, is the definition of the water table. Thus, SLR is expected to raise elevations of coastal aquifers. Depending on local geological and soil properties, the water table may rise above subsurface assets not designed for saturated soil conditions. If water table rise is extreme or existing water table elevations are very shallow, the water table may rise above the ground elevation, causing groundwater inundation.

Based on a review of San Luis Obispo County soil classifications and liquefaction hazards, soils in the Low-Lying Study Area are preliminarily considered relatively vulnerable to groundwater intrusion hazards. The USGS CoSMoS development team is currently modeling predicted groundwater impacts of SLR. Even if groundwater inundation is not a predicted hazard for the Low-Lying Study Area, increased groundwater levels and reoccurring tidal or storm flooding will worsen the existing liquefaction hazard of soils in this area. Liquefaction impacts are most likely to occur due to additional stress from a severe local or regional earthquake. Increased groundwater elevations can also result in additional buoyancy forces that can impact below ground infrastructure such as utility vaults, lift and pump stations, and parking garages.

4.11 Social Vulnerability & Environmental Justice

Social vulnerability, a broad term referring to how the impacts of physical hazards such as flooding can be amplified by social characteristics, and environmental justice components of future SLR hazards were evaluated using the 2016 Social Vulnerability Index (SOVI), published by the U.S. Center for Disease Control (CDC), and the results of CalEnviroScreen 3.0, an environmental health screening tool developed by the California Environmental Protection Agency (CalEPA) and the Office of Environmental Health Hazard Assessment (OEHHA). Because both these screening tools utilize socioeconomic and demographic factors at the census tract level, nearly the entire area of the City seaward of Highway 101 is evaluated as one unit. This results in the screening tools identifying the population of the City in the lowest 5th-20th percentiles of vulnerability.

City staff have identified the Low-Lying Study Area as an area of concern for social vulnerability, as the area contains multiple senior citizen-exclusive mobile home parks and low-cost accommodations such as RV resorts and the Pismo State Beach North Beach Campground. In planning adaptation measures, special consideration should be taken of the increased vulnerability of elderly populations in emergency situations and potentially disproportionate relative economic costs of adaptation for fixed and low-income residents.

Potential impacts to coastal access are also a point of concern when considering the environmental justice implications of SLR. As described in Section 4.2 and 4.3 the coastal access

and recreational resources along the Bluffs Study Area are among the first impacts expected with SLR. Sea level rise scenarios of 3.3 ft and higher will also result in significant loss of recreational beach area along Pismo State Beach and increase the potential for Pier damage during an extreme wave event. These resources offer unique opportunities to residents and visitors of all socioeconomic backgrounds due to the low cost of parking and ease of access. The loss of these resources due to coastal erosion and flood hazards could significantly reduce these opportunities in the future if no adaptation strategies are implemented.

5. Adaptation

The purpose of this vulnerability assessment is to identify areas, resources, and assets in the City of Pismo Beach that may be vulnerable to rising seas in the future so that the City may begin to consider adaptation strategies to improve and enhance coastal resiliency in the near term and for the long term.

This section provides an overview of adaptation planning goals and general strategies that will be further evaluated in the Adaptation Plan and incorporated into the GP/LCP update. Identified adaptation strategies and goals build on work done by other municipalities that are updating their local coastal programs (LCPs) and are designed to be compatible with model adaptation measures included in CCC SLR guidance documents (California Coastal Commission, 2018b, 2018a). Listed adaptation strategies and goals are not intended to be exhaustive or fully developed but are instead designed to be used as a high-level SLR adaptation planning framework to set consistent priorities for future adaptation measure development, analysis, and evaluation within the City of Pismo Beach.

5.1 Overview of Adaptation Planning Goals

The updated GP/LCP document will include policies intended to disseminate information related to coastal hazards and sea level rise, manage development in hazard areas and reduce impacts to coastal resources from coastal hazards. These planning goals for which policies may be developed are discussed in this section.

5.1.1 Understand SLR Hazards

Knowledge of the timing, magnitude, and location of future SLR hazards is critical to SLR planning and adaptation efforts. Policies in pursuit of this goal will focus on ways to best obtain, utilize, and disseminate current and forecasted SLR information to inform decision-making in coastal areas. Ensuring the use of best-available climate science will provide a consistent standard for SLR adaptation planning in the City and facilitate the coordination of adaptation strategies with other jurisdictions.

Disseminating identified best-available science is also necessary to support public understanding and participation in SLR adaptation and planning. Policies designed to inform the general public of projected future hazards due to SLR encourage responsible decision-making at the individual level and can potentially increase public support for SLR adaptation initiatives within the City. Policies focused on disclosing risks associated with new development can also provide an important mechanism for educating property owners about projected SLR hazards and their options for addressing them.

Adaptation policies focused on continued hazard monitoring can be used to update SLR adaptation strategies and provide concrete information on when critical hazard thresholds have

been reached. Hazard monitoring programs can take a number of forms including tracking regional SLR rates, documenting bluff erosion processes, and quantifying shoreline change trends.

5.1.2 Manage Development in Hazard Areas

Siting and construction standards for new coastal development or redevelopment projects represent key mechanisms to reduce SLR hazard impacts to new and existing development. Existing policies related to development on or near the bluff top, which involve site-specific hazard assessments and setbacks from defined hazard areas, are an example of how development can be managed to reduce impacts from natural hazards such as bluff erosion.

Incorporating projected SLR hazards into the initial siting of new development is an important step in mitigating SLR vulnerabilities and avoiding the need for future adaptation measures which could impact coastal uses and resources. Considerations for SLR scenarios higher than 3.3 ft, though unlikely to occur this century, could be included in the design of new development or redevelopment in the form of parcel-scale adaptation measures that could be implemented at a future date in response to SLR or other hazards, if needed.

Managing redevelopment is another method to control SLR vulnerability. Policies that establish limitations on continued redevelopment of high-risk structures in hazard areas reduce future SLR vulnerability and the potential for repetitive losses due to increased hazards. These policies can be triggered by specific SLR thresholds at which impacts from coastal hazards are expected to occur more frequently.

5.1.3 Reduce Coastal Hazards

Enhancements and additions to existing coastal hazard reduction measures are often necessary to account for potential increases in hazard levels due to SLR. Policies in pursuit of this goal will focus on protection from and accommodation of current and future SLR hazards through both structural and nature-based means.

Managing the establishment and maintenance of shoreline protection structures can provide multiple benefits to SLR adaptation efforts. Policies that establish standards for the evaluation, repair, and maintenance of existing shoreline armoring enable the ongoing functionality of protective structures as coastal hazards change with rising water levels, reducing potential for structural failure under future conditions. Policies related to new or additional shoreline armoring can reduce the potential for unwarranted or ineffective shoreline protection structures and can also help ensure that alternative, nature-based strategies are given appropriate consideration.

Standardizing approaches to structural floodproofing can also benefit adaptation efforts. Policies that establish appropriate situations and best practices for floodproofing retrofits or redesign allow for the consistent and effective application of these strategies within hazard areas. These

types of policies can also improve awareness of available floodproofing mechanisms by providing a standardized reference for interested parties.

5.1.4 Maximize Protection of Coastal Resources

Coastal resources, including public access points, parks, marine habitats, and scenic resources play important cultural, social, and economic roles within the City of Pismo Beach. Policies in pursuit of this goal will help ensure that these important resources are maintained and enhanced as a part of future SLR adaptation efforts.

Replacing any projected loss of coastal access points, recreation areas, or visitor serving facilities is an important consideration for SLR adaptation efforts. Policies that establish appropriate standards for replacement of any access or recreational resources within hazard areas reduce the potential for permanent or temporary loss of these functions within coastal areas as SLR increases. Requirements related to consideration of SLR in planning for any new or redeveloped public access or recreation facilities can also mitigate potential hazards, future disruptions in service, and the need for additional SLR adaptation measures.

5.1.5 Use a Coordinated Approach to SLR Adaptation

SLR will affect regional coastal and fluvial processes that often span multiple municipalities and jurisdictions. Participating in coordinated SLR hazard mitigation planning can substantially increase the efficiency and cost-effectiveness of SLR resilience measures. Policies in pursuit of this goal will focus on potential coordination programs that could benefit coastal resources vulnerable to SLR but perhaps under the jurisdiction of another agency such as Caltrans (Highway 1), State Parks, or the railroad corridor.

5.2 Overview of Adaptation Strategies

Changing coastal hazards due to SLR can be addressed in a number of different ways. Though numerous adaptation methods are available, individual adaptation measures generally fall into one of three main categories: protection, accommodation, and retreat (Figure 5-1). In an SLR adaptation context protection refers to those strategies that employ an engineered structure or other measure to defend existing development from future SLR hazards without changes to the development itself. Accommodation refers to strategies that involve modifying existing development or designing new developments in a way that reduces the potential future impacts of SLR. Adaptation strategies centered on retreat focus on measures to relocate or remove existing development from identified high-hazard areas, while limiting the construction of any new development in such areas. In practice, SLR adaptation often relies on hybrid approaches that combine elements from multiple categories over different spatial and temporal scales.

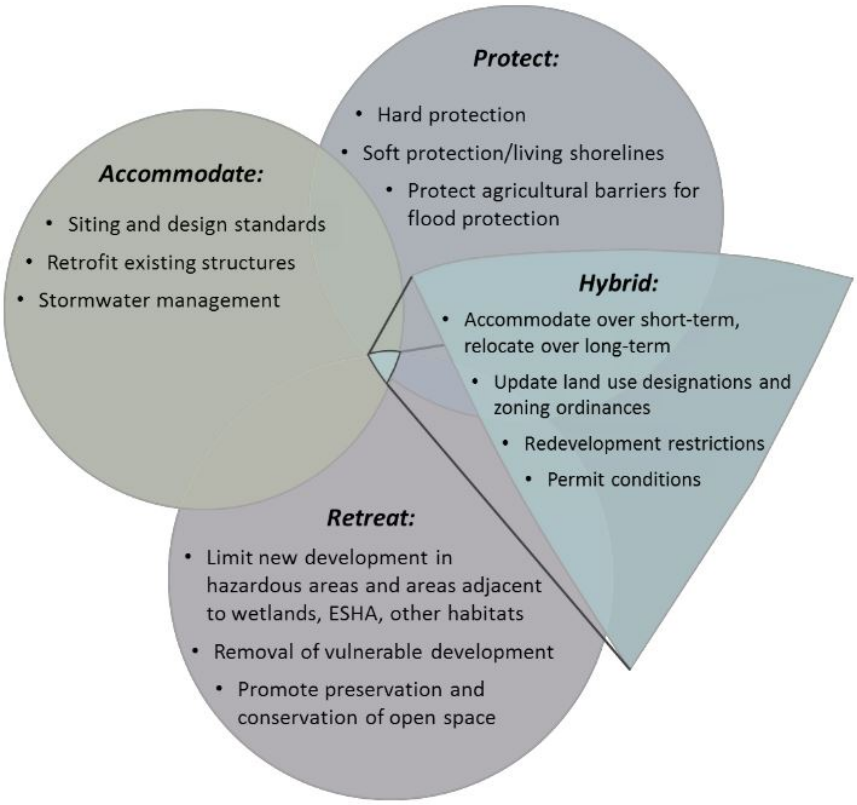


Figure 5-1: General SLR adaptation strategies and mechanisms (California Coastal Commission, 2018a).

For the purposes of this study, no individual adaptation strategy or category is to be considered a categorical "best" option for SLR adaptation planning within the City of Pismo Beach. It is understood that a variety of adaptation strategies will be necessary to account for the different hazard vulnerabilities and coastal resources present at various locations within the City, and that adaptation strategies will need to be adjusted over time in response to changing coastal hazards and the effectiveness of each strategy.

5.2.1 Protection

Adaptation aimed at protecting coastal resources can come in the form of hard and soft shoreline protection strategies. Hard shoreline protection strategies have been a key element of coastal hazard adaptation for the City of Pismo Beach throughout its history. As described in Section 2, a variety of shoreline protection structures have been constructed along the City's coastline to limit damage from erosion and storm-related hazards. Concrete seawalls have lined downtown areas near the pier since the 1970s in addition to more recent steel sheet pile seawalls that line much of the Pier plaza and development to the south. A variety of shoreline and bluff stabilization measures are in place along the bluffs including armor stone revetments and multiple types of seawalls. An example of bluff stabilization for infrastructure protection and improved coastal access is illustrated in Figure 5-2 where the bluff stabilization structure (foreground) was designed to match the aesthetics of the natural bluff face in the background of the photo.



Figure 5-2: Bluff Stabilization and access stairway at St Andrews lift station

Due to the widespread presence and long history of shoreline protection structures within the City of Pismo Beach, the continued maintenance and improvement of shoreline infrastructure will be an important component of reducing hazards such as bluff erosion and coastal storm damage over each increment of SLR. Many of the modern engineered shoreline protection structures will continue to be effective over the likely range of SLR projections through 2050 provided they are regularly inspected and maintained. However, other existing structures have

been in place for extended time periods and appear to be approaching the end of their service life. These structures will likely require significant retrofits or replacement to protect against coastal hazards and sea level rise.

Soft shoreline protection strategies typically refer to beach nourishment, dune restoration and construction of living shorelines. Aside from some temporary sand berms constructed for bluff protection along Pismo State beach there is no record of any significant beach nourishment activities in the City. However, beach nourishment and dune restoration could be effective measures to offset the loss of beach width expected with each increment of SLR. An example of beach nourishment applied along the bluff backed beaches of Solana Beach in Southern California is illustrated in Figure 5-3.



Figure 5-3: Beach nourishment in progress at Solana Beach in 2018

5.2.2 Accommodation

Accommodation strategies can be employed as alternative to or in conjunction with protective measures. These strategies are often employed for low-lying coastal structures or resources that are exposed to temporary flooding during extreme storm events. Depending on the characteristics of the coastal resource and type of accommodation employed, accommodation strategies can address coastal hazards across low, moderate, and severe SLR scenarios.

Coastal resources and structures can accommodate SLR hazards through both modification of existing development and design of new development. Accommodation strategies based on structural modification include actions such as structural elevation, retrofitting existing structures with flood proofing measures, and the use of flood resistant materials during construction (Figure 5-4, Figure 5-5). Accommodation strategies based on design can address SLR hazards by including potential relocation, redesign, or other form of adaptation in initial structural plans or by employing additional shoreline setbacks where possible. These strategies

can be employed on an individual basis or on a community-wide scale through specific land-use designations, zoning ordinances, or other measures.

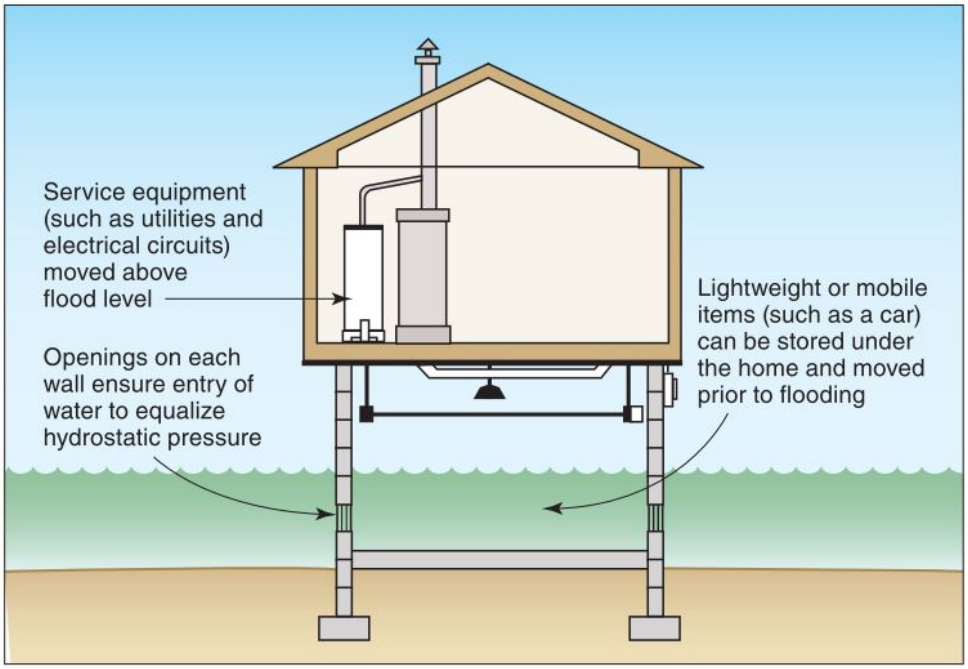


Figure 5-4: Example cross section of an elevated home using continuous foundation walls (FEMA, 2014).

Accommodation strategies are most effective at reducing damages from periodic and temporary flooding associated with rare but extreme storm events such as coastal flooding that occurred in the 1983 El Niño storms. Temporary or permanent floodproofing retrofits can be employed within current and projected future flood prone areas to reduce the impacts and recovery time following flood events. These accommodation strategies are most relevant for low-lying areas adjacent to Pismo Creek and within the present day 100-year floodplain.

Elevation is also an option for other structures within low-lying areas, but the effectiveness of this strategy will be reduced if non-storm flooding prevents access to structures on a consistent basis. While structural elevation can successfully mitigate coastal hazards driven by SLR (Figure 5-5), potential drawbacks are also present. If elevation of structures along a shoreline becomes widespread, elevated structures may reduce the aesthetic value of coastal areas or impact community character. Uncoordinated structural elevation initiatives, where only select structures are elevated in an area, can also result in a patchwork of different vulnerabilities within hazard zones, complicating future adaptation planning. Under high to extreme SLR scenarios, the continued elevation of structures in their current location can also result in a situation where structures unintentionally become elevated directly over tidelands, presenting access and maintenance challenges.



Figure 5-5: Pile supported home on Addie Street during the February 1983 storm event.

5.2.3 Retreat

Directly removing or relocating vulnerable structures away from hazard areas represents an effective long-term form of SLR adaptation under high to extreme SLR scenarios. Retreat strategies can be employed for cases in which any feasible protection or accommodation strategies become insufficient to address coastal hazards. Retreat strategies can be implemented in a variety of ways including land use designations or zoning ordinances designed to encourage new development within less vulnerable areas. Property acquisition programs, rolling easements, transfer of development rights programs, and permit conditions can additionally be used to gradually move highly vulnerable existing development away from current and future hazard areas.

Successful employment of retreat strategies often requires available areas located landward of vulnerable structures or resources. Limited available space is a complicating factor throughout much of the City due to the high density of development along the bluffs and downtown study areas. However, some elements of retreat, such as bluff-top setbacks, can be combined with other adaptation measures to further reduce vulnerabilities from coastal hazards. Despite these limitations retreat strategies can potentially result in greater resilience to SLR hazards at a lower cost than protecting structures in place under extreme SLR scenarios, while also avoiding recreation and coastal access issues that could result from additional shoreline protection. Retreat strategies can also be implemented in combination with protection or accommodation strategies as a method to plan for and address SLR hazards under a worst-case scenario. Retreat

could be a viable strategy for adaptation to extreme SLR scenarios in the low-lying study area, through reconfiguration of the RV resorts, campgrounds and mobile home parks in this area.

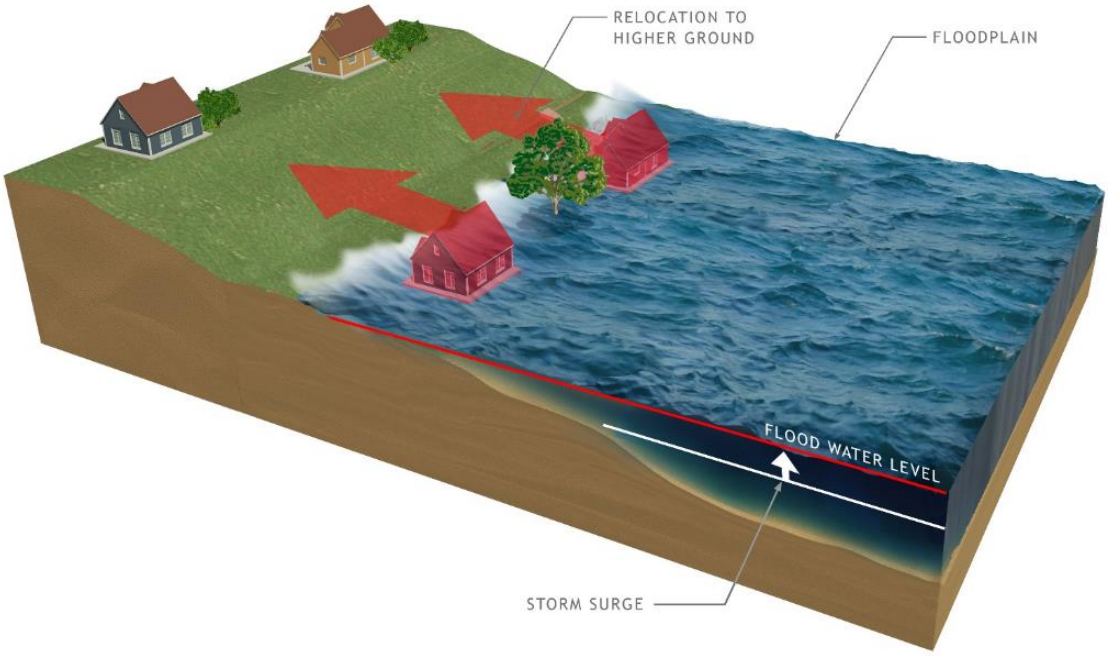


Figure 5-6: Example of retreat strategies within high-hazard areas.

6. Next Steps

Planning for and adapting to a changing coastline is a critical challenge facing many coastal communities throughout California. This Sea Level Rise (SLR) Vulnerability Assessment was intended to determine the potential vulnerability of coastal resources for a range of potential SLR scenarios that could occur this century to inform adaptation planning efforts and policy development that will be incorporated into the General Plan and Local Coastal Program Update.

Sea level rise is unique among other natural hazards because it's a slow moving disaster of uncertain magnitude that will develop over the span of decades and the impacts will be permanent. The vulnerabilities identified for worst-case sea level rise projections at the end of the century are overwhelming but the likely range of SLR expected over the next 50 years (less than 2 feet) is manageable. There is time to responsibly plan, fund and implement adaptation strategies to mitigate potential impacts.

The next phase of the project will develop and Adaptation Plan that focuses on adaptation strategies and policy updates to address present day hazards and potential near-term vulnerabilities identified for the 2050 timeframe, represented by the 1.6 ft SLR scenario. A long-term vision for adaptation strategies to address more significant impact thresholds identified for SLR scenarios of 3.3 ft and higher will also be included in the Adaptation Plan.

Adaptation measures will need to involve coordination with stakeholder groups and agencies to balance the costs, benefits, and trade-offs of these measures. The City is currently conducting an outreach effort to community members as part of its General Plan and Local Coastal Program Update. In addition, focused stakeholder feedback and oversight is being provided by the City's Local Coastal Program Advisory Committee. Stakeholder input will be incorporated into a Final Vulnerability Assessment that will inform preparation of a SLR Adaptation Plan.

7. List of Report Preparers and Contributors

This report was prepared based on a collaborative effort among City staff, stakeholders and the consultant team.

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Appendix A Coastal Hazard Maps



Figure A-1: CoSMoS erosion hazard projections for baseline to 6.6 ft SLR scenarios along NW and central bluff areas

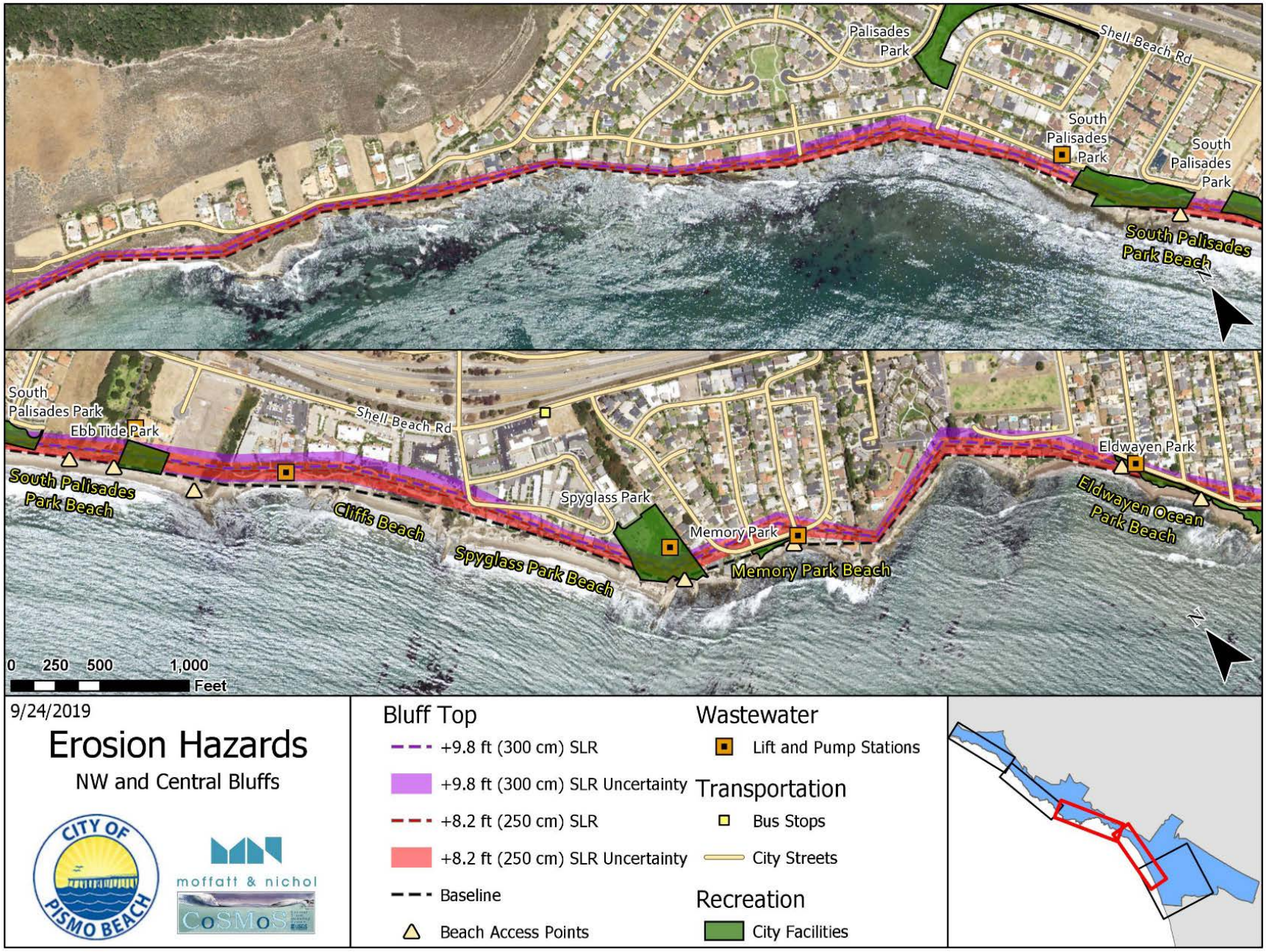


Figure A-2: CoSMoS erosion hazard projections for 8.2 ft and 9.8 ft SLR scenarios along NW and central bluff areas



Figure A-3: CoSMoS erosion hazard projections for baseline to 6.6 ft SLR scenarios along SE bluffs and Downtown



Figure A-4: CoSMoS erosion hazard projections for 8.2 ft and 9.8 ft SLR scenarios along SE bluffs and Downtown

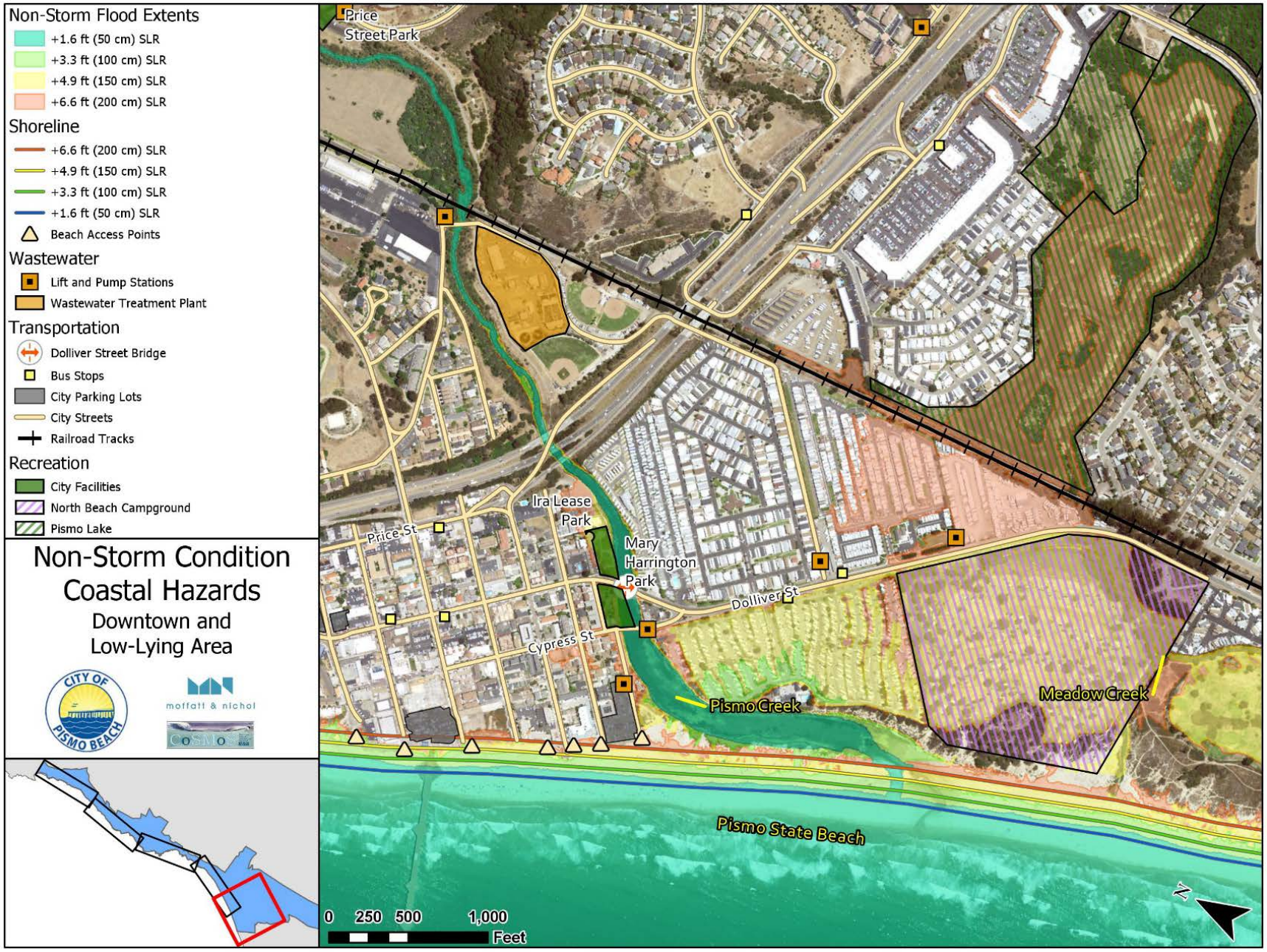


Figure A-5: CoSMoS non-storm coastal hazard projections for 1.6 ft to 6.6 ft SLR scenarios along Downtown and Low-Lying areas

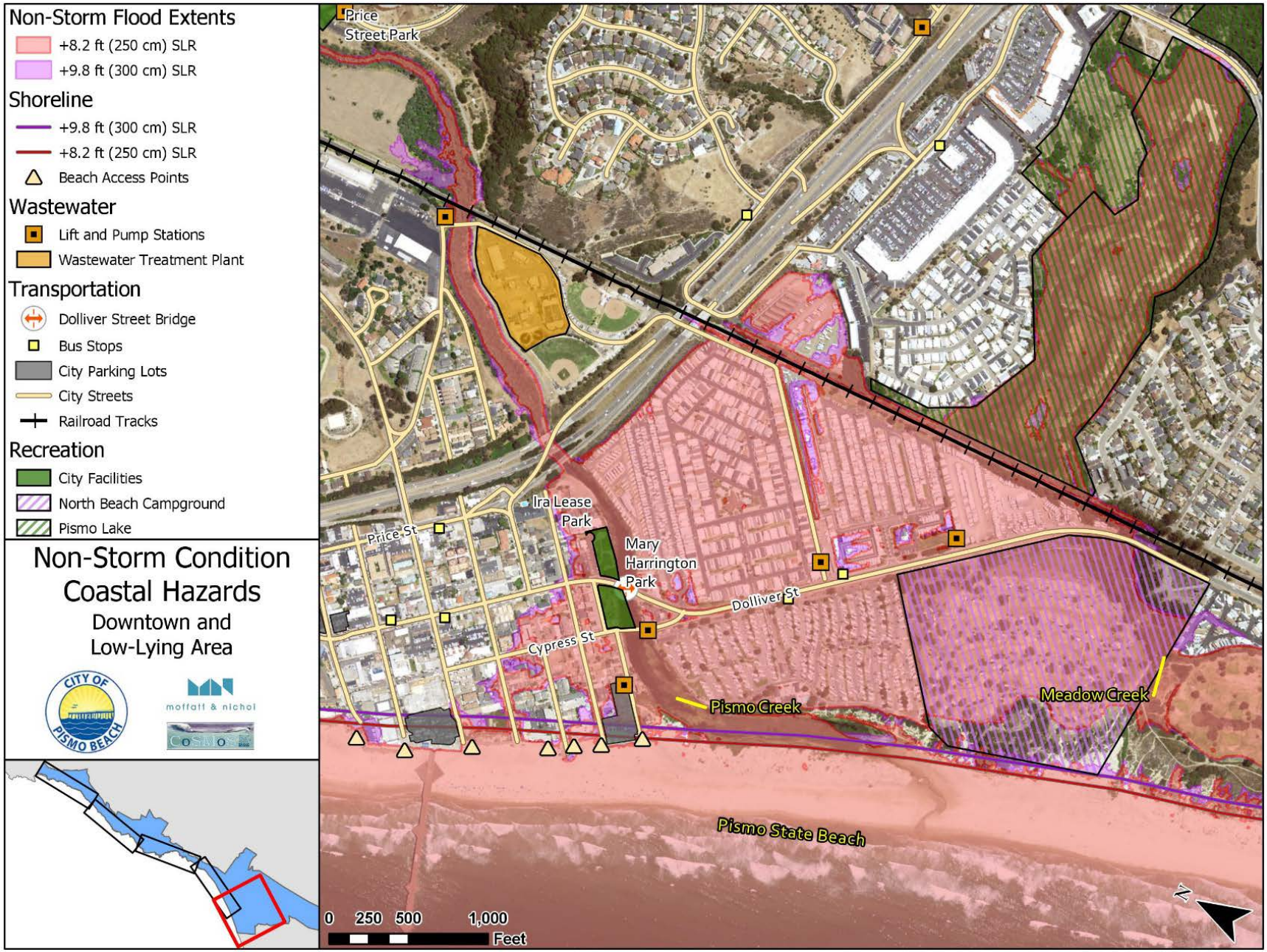


Figure A-6: CoSMoS non-storm coastal hazard projections for 8.2 ft and 9.8 ft SLR scenarios along Downtown and Low-Lying areas

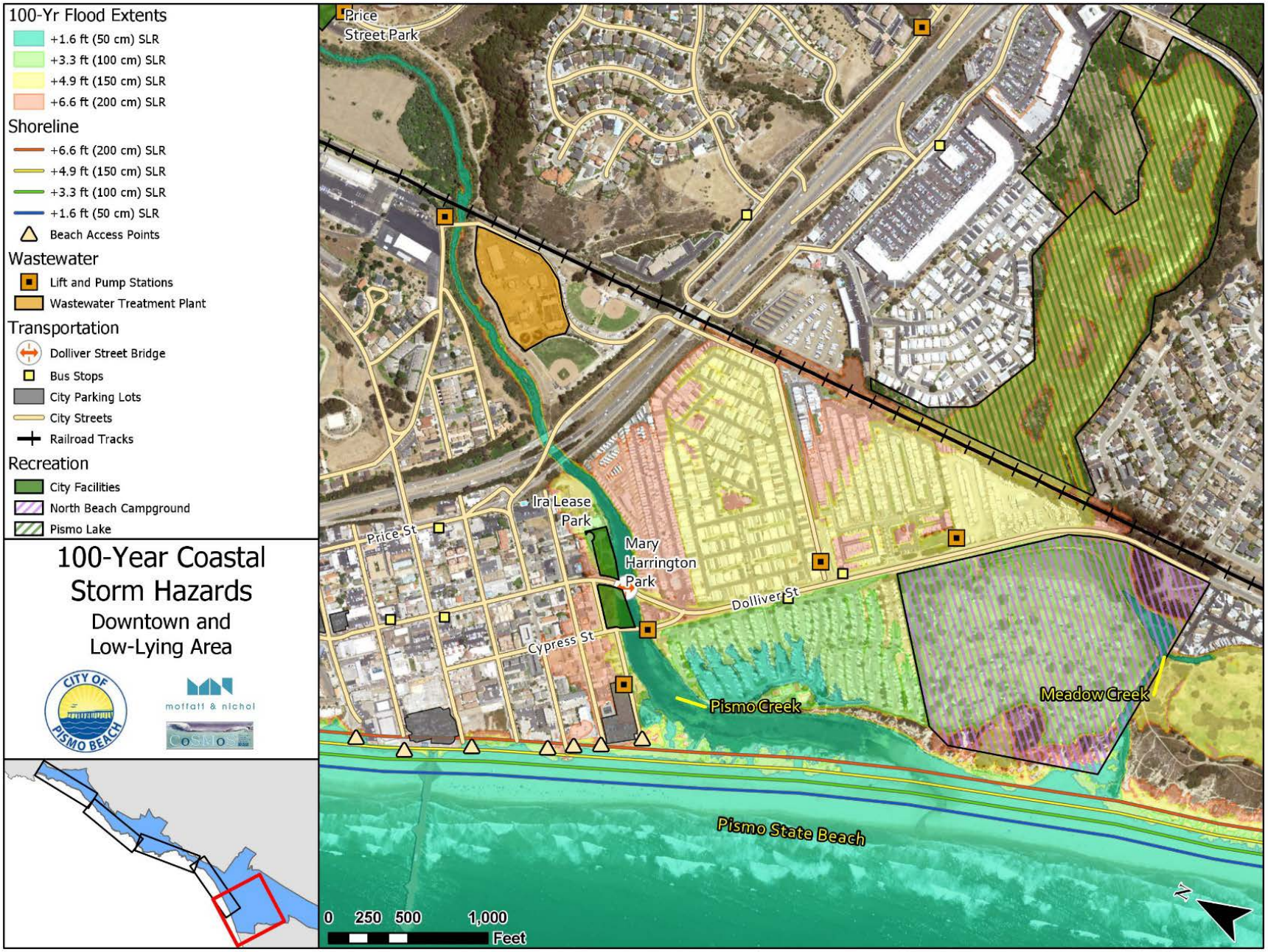


Figure A-7: CoSMoS 100-year storm coastal hazard projections for 1.6 ft to 6.6 ft SLR scenarios along Downtown and Low-Lying areas

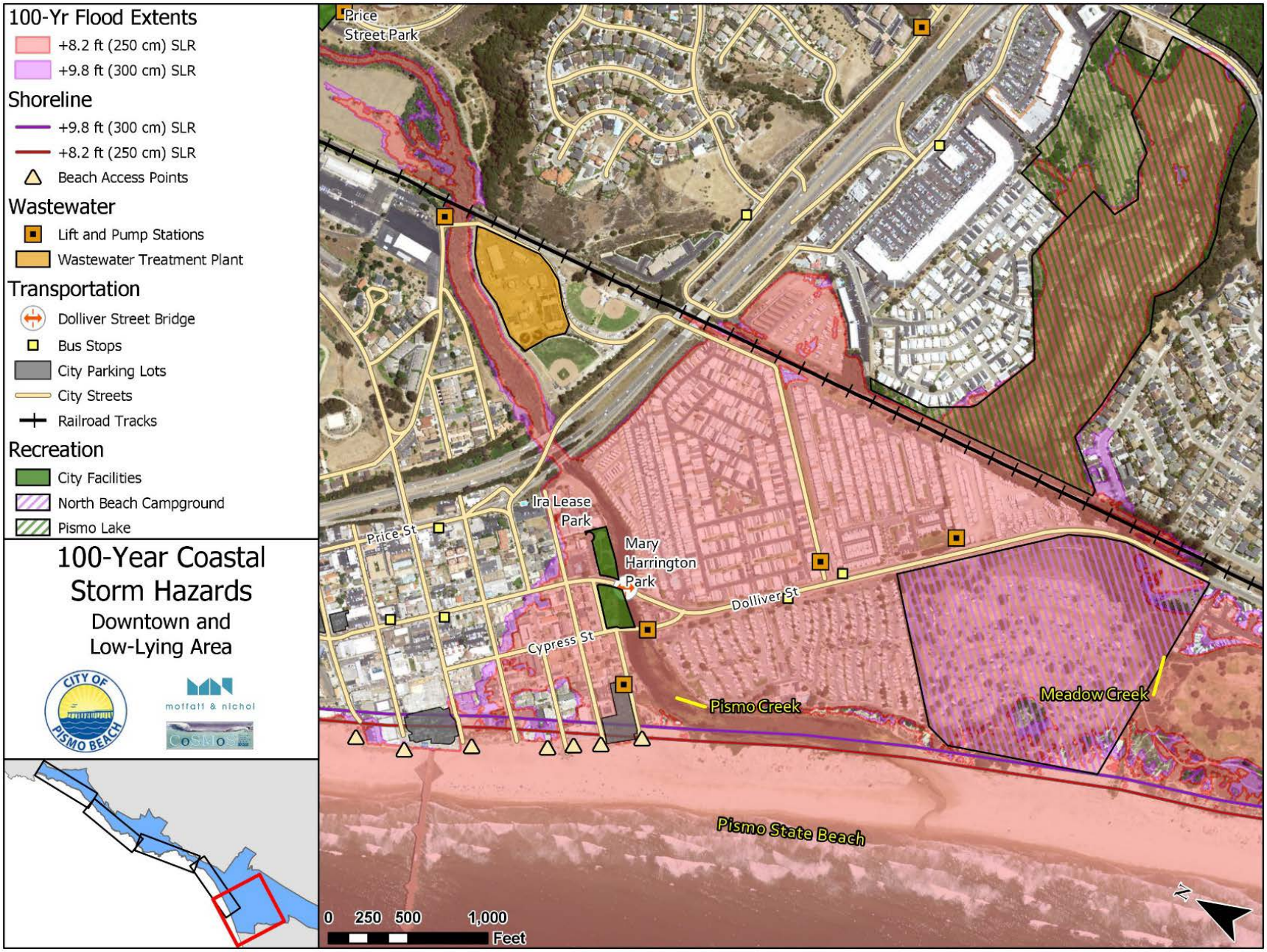


Figure A-8: CoSMoS non-storm coastal hazard projections for 8.2 ft and 9.8 ft SLR scenarios along Downtown and Low-Lying areas