Draft

CITY OF SANTA BARBARA SEA-LEVEL RISE ADAPTATION PLAN FOR THE LOCAL COASTAL PROGRAM UPDATE

Vulnerability Assessment Update

Prepared for
City of Santa Barbara

November 2018

ESA

Funded By:

Coastal Conservancy

CALIFORNIA COASTAL COMMISSION

SEAL OF THE CITY OF SANTA BARBARA CALIFORNIA

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TABLE OF CONTENTS

City of Santa Barbara Sea-level Rise Adaptation Plan for the Local Coastal Program Update: Vulnerability Assessment Update

Page

Appendices

Page

List of Figures

Page

List of Tables

CITY OF SANTA BARBARA SEA-LEVEL RISE ADAPTATION PLAN FOR THE LOCAL COASTAL PROGRAM UPDATE:

Vulnerability Assessment Update

Executive Summary

Introduction

While Santa Barbara has only experienced a relatively small amount of sea-level rise to date from climate change, the rate of sea-level rise in the region is expected to significantly accelerate in coming years. Rising sea-levels will present increased physical risks to the City of Santa Barbara, including shoreline erosion and degradation, decreased beach widths, amplified storm surges, and inundation of coastal flood waters. There is a need for the City and the community to better understand these vulnerabilities, to analyze the physical and economic risks, and consider possible actions to prepare and adapt to the impacts of sea-level rise.

The purpose of the 2018 Vulnerability Assessment Update is to enhance the understanding of the City of Santa Barbara's coastal resources and assess existing and future vulnerabilities to projected sea-level rise, coastal flooding, and erosion. The 2018 Vulnerability Assessment Update is intended to build on previous work, including previous vulnerability work, completed at a local and regional level and to serve as a first step in the adaptation planning process.

The Vulnerability Assessment Update assesses what will happen if no action is taken to mitigate the increased hazard risks associated with sea-level rise. This will inform the development of an Adaptation Plan that will analyze the feasibility, effectiveness, economic and fiscal impacts, environmental consequences, recreation impacts, and other costs and benefits of various adaptation strategies to avoid and/or mitigate coastal hazards over time. The Adaptation Plan will include a detailed Economic and Fiscal Impacts Analysis that is currently underway. The information in the Adaptation Plan will be used to amend policies and development standards in the City's Local Coastal Program (LCP) to implement adaptation strategies.

Study Area

The study area includes all portions of the City projected to be impacted by sea-level rise to the year 2100. This includes approximately 6.5 linear miles of coastline from Arroyo Burro to the Andree Clark Bird Refuge. It also includes Santa Barbara Harbor and extends inland far enough to capture the extent of projected flooding of the downtown Santa Barbara area. The study area does not include the Santa Barbara Airport and Goleta Slough, which has been the subject of separate studies.

The study area was divided into 11 Shoreline Hazard Planning Subareas as depicted below in Figure ES.

Coastal Hazards and Vulnerabilities

The Vulnerability Assessment Update evaluated hazards to the coastal zone for existing conditions and three main future sea-level rise scenarios:

- 0.8 feet at 2030,
- 2.5 feet at 2060, and
- 6.6 feet at 2100

Use of these scenarios is consistent with the recommendations of the State of California Sea-level Rise Guidance (OPC, 2018) and the California Coastal Commission Sea-level Rise Policy Guidance document (CCC, 2015) and represent the high greenhouse gas emissions scenarios. Recent scientific studies indicate that there is a possibility that sea-levels could rise faster than these projections due to the potential loss of the West Antarctic ice sheet. While the probability of this extreme scenario (called the H++ scenario) is not known at this time, OPC and CCC in their guidance documents recommend considering the H++ scenario in the planning of very critical infrastructure. For very critical infrastructure, therefore, this Vulnerability Assessment considers the possibility that 6.6 feet of sea-level rise may occur sooner at 2080 under the extreme H++ sea level rise scenario..

The following coastal hazards were analyzed and mapped:

- Shoreline Erosion – which refers to the permanent loss of sandy beaches, dunes, and the low-lying backshore that occurs with changing sea-level or sand supply.
- Bluff Erosion –the loss of coastal bluffs as material falls or collapses onto the beach (or into the ocean) below.
- Tidal Inundation –areas that are below the typical non-storm high tide elevation when sea-level rise is added.
- Storm Waves –exposure of the Santa Barbara shore to large waves generated by local and distant storms.
- Storm Flooding –the combination of the high water levels that come with a storm estimated to have a 1% chance of occurring each year (i.e., a “100-year storm”) and including some of the effects of waves.

Low-lying areas that may potentially be subject to tidal and storm flooding were also identified.

The assessment used the United States Geologic Society (USGS) coastal hazard model released in 2017 (CoSMoS v3.0) augmented by wave hazard zones from Coastal Resilience Santa Barbara, a study of sea-level rise impacts conducted by ESA for the County of Santa Barbara in 2015, and a 2009 geology and geohazards study of the City by URS.

The City of Santa Barbara's public and private assets were organized into 8 sectors for the purpose of the analysis, including:

- Transportation Infrastructure
- Fire Stations, Police Stations and Wildland Fire Evacuation Routes
- Stormwater Infrastructure

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SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Shoreline Hazard Planning Subareas

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- Recreational Areas
- Harbor and Stearns Wharf
- Public and Private Properties
- Communication Infrastructure
- Water Supply and Wastewater Infrastructure

Summary of Physical Vulnerabilities

Bluff Areas

Much of the westerly portion of the City's coastal zone is situated on bluffs overlooking the beach. Bluff areas in the City include subareas A –F, from approximately Sea Edge Lane at the west end of the City of Santa Barbara to approximately Santa Barbara Point, as well as subarea K at the far easterly portion of the City by the Bellosguardo Estate.

These bluffs are currently eroding with exposure to waves. As sea level rises, they will be exposed to more extreme waves more often. Bluff erosion rates are expected to increase by 40% by 2060 and by 140% by 2100.

By 2060 the City could lose 78% of its bluff-backed beaches to erosion, and by 2100, the City could lose 98% of its bluff-backed beaches. In locations where these beaches are lost, the bluffs behind them will be more exposed to waves and are expected to erode more quickly. The extent of the hazards in these areas are expected to reach bluff-top infrastructure, including roads and utility infrastructure and public and private properties by 2100.

Low-Lying and Waterfront Areas

The low-lying areas of the City include the City's waterfront, lower downtown area, and Arroyo Burro County Beach Park. In these areas, sandy beaches and low-lying areas in the City are also expected to see a change in exposure with sea-level rise, predominantly due to increased tidal inundation and storm flooding. Under current conditions and through 2060, impacts from erosion, tidal inundation, and storm waves are generally limited to the area south of Cabrillo Boulevard. However, by 2100 these hazard zones are expected to reach north of Cabrillo Boulevard, exposing more assets in the City. Furthermore, by 2060 the City could lose 32% of its sandy beaches in these low lying areas to erosion, and by 2100, the City could lose 60% of its sandy beaches in low lying areas. Erosion and tidal inundation are expected to lead to loss of 28% of recreational areas, open space areas, and parks in coastal parts of the City by 2060, and 67% by 2100. Much of these are located in low-lying waterfront areas, though some are in bluff-backed stretches of the coast.

Harbor and Stearns Wharf

The Santa Barbara Harbor and Stearns Wharf are valuable and important assets in the City. Under existing conditions, Stearns Wharf is exposed to wave damage during large storms and a 100-year coastal event is expected to require temporary closure and significant structural repairs. As sea level rises through 2060 and into 2100, events large enough to damage Stearns Wharf are expected to become more common, though tidal conditions are not likely to pose a risk of damage for the wharf deck.

The harbor includes the marina, commercial uses, parking, industrial areas, and the City Pier (sometimes called the "harbor pier"), which supports the Coast Guard and houses a fuel dock. Under existing conditions, storm events and especially high tides (e.g. "King Tides") can dislocate pile caps at the floating docks, and waves can overtop the harbor breakwater and reduce public access. More than two feet of sea-level rise (for example, the 2060 case) is expected to regularly impede normal harbor functions, and the harbor in its current configuration would be unusable by 2100, with over six feet of sea-level rise.

Storm Flooding Areas

Flooding from coastal storms is expected to significantly increase in extent and frequency, particularly by 2100. FEMA flood insurance rate maps (FIRMs) are another hazard map generally used to assess exposure and vulnerability, so there is interest in how these relate to the results of this study. The City of Santa Barbara Flood Plain Management Ordinance (Municipal Code Section 22.24) also requires certain building standards based upon the location of the flood hazard zones and base flood elevations contained on FEMA FIRMs. FIRMs do not include future conditions or erosion hazards, so they indicate less severe coastal hazards than the hazard zones in this assessment in coastal areas. The FIRMs do, however, include extreme fluvial (river) events. The coastal and river flood event are mapped together on the FIRM, though they are not expected to occur simultaneously.

Flood hazard areas currently mapped in the FIRMs are expected to experience more frequent flooding with sea-level rise, and the water levels are expected to change. The future coastal hazard zones in areas dominated by coastal flooding that are near the waterfront and downtown south of Highway 101 are expected to experience higher water levels and more severe flooding than currently shown on FEMA FIRMS (water levels up to 2-3 feet higher). Some areas south of Highway 101 that are not currently mapped in any flood hazard zone on the FEMA FIRMS right now are projected to experience flooding by 2100.

However, further inland (for example, downtown north of Highway 101), fluvial flooding is expected to be more extreme than coastal flooding, so the FEMA FIRM (existing conditions) represent more extreme conditions than the hazard zones from this assessment (future conditions). These areas would likely experience more frequent flooding events by 2100 due to sea-level rise, but the flood depths from sea-level rise alone would likely not be more than the base flood elevations currently shown on the FEMA FIRMs.

Other changing climatic factors, such as increasing precipitation intensity, could increase the fluvial hazard and flood extents and depths. However, this would require further study and analysis outside the scope of this vulnerability assessment to fully understand.

Major Infrastructure Facilities

Major infrastructure facilities, including the El Estero Wastewater Treatment Plant, the Charles E. Meyer Desalination Plant, and several major roads including Highway 101 are expected to experience increased flood risk by 2100. While they are expected to be exposed, facility-specific vulnerability assessments are recommended to better understand the adaptive capacity to flood proof these facilities and the actual risk to these facilities.

The vulnerability assessment shows the El Estero Wastewater Treatment Plant partially in the tidal inundation and storm flooding hazard zones by 2100 and the Charles E. Meyer Desalination Plant, at least partially exposed to the tidal inundation and storm flooding hazard zones by 2100. However due to tidal inundation of the infrastructure associated with these plants, as well as portions of the plants themselves, both the El Estero Wastewater Treatment Plant and Desalination Plant will be permanently inoperable by 2100 if no action is taken. Tidal inundation of some of the wastewater piping system flowing into the plant will occur by 2060 if no action is taken. Additional analysis is needed to determine how much this will interrupt operations of the plant. In addition, by 2100 much of Cabrillo Boulevard is exposed to erosion or tidal inundation, Highway 101 may experience storm flooding near Andrée Clark Bird Refuge, and Shoreline and Cliff Drive could be threatened by shoreline and bluff erosion.

Next Steps

The City will use the findings of the vulnerability assessment to identify adaptation strategies that will address the impacts of coastal hazards and reduce the city's vulnerabilities. The City will prepare an Adaptation Plan that will provide a more detailed economic and physical analysis of adaptation scenarios, including a baseline scenario. A baseline scenario generally assumes the City will continue to manage their coastal resources as they have historically and provides an important point of comparison, in particular for the economic analysis, to consider and weigh the costs and benefits of other adaptation scenarios. The adaptation planning process will include working with the City and the community to discuss their priorities and to develop guiding principles that will help guide future adaptation choices and development of the Adaptation Plan.

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CITY OF SANTA BARBARA SEA-LEVEL RISE ADAPTATION PLAN FOR THE LOCAL COASTAL PROGRAM UPDATE:

Vulnerability Assessment Update

1 Introduction

This report addresses existing conditions and future vulnerability of the City of Santa Barbara (City) and its coastal resources to projected sea-level rise, coastal flooding and erosion if no action is taken to address these hazards. The report is an update to the Vulnerability Assessment previously completed for the County of Santa Barbara (County) (ESA 2015; 2016b), and builds on the refined hazard mapping prepared for the City (ESA, 2016a) and its assets (ESA, 2015). This update incorporates the most recent hazard mapping associated with the Coastal Storm Modeling System (CoSMoS) applied to southern California (version 3.0; Erikson et al., 2017). The updated Vulnerability Assessment will serve as a planning-level assessment meant to inform the development of a Sea-level Rise Adaptation Plan that will analyze the feasibility, effectiveness, economic and fiscal impacts, environmental consequences, recreation impacts, and other costs and benefits of various adaptation strategies to avoid and/or mitigate coastal hazards over time. The Adaptation Plan will include a detailed Economic and Fiscal Impacts Analysis that is currently underway. The information in the Adaptation Plan will be used to amend policies and development standards in the City Local Coastal Program (LCP) to implement adaptation strategies. The City has been in the process of updating the LCP since 2014 and recently adopted an update to the LCP Land Use Plan[1].

The City and County of Santa Barbara have performed several sea-level rise (SLR) vulnerability studies, described in further detail in Appendix H. This study does not, and is not intended, to recreate the work performed in these previous studies. Instead, the Vulnerability Assessment Update augments those studies using the latest available data about coastal assets and infrastructure in the City. It also provides updated hazard information provided by the US Geological Survey (USGS), a focused study of local geology, and an investigation of the ecological effects of beach loss with SLR. These elements fill gaps in the existing studies and provide the City with a more complete picture of its vulnerability to SLR. The findings of this

[1] An LCP amendment to update the LCP Land Use Plan was approved by the City Council on August 7, 2018. As of the date of this study, the LCP Amendment had been submitted to the CCC for certification, but had not yet been scheduled for hearing.

assessment will enable ESA to assist the City with development of adaptation strategies to prepare for future impacts and policy language for incorporation into the City's LCP Update.

The Vulnerability Assessment Update has been prepared consistent with the recommendations of the State's most recent update to the California Coastal Commission Sea-level Rise Policy Guidance document (OPC, 2018). The guidance document provides a synthesis of the best available science on sea-level rise in California, a step-by-step approach for state agencies and local governments to evaluate sea-level rise projections, and preferred coastal adaptation strategies. As State grant funded work, the project is also guided by the Safeguarding California Plan for Reducing Climate Risk (Safeguarding Plan) and supports the principles of the Safeguarding Plan[2].

To support the adaptation planning process, vulnerability to erosion, tidal inundation, storm waves, and storm flooding hazards were analyzed under existing conditions and three future SLR scenarios: 0.8 feet at 2030[3], 2.5 feet at 2060, and 6.6 feet at 2100. These scenarios were selected based on the latest State of California Sea-level Rise Guidance (OPC 2018), which gives a range of sea-level rise projections for a region based on assumptions of risk aversion and low- versus high-emissions scenarios (the low being if emissions are greatly reduced in coming years and the high being if emissions continue as they have since the early 21st century). This document utilizes the high emissions scenario as recommended by California Coastal Commission (CCC) and others since 2013. A discussion of the selected sea-level rise scenarios and the State and Federal guidance that informed the selection of these scenarios and the approach to this Vulnerability Assessment Update is summarized in Section 3 and detailed in Appendix A.

Vulnerability was assessed by identifying potential hazard areas using available regional tools. Existing and potential future coastal tidal inundation, coastal storm flooding and coastal waves and erosion were mapped based on the results from the USGS's the Coastal Storm Modeling System (CoSMoS) version 3.0 (Erickson et al., 2017) with some refinements provided by the Coastal Resilience Santa Barbara study (ESA, 2016) for wave hazard zones. The next steps were to identify assets located within the study area, assess the potential exposure of these assets to the different hazard areas, and evaluate the consequences. As sea levels rise, the extents of mapped hazards are expected to increase and a greater amount of assets will become exposed and vulnerable. Using available coastal hazard mapping products as further discussed in Sections 3

2 Safeguarding Plan principles:

- Use the best available science to identify risks and adaptation strategies;
- Understand that an effective strategy for preparing climate risks should evolve as new information is available;
- Involve all relevant stakeholders;
- Establish and maintain strong partnerships across all levels of government, tribes, businesses, landowners, and non-governmental organizations;
- Give priority to strategies that also achieve benefits other than climate risk reduction benefits, including additional benefits to public health, the economy, environmental justice, and conservation of natural resources; and
- Ensure that strategies to reduce climate risk are coordinated, to the extent possible, with the state's efforts to reduce GHG emissions and other local, national and international efforts.

3 The OPC 2018 Guidance recommends 0.7 feet at 2030 (see Section 3.1). The closest CoSMoS Scenario is 25 cm, which is 0.8 feet. This difference is negligible at the scale of this study, and 0.8 feet is used throughout this report.

and 4, this assessment relies on reasonable assumptions and engineering judgement to simplify the analysis where needed.

The Vulnerability Report is organized as follows:

- Section 1 – Introduction
- Section 2 – Project Setting
- Section 3 – Existing and Future Coastal Hazard Zones
- Section 4 – Asset Exposure Analysis
- Section 5 – Ecological Vulnerability of Shoreline Habitats to Sea-level Rise
- Section 6 – Conclusions
- Section 7 – References

1.1 Disclaimer and Use Restrictions

1.1.1 Funding Agencies

These data and this report were prepared for the City of Santa Barbara and is partially funded by California Coastal Commission (CCC) and the State Coastal Conservancy through the Local Coastal Program Local Assistance Grant Program. The data and report do not necessarily represent the views of the funding agencies, their respective officers, agents and employees, subcontractors, or the State of California. The funding agencies, the State of California, and their respective officers, employees, agents, contractors, and subcontractors make no warranty, express or implied, and assume no responsibility or liability, for the results of any actions taken or other information developed based on this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. These study results are being made available for informational purposes only and have not been approved or disapproved by the funding agencies, nor have the funding agencies passed upon the accuracy, currency, completeness, or adequacy of the information in this report. Users of this information agree by their use to hold blameless each of the funding agencies, study participants and authors for any liability associated with its use in any form.

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The data are provided "as is" without any representations or warranties as to their accuracy, completeness, performance, merchantability, or fitness for a particular purpose. Data are based on model simulations, which are subject to revisions and updates and do not take into account many variables that could have substantial effects on erosion, flood extent and depth. Real world results will differ from results shown in the data. Site-specific evaluations may be needed to confirm/verify information presented in this dataset. This work shall not be used to assess actual coastal hazards, insurance requirements, or property values, and specifically shall not be used in lieu of Flood Insurance Studies and Flood Insurance Rate Maps issued by FEMA.

The entire risk associated with use of the study results is assumed by the user. The City of Santa Barbara, ESA, and all of the funders shall not be responsible or liable for any loss or damage of any sort incurred in connection with the use of the report or data.

2 Project Setting

This section presents information relevant to the physical context of the study area for the purposes of analyzing sea-level rise vulnerability. This includes a description of the study area in the City of Santa Barbara, a summary of a geologic review of seacliff areas in the City, a summary of the existing Federal Emergency Management Agency (FEMA) flood hazards, and a brief description of documented historic storm impacts to the City. Additional project setting information, including that related to coastal hydrology is included in Appendix B.

2.1 Study Area

The study area[4] includes the coastal portion of the City, about 6.5 linear miles of coastline from Arroyo Burro in the west to the Andrée Clark Bird Refuge in the east. It also includes Santa Barbara Harbor and extends inland far enough to capture the inland extent of projected flooding of the downtown Santa Barbara area. The study area does not include the Santa Barbara Airport and Goleta Slough, which have been studied in a separate sea-level rise report as further described in Appendix H. The study area was divided into 11 planning subareas based on land use composition and shore type morphology (e.g., bluff versus low-lying beach and backshore) for discussion purposes and to investigate the spatial variability of sea-level rise vulnerability in these areas. These subareas are shown in **Figure 1** and their primary coastal characteristics, key features, and land uses are summarized in **Table 1**, below.

2.2 Geology

The geography within the study area is a mix of coastal bluffs and low-lying sandy beaches and backshores[5]. The bluffs are composed of Monterey formation silt-mudstone, Casitas formations (which are moderately consolidated and mostly coarse sediment matrix formations), and unconsolidated sand and silt marine terrace deposits. The typical layering entails Monterey or Casitas formations overlain by marine terrace deposits. The layering geometry is not uniform owing to land movements as well as landslides. There is evidence of past landslides along the coastal bluffs, and landslides are expected to occur in the future. Beach sands and fill overlay the geology. Additional information on the geology of the study area is provided in a report prepared by Campbell Geo Inc. included in Appendix C. Additional information about geology and bluff erosion is provided in the existing studies described in Appendix H and include work by ESA (ESA, 2015; 2016, 2016b) and Erikson et al. (2017).

4 The study area was defined by the extent of the projected future coastal hazards occurring at 2100 under the medium high risk aversion scenario, or 6.6 feet of sea -level rise. This covers areas within the City's jurisdiction that could be exposed to any of the hazards used in this study.

5 Backshores are areas of a beach that extend inland from the limit of high water foam lines to the extreme inland limits of the beach, including bluffs and dunes that are in the coastal flood plain now or may be in the coastal flood plain in the future based on erosion and sea level rise. Backshore areas are typically only affected by waves during exceptional high tides or severe storms.

2.3 Existing FEMA Flood Zones

FEMA provides flood insurance rate maps (FIRMs) showing flood hazard information in support of the National Flood Insurance Program (NFIP). FEMA maps include Base Flood Elevations (BFEs) for flooding with a 1% chance of occurrence in a given year (otherwise known as a "100-year event") from coastal and rainfall sources. FEMA maps show flood risk for current conditions. FEMA maps do not include coastal erosion or consider future coastal flooding or hazards resulting from sea-level rise. The City of Santa Barbara Flood Plain Management Ordinance (Municipal Code Section 22.24) requires certain building standards based upon the location of the flood hazard zones and BFEs contained on FEMA FIRMs.

This Vulnerability Assessment addresses future coastal hazards with projected sea-level rise for the purpose of informing adaptation planning and policy development. This Vulnerability Assessment is based on the U.S. Geological Survey's Coastal Storm Modeling System (CoSMoS) results, which are described further in Section 3. CoSMoS provides coastal flood hazard results for a coastal storm with an approximate 1% annual chance or 100-year event, including flood hazards due to creek/river flows estimated to occur during such a coastal storm. [6,7] In contrast to FEMA maps, CoSMoS results do not include flood hazards due to the 1% annual chance or 100-year river flow. Nuance of these differences is discussed in Appendix B.

Figure 2 presents the FEMA special flood hazard areas for the City of Santa Barbara. A significant portion of Santa Barbara is mapped in the FEMA 100-year floodplain, due primarily to fluvial (river and creek) sources, including Mission Creek, Laguna Channel, Sycamore Creek, and Arroyo Burro Creek. The downtown Santa Barbara area north of Highway 101 is a low-lying area with restricted drainage, and has flooded during historical precipitation storm events. Along the coast, areas denoted Zone VE indicate that waves are a main contributor to the BFEs. Coastal areas denoted Zone AE, for example at the outlet of Sycamore Creek in the east of the City, indicate that while waves are present, they are significantly lower in elevation than the fluvial flood hazards. Section 3.10 includes further comparison and discussion of FEMA flood mapping and the coastal hazard mapping used for this Vulnerability Assessment. Appendix D includes FEMA FIRM panels for the study area.

[6] Note that CoSMoS flood hazard results for the 100-year coastal event and fluvial (river and creek) flooding during the coastal storm event are less extensive than FEMA's mapping of the 100-year fluvial flood extents because CoSMoS' estimates of the fluvial flows in Arroyo Burro, Mission creek, and Sycamore creek during the 100-year coastal storm are less than FEMA's estimates of the 100-year fluvial flows due to extreme inland precipitation events.

[7] FEMA also determines the flood extent and BFEs using statistics to estimate the 1% annual chance conditions based on many possible storms and runoff events, while CoSMoS uses a single storm with a 1% annual chance. CoSMoS' selection of a single storm may capture most flooding at the 1% chance level, but may not fully capture the extent of 1% chance flooding.

SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 1
Shoreline Hazard Planning Subareas

ESA

SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018; FEMA, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 2
FEMA Special Flood Hazard Zones in Santa Barbara

TABLE 1
DESCRIPTIONS OF SUBAREAS IN STUDY AREA

Subarea	Location	Shore Development Type	Shoreline and Backshore Types	Other Key Facilities/Landmarks
Subarea A	Sea Ledge Lane to west side of Arroyo Burro Beach County Park	urban blufftop - residential	• bluff-backed beach • ancient landslide at Sea Ledge Lane	• residential development
Subarea B	Arroyo Burro Beach County Park to east edge of Douglas Family Preserve	natural blufftop – open space	• bluff-backed beach • low-lying drainage and coastal lagoon • Arroyo Burro Lagoon	• Arroyo Beach County Park (natural preserve) and parking • Douglas Family Preserve (natural preserve)
Subarea C	west end of Medcliff Road to East End of El Camino de la Luz	urban blufftop - residential	• bluff-backed beach • modern landslide at El Camino de la Luz	• Mesa Lane beach access • residential development
Subarea D	Lighthouse	natural blufftop – open space	• bluff-backed beach	• Lighthouse • La Mesa Park • Washington Elementary
Subarea E	Meigs Road to Shoreline Park	urban blufftop - residential	• bluff-backed beach	• 1,000 Steps beach access • residential development
Subarea F	Shoreline Park to Santa Barbara Point	natural blufftop – open space	• bluff-backed beach	• Shoreline Park and parking • Shoreline Park beach access • residential development
Subarea G	Leadbetter Beach	urban beachfront	• low-lying beach and backshore	• public parking • Santa Barbara Community College • park and open space • commercial establishments
Subarea H	Harbor to Laguna Tide Gates	harbor	• protected harbor • low-lying beach and backshore • Mission Creek Lagoon	• harbor marinas • Harbor Pier (City Pier) • yacht club and boat yard • US Coast Guard office • Waterfront Department offices • park areas • Waterfront Coastal Trail • West Beach • Sandspit (surf spot) • recreation facilities (Los Banos del Mar Pool) • Stearns Wharf • Laguna Tide Gates and Pump Station • commercial establishments

Subarea	Location	Shore Development Type	Shoreline and Backshore Types	Other Key Facilities/Landmarks
				• residential development • public parking lots
Subarea I	Chase Palm Park & Downtown	sandy beach	• low-lying backshore • inland areas	• Chase Palm Park and other parks • Waterfront Coastal Trail • El Estero Wastewater Treatment Plant • railroad and train station • recreation facilities • Downtown area (north of Highway 101) with commercial establishments • East Beach • Highway 101 • Santa Barbara High School • Santa Barbara Junior High School • residential development
Subarea J	South Milpas Street to Andree Bird Clark Refuge	sandy beach – low lying and backshore	low-lying backshore inland areas	• East Beach • Sycamore Creek Lagoon • Waterfront Coastal Trail • Andrée Clark Bird Refuge • Santa Barbara Zoo • recreational facilities • commercial establishments • Cabrillo Pavilion Bathhouse • residential development
Subarea K	Bellosguardo Estate	urban blufftop - recreational	bluff backed beach	• Bellosguardo Estate

2.4 Historical Damages from Storms

The City of Santa Barbara has been exposed to several severe floods in the last three decades, with particularly large events associated with El Nino events in 1983 and 1998. These events resulted in several forms of damage, including significant wave overtopping at the breakwater, damage to slips and vessels in the Harbor, flooding of coastal parking lots, localized erosion along the sandy shoreline, and flooding in the downtown area from Laguna Channel. Some examples of historical flooding are shown in **Figure 3** and **Figure 4**.

City of Santa Barbara Sea-level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: City of Santa Barbara

Figure 3
Overtopping at the Southwest Corner of the Harbor Breakwater in March 2014

Historical flooding offers tangible examples of the damage caused by flooding, erosion, and waves in the City. Leadbetter Beach was eroded over 100 feet horizontally and over 10 feet vertically in 1978 and 1980 (NRC, 1982) In 1983 the shore retreated about 200 feet (NRC, 1984). The 1983 events also eroded West Beach and East Beach. The eroded beaches allowed breaking waves to propagate farther landward than normal, exposing inland facilities including Shoreline Drive and boat berths to waves. The beach erosion also allowed wave runup to flood inland areas. Coastal structures were constructed to mitigate future damage risk, including the breakwater extension built in 1986 and the beaches have recovered through both natural sand deposition and augmentation with dredged sand.

City of Santa Barbara Sea-level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: City of Santa Barbara

Figure 4
Flooding at the Harbor West Parking Lot in January 2014

Future flooding is likely to follow similar patterns, leading to similar damage unless measures are taken to protect infrastructure along the coast. Furthermore, rare events like the 1983 and 1998 storms and sustained damage from rising water, waves, and coastal erosion are likely to become more common as sea level rises. While the extent of exposure and vulnerability outlined in the following chapter may seem extreme in some cases, it is worth remembering that similar damage has already occurred (if rarely) in the past, and is apt to become more common with sea-level rise.

3 Existing and Future Coastal Hazard Zones

This section describes coastal hazard zones under current conditions and future conditions. The sea-level rise scenarios that were used as a basis for the vulnerability analysis are discussed, with further information available in Appendix A. Coastal hazard zone mapping for this vulnerability assessment is addressed, both in general and with a more detailed description of each hazard that was mapped.

3.1 Sea-level Rise

As discussed in the Introduction of this report, vulnerability to erosion, tidal inundation, storm waves, and storm flooding hazards were analyzed under existing conditions and three future SLR scenarios: 0.8 feet at 2030, 2.5 feet at 2060, and 6.6 feet at 2100. These scenarios were selected based on the latest State of California Sea-level Rise Guidance (OPC 2018), which gives a range of sea-level rise projections for a region based on assumptions of risk aversion and low- versus high-emissions scenarios (the low being if emissions are greatly reduced in coming years and the high being if emissions continue as they have since the early 21st century). This document utilizes the high emissions scenario as recommended by CCC and others since 2013.

The guidance document also recommends ranges in sea-level rise values for a region based upon likelihood of occurrence. Scenarios that are very likely to occur are to be utilized for low risk aversion planning, such as planning for trails or other assets that are easily moved. Scenarios that are less likely to occur are to be utilized for moderate/high risk aversion decisions, such as buildings and infrastructure that are harder to move. This Vulnerability Assessment Update utilizes the medium/high risk-aversion scenarios. The State of California Sea-level Rise Guidance (OPC, 2018) also recommends considering an extreme risk aversion scenario, termed “H++” for the planning and design of “highly vulnerable or critical assets”. This report is a planning-level document that will inform adaptation planning and policy development; this report does not provide an engineering-level analysis. Therefore, this report generally uses the medium-high risk aversion scenario to indicate whether an asset is located in a hazard zone and to identify critical assets that will require subsequent, more detailed analyses in order to inform further planning and design. This report does not provide a detailed analysis of vulnerability under the H++ scenario, but it does use the H++ scenario to understand how much earlier the projected sea-level rise amounts could occur.

Table 2 summarizes these sea-level rise scenarios, including the amount and associated time horizon, used for the technical analysis in this vulnerability assessment. OPC (2018) provides guidance for communities based on their risk aversion and based on different greenhouse gas emissions scenarios. A community with relatively little coastal exposure or easily replaceable assets may opt to prepare for the low risk aversion SLR values, while a community with extensive coastal exposure or assets that are difficult or impossible to replace may opt to prepare for extreme risk aversion. Within the risk aversion categories, communities can make different assumptions about future greenhouse gas emissions. OPC (2018) provides low and high emissions scenarios. The three rows of **Table 2** represent the risk aversion thresholds defined by

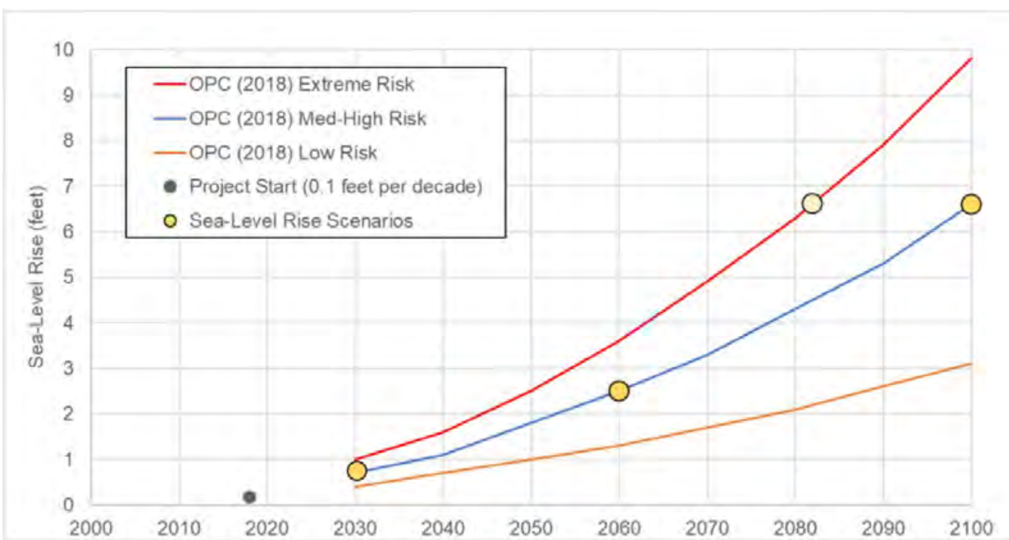
OPC (2018), and the range in values at future time horizons represent the low and high greenhouse gas emissions scenarios.

TABLE 2
SEA-LEVEL RISE SCENARIOS FOR PROJECT (UNDERLINED, BOLD) ARE BASED ON OPC 2018 GUIDANCE

Scenario	2030	2060	2080	2100
Low Risk Aversion[a]	0.4 feet	1.0 to 1.3 feet	--	2.0 to 3.1 feet
Med-High Risk Aversion[b]	<u>**0.7 feet**</u>[c]	2.2 to <u>**2.5 feet**</u>	--	5.3 to <u>**6.6 feet**</u>
Extreme Risk Aversion	--	--	5.3 to **6.6 feet**	--

NOTES:
a Low Risk Aversion values not used for this analysis
b Bold and underlined values in the Med-High Risk Aversion are used in this analysis
c The OPC 2018 Guidance recommends 0.7 feet at 2030. The closest CoSMoS Scenario is 25 cm, which is 0.8 feet. This difference is negligible at the scale of this study, and 0.8 feet is used throughout.

This study applied a range of SLR amounts and time horizons consistent with the State's guidance (CCC 2015, OPC 2018) which calls for consideration of a range of scenarios in order to bracket the range of likely impacts. Mid- and late-century timeframes of 2060 and 2100, respectively, were selected and are consistent with the timeframes selected in earlier vulnerability studies prepared for the City and County of Santa Barbara (ESA 2015; 2016). A near-term scenario at 2030 was reviewed and was deemed similar enough to existing conditions, therefore it was not analyzed in detail. **Figure 5** depicts the selected sea-level rise scenarios used in this study.



City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: OPC 2018

Figure 5
Updated OPC (2018) Sea-Level Rise Guidance Curves, with Selected Scenarios

As stated previously, the extreme risk aversion scenario (H++) is used to understand how much earlier the selected sea-level rise amounts would occur if catastrophic melting of ice sheets was to occur. In this case, SLR could reach 6.6 feet as early as 2080, not 2100. This serves to warn the City that the analysis and results described for 2100 could occur almost 20 years earlier.

Further information on SLR guidance and scenario selection is provided in Appendix A.

3.2 Hazard Zones

The Coastal Storm Modeling System (CoSMoS) implemented for Southern California (Version 3.0, Erikson et al. 2017, O'Neal et al 2018, Erikson et al, 2018) provides projections of erosion, permanent inundation, and temporary (storm event) inundation under future conditions. These projections were used to establish the hazard zones in this analysis. Based on our review and comparison with hazard data from previous studies, and further direction from the City of Santa Barbara, ESA augmented the CoSMoS wave runup estimates with additional wave hazard data represented in the Santa Barbara County *Coastal Resilience* maps (ESA 2016).

The hazard zones used in this analysis are described as follows:

- Shoreline Erosion – Over time, sandy beaches and dunes experience temporary erosion, with sand moving seasonally to and away from the beach, and permanent erosion, with sand moving away from the beach without returning. In this study, "shoreline erosion" refers to the permanent loss of sandy beaches, dunes, and the low-lying backshore that occurs with changing sea level or sand supply.
- Bluff Erosion – Over time, erosion causes the edge of coastal bluffs to move inland as material falls or collapses onto the beach (or into the ocean) below.
- Tidal Inundation – Tidal inundation refers to areas that are below the typical high tide elevation under non-storm conditions.
- Storm Waves – Storm waves refer to the exposure of the Santa Barbara shore to large waves generated by local and distant storms. These waves arrive at the Santa Barbara coast from a range of directions, and influence the coastal water levels and also directly induce flooding, erosion, and wave damage hazards, described generally as a wave hazard zone landward of the high tide line.
- Storm Flooding – When storms strike the Santa Barbara coast, they generally bring high water levels and waves. In this study, "storm flooding" refers to the combination of the high water levels that come with a storm, including some of the effects of waves. The coastal storm used to define the hazard zone is estimated to have a 1% chance of occurring each year (i.e., a "100-year storm").

Some portions of the City are below the tidal inundation and storm flooding elevations, but are not directly connected to the ocean. These disconnected low-lying areas are subject to flooding and are further described in Section 3.8.

Table 3 presents a summary of the hazard types, their impact class and the data sources used to prepare hazard maps. This approach assumes that permanent impacts occur when assets are exposed to long-term erosion of sandy beach and dunes, long term erosion of bluffs, and tidal inundation, while temporary impacts occur when assets are exposed to storm flooding and storm wave impacts[8].

It should be noted that the previous vulnerability assessment (which this updates) used the Coastal Resilience projections (ESA 2016), and these could be used instead of CoSMoS. However, based on discussions with City staff and our understanding that the State of California intends to continue to use CoSMoS as the State standard and that use of CoSMoS as the standard is further supported by the USGS, the CoSMoS projections were selected going forward.

TABLE 3
SUMMARY OF HAZARD MAPPING DATA ORGANIZED BY HAZARD TYPE AND IMPACT CLASS

Hazard Type	Impact Class	Mapping Data Source
Long-Term Erosion – Sandy Beach and Dune	Permanent	CoSMoS 3.0[a]
Long-Term Erosion – Bluff	Permanent	CoSMoS 3.0
Tidal Inundation	Permanent	CoSMoS 3.0
Storm Waves	Temporary	Coastal Resilience – Santa Barbara[b]
Storm Flooding	Temporary	CoSMoS 3.0

NOTES:
[a] CoSMoS 3.0: Erikson et al. 2017
[b] Coastal Resilience – Santa Barbara: ESA (2015; 2016)

A hierarchy of the coastal hazard zones was used to identify the primary impact to an asset so that impacts are not double-counted. That is, if an asset is shown as being exposed to bluff erosion, it is not also presented as exposed to tidal flooding. This is because assets in eroded areas are considered permanently lost, so adding a flooding impact would be redundant. Using mutually exclusive hazard zones prevents over-estimating exposure to less severe hazards (i.e. storm flooding) which may cover large areas that have already been addressed with other hazards (i.e. tidal inundation). Hazard zones are evaluated in the order listed in **Table 3**, with erosion taking highest precedence and storm flooding taking lowest. Note that the figures below include disconnected low-lying areas in addition to the hazards in **Table 3**, which are used to indicate potential flood-prone areas and locations where future groundwater elevations could become a nuisance. The following figures present existing and future sea-level rise hazard zones:

- Existing Conditions: **Figure 6** (east) and **Figure 7** (west)
- 2030: **Figure 8** (east) and **Figure 9** (west)
- 2060: **Figure 10** (east) and **Figure 11** (west)
- 2100: **Figure 12** (east) and **Figure 13** (west)

[8] Because large waves on the west coast are often generated at storms in the open ocean, while storm flooding occurs during local storms, storm flooding and storm waves may not occur at the same time and may affect different areas. The storm waves hazard zones represent the areas temporarily affected by waves when waves from these distant storms arrive at the coast.

Upon reviewing the hazard zones for 2030, it was determined that this time horizon is similar to existing conditions, showing no significant changes from the present. Some of the beach areas along the coast are exposed to erosion hazards in 2030, rather than tidal flooding in existing conditions; however, these are both permanent loss hazards and therefore existing and 2030 hazards are similar in terms of asset impacts). This allowed the study to focus on assets that are exposed and vulnerable to coastal hazards in 2060 and 2100.

3.3 Long-term Shoreline Erosion

CoSMoS incorporates historical trends in shoreline position, longshore transport, and cross shore transport to provide a line indicating the inland extent of shoreline[9]. This inland extent is defined as the mean high water mark and is averaged over all seasons to avoid capturing seasonal variation in the shoreline position. The shoreline erosion hazard zone is the area between the existing shoreline and estimated inland extent of the shoreline, and assets in this zone were deemed exposed to shoreline erosion. In this study, shoreline erosion is considered a **permanent loss hazard**, since assets in eroded areas will be completely lost.

3.4 Long-term Bluff Erosion

CoSMoS incorporates cliff materials, changing water levels, and wave conditions to provide a line indicating the inland extent of bluff erosion[10]. This line represents the potential bluff edge at each time horizon. The assets between this line and the tidal inundation hazard zone were deemed exposed to bluff erosion, since they would be affected as the bluff edge moves inland over time. In this study, bluff erosion is considered a **permanent loss hazard**, since assets in eroded areas will be completely lost.

A review of the CoSMoS and Coastal Resilience erosion projections for the Santa Barbara shore is provided by Campbell Geo (Appendix C). The comparison concludes that the two methods provide similar results in general, but differ at specific locations due to differences in the methods used. The Coastal Resilience results are sensitive to the increase in wave runup (e.g., total water level) reaching the bluff face with future sea levels. The CoSMoS results are sensitive to the historic erosion rate used. Based on a review of the average erosion projections over the century, bluffs will erode about 1.5 times as fast by 2060 (a 40% increase over the historic rate), and more than twice as fast by 2100 (a 140% increase over the historic rate). Therefore, bluff top areas are expected to be increasingly exposed to hazards with sea-level rise.

The Coastal Resilience erosion projections are higher than the CoSMoS projections in some locations. The bluff erosion projections from the Coastal Resilience study identified existing cliff failure hazards (since cliff or bluff erosion is often episodic) and included a “factor of safety” based on the statistical uncertainty in bluff erosion rates. While the Coastal Resilience bluff erosion projections are higher than the CoSMoS projections, the Coastal Resilience erosion

9 CoSMoS includes a transect based shoreline change model, which was used to estimate the regions along the Santa Barbara coast that may erode by the study’s two time horizons. The model assumes a Bruun type geomorphic response to sea-level rise.

10 CoSMoS includes a transect based cliff recession model, which was used to estimate the regions along the Santa Barbara coast that may erode by the study’s two time horizons.

projections were not used in this vulnerability assessment. ESA notes that future bluff erosion may be higher than projected by CoSMoS. Because the methods have similar results, as discussed previously, the CoSMoS results were selected for consistency with applying the CoSMoS inundation and flooding hazard zones.

Coastal bluff erosion is expected to accelerate with sea level rise, but evidence of historical landslides in the City indicate that geologic factors may lead to further loss of bluff areas. These upland bluff retreat hazard areas were investigated by URS (2009) and are described in more detail in Appendix I. The upland bluff hazard areas identified by URS are presented in the hazard figures below, but the exposure tables in Appendix F include only long-term bluff erosion from CoSMoS, not the regions identified by URS (2009).

3.5 Tidal Inundation

CoSMoS uses a series of models[11] to determine tidal flooding extents under current and future conditions. Flood extents and depths for non-storm conditions correspond to tidal conditions that occur during a spring tide, which is a semi-monthly occurrence as a result of the moon being new or full. CoSMoS selected a spring tide elevation representative of this condition with high tides representing a near-worst case scenario (Erikson et al. 2017). This hazard would affect assets on the surface by inundation, and buried assets (like sewer lines) could be exposed to saltwater intrusion and corrosion as higher sea levels change groundwater depth and salinity. This hazard does not include changes to stormwater drainage and specific culverts and resulting changes to flooding. In this study, tidal flooding is considered a **permanent loss hazard**, since assets regularly beneath high tide will likely be effectively unusable.

3.6 Storm Waves

CoSMoS provides some wave conditions and runup elevations that are associated with the storm flooding extents. However, the wave runup outputs do not represent the potential for increased damages along the shoreline and backshore resulting from the force of waves during a large coastal storm event (similar to the VE zone hazard mapped in FEMA flood insurance maps).

For this study, ESA utilized wave runup hazard zones that were previously developed for the City and County of Santa Barbara for the Coastal Resilience project (ESA,2016b)[12, 13]. Storm flooding mapped by CoSMoS does not extend to the landward limit of wave runup; rather, the CoSMoS storm flooding zone only includes areas that are inundated for more than one minute during the

[11] CoSMoS uses a regional Delft3D model to drive a local SWAN model, which provides boundary conditions for XBeach models at the shore. This provides relatively fine-scale hydrodynamics, including wave setup.

[12] Coastal Resilience storm wave hazard zones are based on real buoy data for existing conditions and utilized synthetic buoy and water level data developed by the USGS, which is consistent with the CoSMoS methodology. Descriptions of the input data and methodology used to develop these wave hazard zones can be found in ESA 2015 and 2016.

[13] The Coastal Resilience wave hazard zones represent an extreme coastal flood based on analysis of time series of modeled wave runup data for several transects along the shore of the City.

modeled storm event[14]. Careful inspection of the CoSMoS maps will show colored "dots" that denote the modeled landward limit of wave runup, which is a CoSMoS output that is separate from the CoSMoS storm flooding zone. These CoSMoS wave runup limit point data are based on modeling of transects and do not accurately provide a wave runup zone beyond the CoSMoS storm flooding zone. For this reason, the Coastal Resilience wave runup limits were used instead as a more accurate representation of wave runup. Wave runup is considered in this vulnerability assessment because wave runup can cause significant damage when it collides with structures (FEMA, 2005). Impacts from storm waves are more severe than storm flooding hazards from standing water because wave momentum can cause structural damage, move vehicles, knock people over, etc. Finally, ESA notes that the CoSMoS runup limit point data were frequently farther landward than the Coastal Resilience wave runup hazard zone area/extents used in this study, and hence this Vulnerability Assessment may under-estimate the future extent of wave runup. However, the existing wave runup (from Coastal Resilience) compares favorably to the FEMA map. Similar to storm flooding (described below), storm waves are considered a **temporary loss hazard**.

The Coastal Resilience storm wave hazard zones used for this study represent an extreme flood based on analysis of time series of modeled wave runup data for several transects along the shore of the City. The 100-year wave runup elevation (known as the total water level and used to represent the 100-year flood) was selected based on statistical analysis of the time series, and represents an extreme wave condition at the shore. Although this type of analysis indicates the statistical extremes, the Santa Barbara shore has been vulnerable to rare but extreme wave conditions due to storms approaching from the southeast. The southeast storm conditions have been historically destructive to the Santa Barbara harbor and other waterfront assets. Both the CoSMoS and Coastal Resilience studies may under-represent the exposure of the City to this type of wave hazard. Adaptation planning should incorporate measures to improve resiliency to these wave directions which may become more frequent in the future.

3.7 Storm Flooding

CoSMoS uses the same set of models to determine storm flooding as tidal flooding (see above), but the analysis is performed for storms of different frequencies. A regional storm[15] with a 1% chance of happening in any year (the "1% annual exceedance probability" or "100-year storm") was selected and used to represent potential storm event flooding. The approach used to select a 100-year event in CoSMoS is not the same as how it is determined for FEMA and other standard flood analyses, where time series of the parameter is statistically analyzed in an extreme value analysis to identify the most extreme conditions based on a variety of storms. Therefore, the

[14] Excerpt from O'Neill et al, 2018, page 16: "The frequency-filtered sustained water levels (constant water levels of durations longer than 1 min) are intended to capture the wave setup at the shore, which is the increase in mean water level above the still water line due to the transfer of momentum by breaking waves. Maximum runup, computed with the Tier III XBeach model, are also output as part of the CoSMoS results, but are mapped as single points and are not included in the flood footprint."

[15] The regional 1% annual exceedance probability storm event is reasonable for a large-scale study, but the selected storm may create flooding that is more or less likely (than 1%) at different locations in the City due to local conditions. While this level of detail is sufficient for the vulnerability assessment update, local analysis would be required for engineering decisions.

selection of the 100-year event resulting from a specific storm event may be different than would be determined using other methods. In this study, storm flooding is considered a **temporary loss hazard**, since assets in the storm hazard zone will be flooded only during extreme events, and service may be restored after the event.

3.8 Disconnected Low-lying Areas

Some portions of the City are below the coastal flooding elevations identified for tidal or storm conditions but are not directly connected to the ocean. While they may be protected from direct exposure by high ground or structures, they may still be susceptible to flooding. Areas below the tidal flooding elevation (called "tidal low-lying areas") may experience flooding from a rising groundwater table with sea level rise. Areas below the storm flooding elevation (called storm flood-prone areas") may experience flooding from precipitation or wave over wash that is unable to drain to the ocean because water levels are too high. In either case, indirect connectivity is unknown, so they are identified as potentially hazardous. In this study, flooding of these low-lying and flood prone areas is considered a **potential loss hazard**, since more analysis would be required to identify and describe the flood source.

3.9 Management Scenarios

CoSMoS provides future hazard zones for two management scenarios, referred to as "hold the line" (HTL) and "let it go" (LIG), for future time horizons. This study presents all hazards using the LIG management scenario. The LIG scenario assumes that no management actions are taken and erosion can continue unabated. While the LIG scenario assumes that no management actions are taken, there are several management actions that are implicit in the CoSMoS mapping. It is assumed that the harbor will remain, though the breakwater could be overtopped with sufficient sea-level rise. In addition, the erosion response of the shore is based on historical rates, so past actions taken by the City to manage sediment by dredging and placement are implicitly included in the results. Adaptation planning will address the effects of nourishment in a more direct manner to measure its effectiveness for mitigating erosion and flooding impacts.

The HTL scenario would assume that management actions are taken to repair and replace damaged structures, and development will be maintained in its current position. In the view of the consultant, the HTL scenario is very conceptual and not appropriate for planning purposes. This is because the "line" is drawn arbitrarily, and the effectiveness of the existing features to prevent overtopping and erosion, and to withstand future sea levels is not addressed from an engineering perspective. Additional information regarding shore armoring can be found in the report ESA prepared for the City of Santa Barbara on this topic (ESA, 2016b).

3.10 Comparison to FEMA Base Flood Elevations

As discussed in Section 2.3 there are significant differences in the methods and intent of the FEMA flood maps and the coastal hazard mapping in this report.

However, this study recognizes that a significant portion of the study area is located within FEMA special flood hazard zones which are subject to the City of Santa Barbara's Floodplain

Management Regulations. The Vulnerability Assessment Update does not include an extensive comparative analysis of the FEMA base flood elevations and the projected depths of water levels included in the coastal hazard zones. As a planning-level assessment and initial step in the adaptation planning process, the Vulnerability Assessment does not include an extensive review of the City's existing regulatory and policy environment including the city's Floodplain Management Ordinance (Municipal Code Section 22.24).

However, it is important to understand if the coastal hazard results generally align with the FEMA flood hazard results. **Figure 14** provides a comparison of the extent of the FEMA special flood hazard zones and the extent of coastal hazard zones at 2100. This report also tested discrete locations to compare the FEMA base flood elevations with the CoSMoS 100-year storm flooding at 2100. The result of this discrete analysis[16] is summarized as follows:

1. North of Hwy 101: CoSMoS 100-year storm flooding at 2100 is 1 to 2 feet lower than the FEMA existing Base Flood Elevation.
2. South of Hwy 101: CoSMoS 100-year storm flooding at 2100 is 2 to 3 feet higher than the FEMA existing Base Flood Elevation. It should be noted that this point was selected in a location that is sheltered from wave action just west of Laguna Channel.

The above comparison is provided to assist the City in assessing whether the use of the FEMA map and current flood plain regulations, which are based on the FEMA hazard zones and identified base flood elevations, is adequate to address future conditions. Obviously use of the FEMA flood map is not sufficient where future water levels due to coastal flooding from sea-level rise exceed the FEMA flood map. Further, it is expected that precipitation intensity will increase due to climate changes and hence the future 100-year flood limits for the creeks in Santa Barbara are expected to be greater than shown on the FEMA map. While the climate-influenced flood hydraulics analysis for the streams in Santa Barbara was not performed for this study, a previous analysis of Carpinteria Creek indicated that the 100-year flow rate would increase 15% to 100% by 2100 (ESA, 2015). An increase in flowrate by 15% to 100% and the elevated ocean water level at the creek mouth would likely increase the depth and extent of creek flooding in Santa Barbara.

[16] This was based on an evaluation of two discrete point locations north and south of Highway 101. This comparison of discrete point locations does not apply to other locations because ground elevations and slopes vary spatially and the discrete point comparison are therefore not accurate for other locations.

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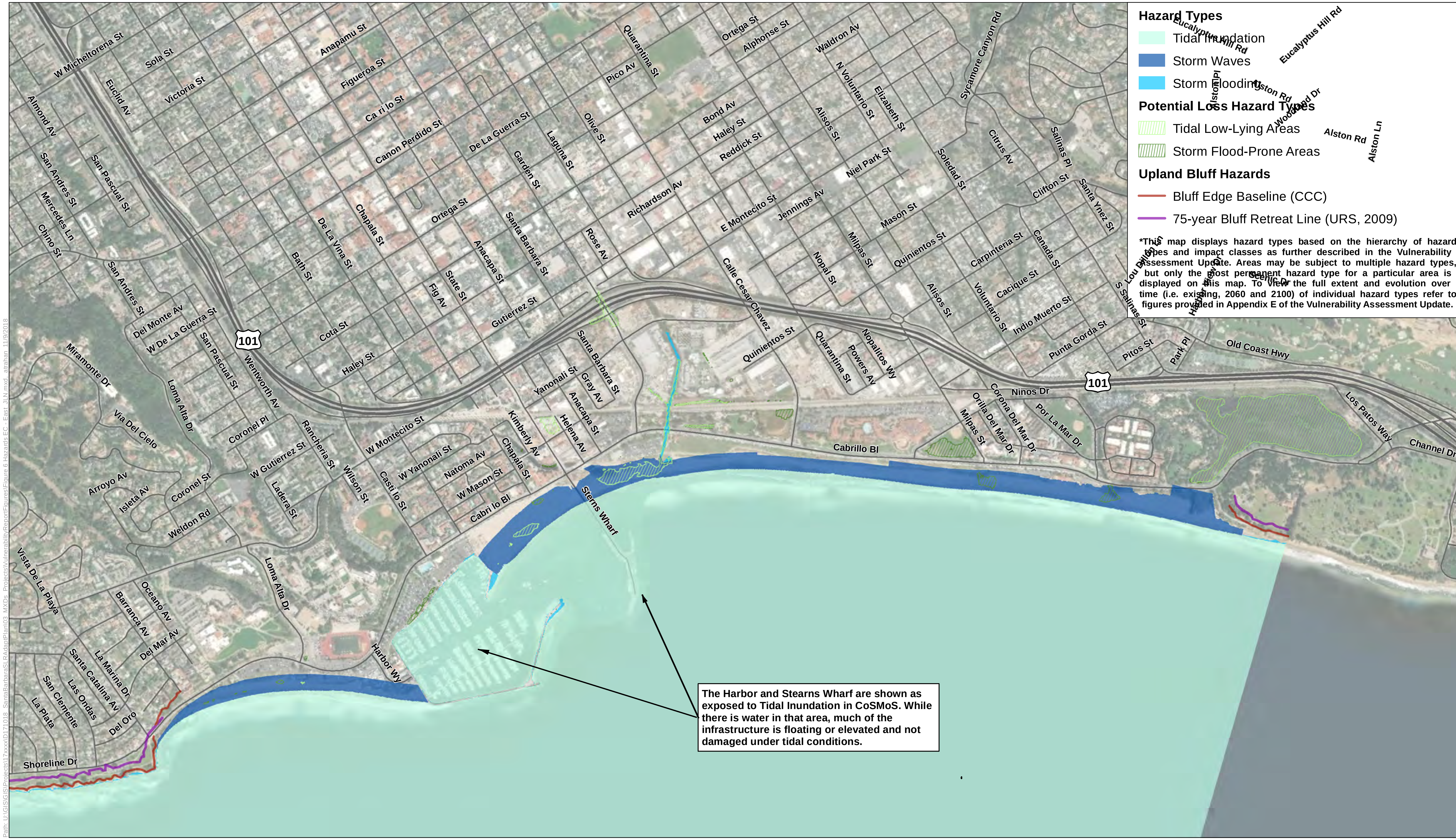


SOURCE: ESRI, 2018; USGS, 2018; ESA, 2018.

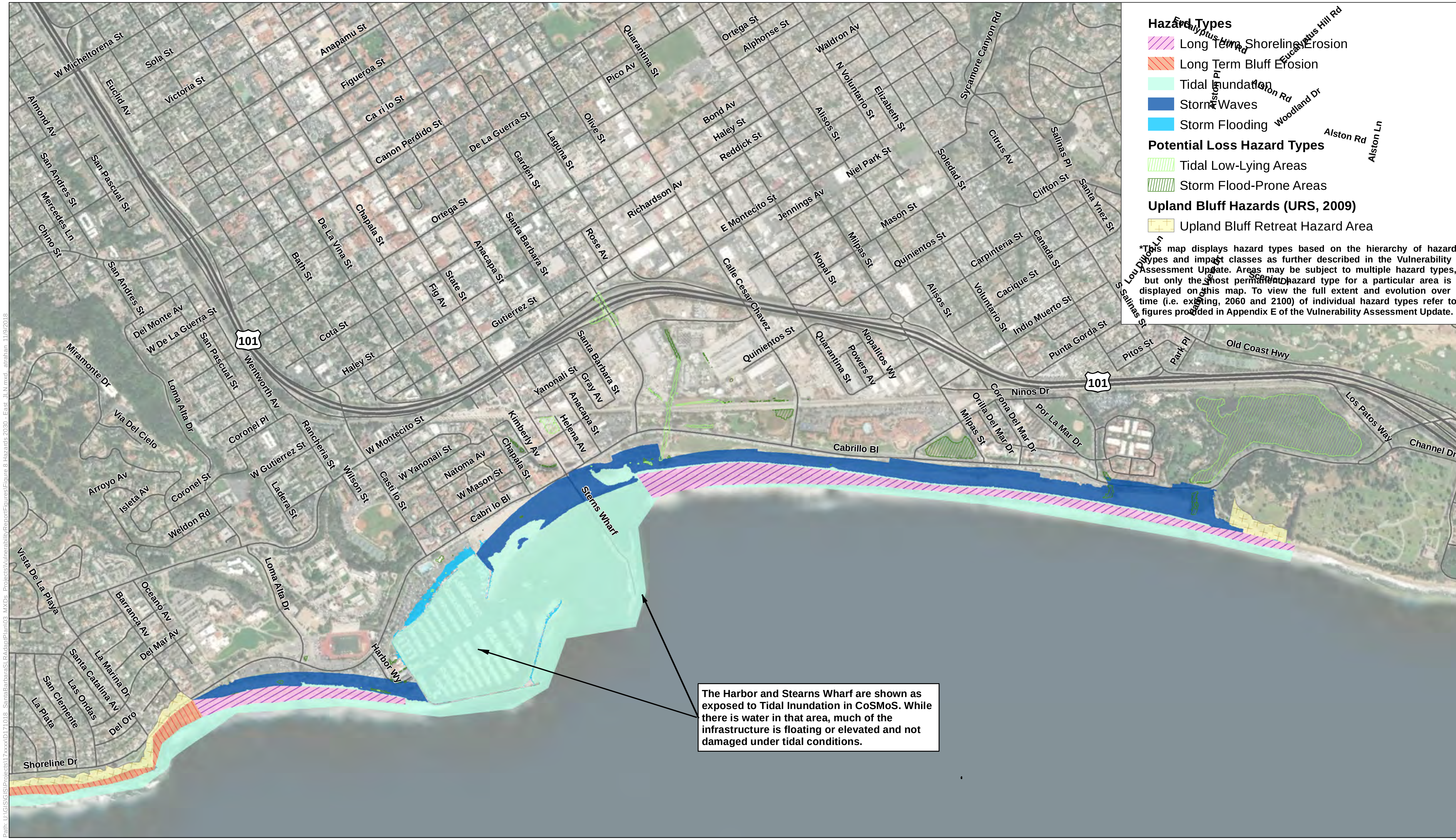
Figure 6
Existing Conditions Hazards (East)

SOURCE: ESRI, 2018; USGS, 2018; ESA, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 7
Existing Conditions Hazards (West)

ESA



SOURCE: ESRI, 2018; USGS, ESA, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 8
2030 Hazards (East)

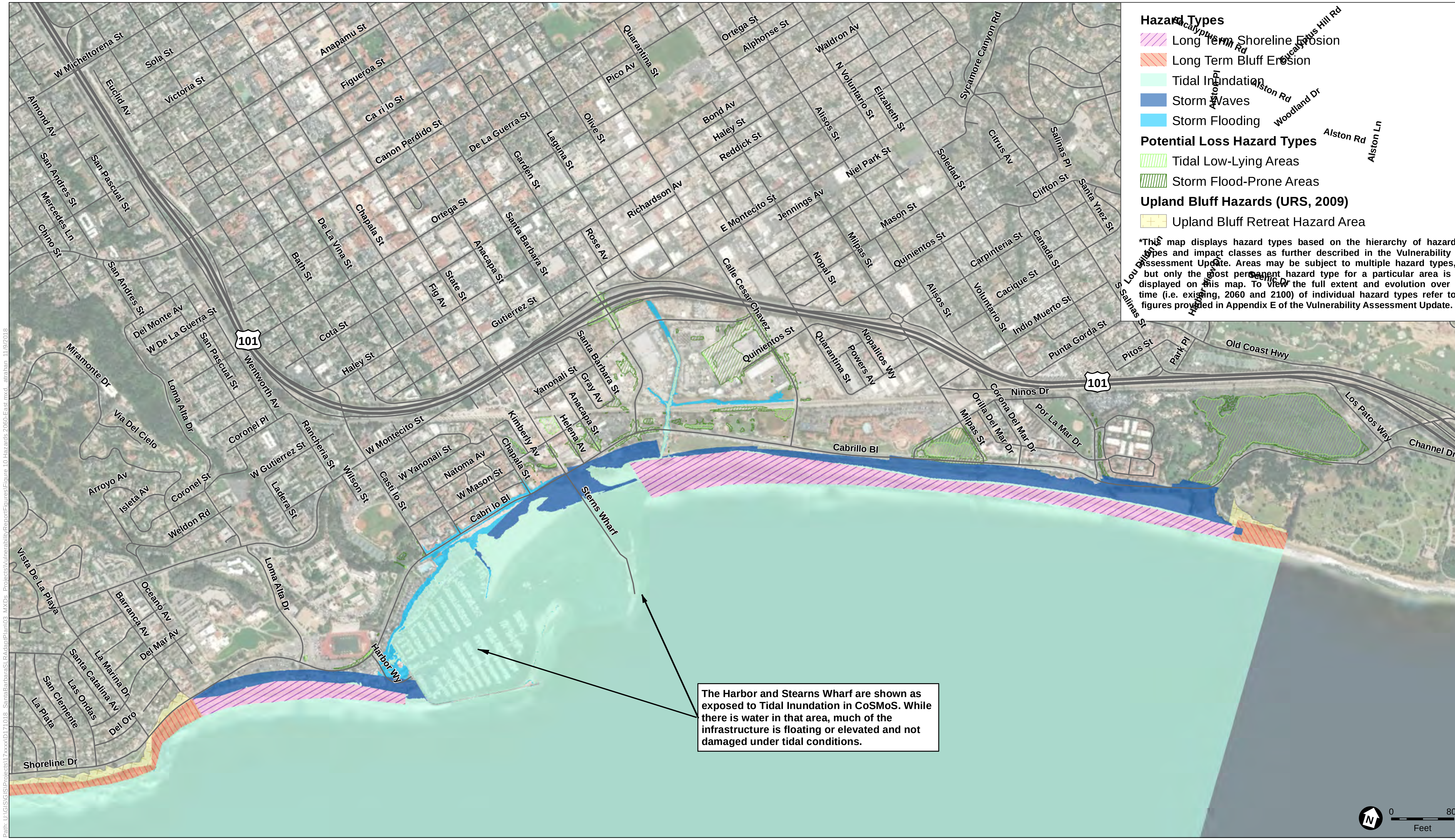
ESA

SOURCE: ESRI, 2018; USGS, 2018; ESA, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 9
2030 Hazards (West)

ESA



SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 10
2060 Hazards (East)

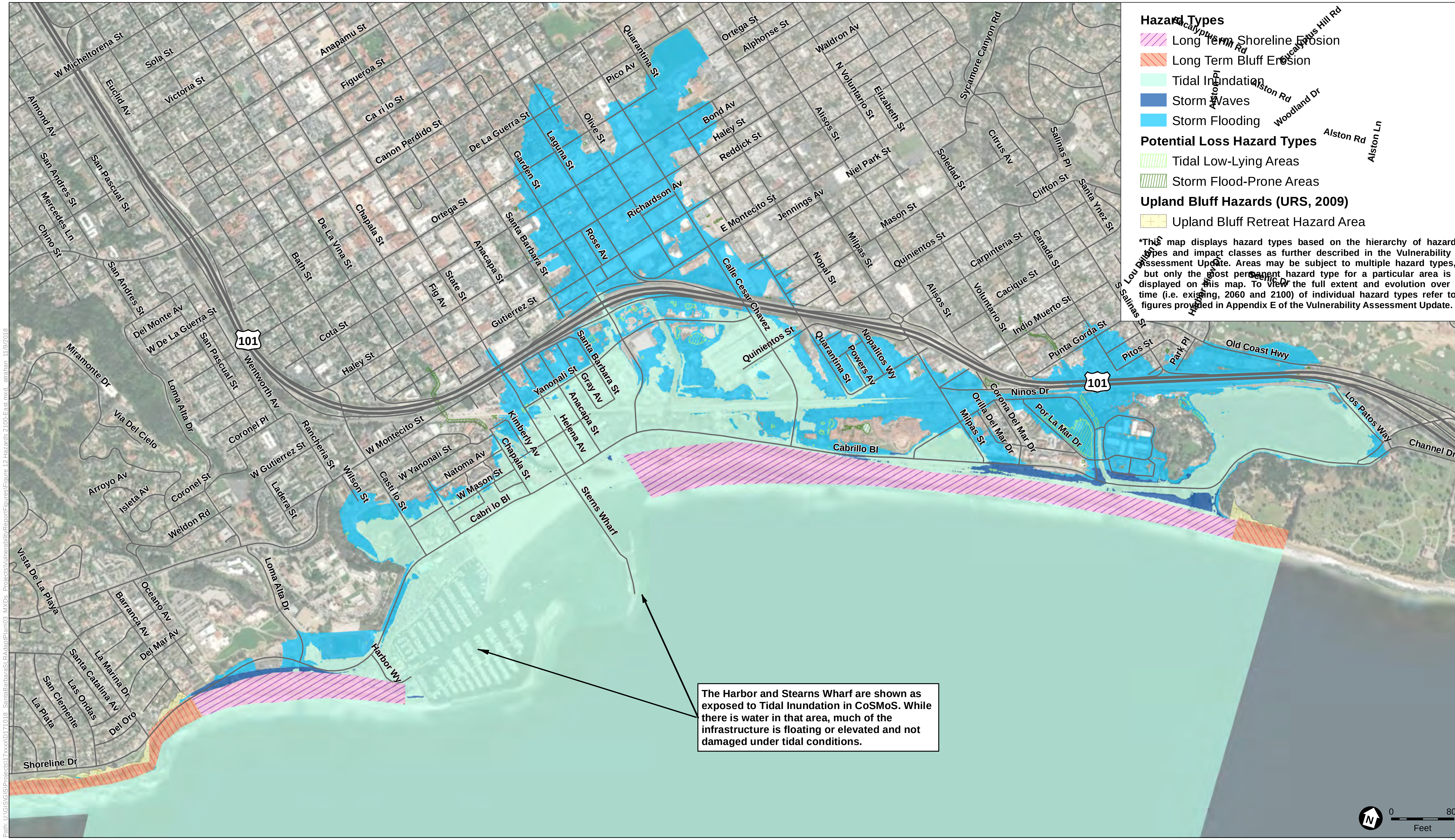
ESA

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 11
2060 Hazards (West)

ESA



SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 12
2100 Hazards (East)

ESA

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 13
2100 Hazards (West)

ESA

SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018; FEMA, 2018.

Figure 14
Comparsion between FEMA Special Flood Hazard Area and Storm Flooding Extent at 2100 (with 6.6 feet of sea-level rise)

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4 Asset Exposure Analysis

The vulnerability assessment is based on the exposure of identified assets to projected future coastal flood and erosion hazards. To assess asset exposure to hazards, the assets in different categories were intersected in Geographical Information System (GIS) software with each potential future hazard zone. Where an asset intersects a hazard zone, it is identified as at risk. Economic or other valuations will be applied to quantify the vulnerability (in a subsequent phase of the adaptation planning process. This type of analysis does not precisely assess the cause of failure or an established threshold for each asset type, and therefore is considered a planning-level vulnerability analysis. A planning-level vulnerability analysis is meant to inform the development of an Adaptation Plan and related LCP policies and it should not be used for asset-specific programing or engineering without additional scrutiny and possible refinements. Assessing the sea-level rise vulnerability of assets in the City requires an understanding of which assets are exposed to different hazards at different time horizons. To determine this, assets provided by the City were intersected with each hazard layer, leading to the exposure results summarized in Section 4.3 and provided in Appendix F.

4.1 Asset Datasets

Asset datasets were divided into categories to better understand the exposure of certain infrastructure systems. In addition to infrastructure assets, the asset datasets include recreational assets (e.g. parks, beaches), critical facilities, and building/parcel information. The datasets were primarily provided by the City with exception of the recreational areas data which was provided in a report prepared by the Bren School of Environmental Science & Management (Denka et al., 2015). There are three different geometries of data: points, lines, and polygons. The datasets, along with their sources, categories, and geometries, are presented in **Table 4** [17].

It should be noted that some asset data was not available at the time this report was prepared; in particular power and gas data is not provided by utility corporations for public uses. Water and wastewater infrastructure assets are included in the analysis, but their locations are not included in maps in the report due to security concerns.

4.2 Analysis of Hazard Exposure

The assets described in Section 4.1 were intersected with seven hazard layers: shoreline erosion, bluff erosion, tidal flooding, storm waves, and storm flooding, low-lying areas, and flood-prone areas. The first three hazards (bluff erosion, shoreline erosion, and tidal flooding) are considered permanent loss hazards, as they result in loss of land or frequent flooding, which are likely to render assets unusable. The next two hazards (storm waves and storm flooding) are considered temporary loss hazards, since they result in occasional, temporary loss of service during storm events, which may lead to damage, but is not likely to destroy assets entirely. The last two hazards (low-lying and flood-prone) are considered potential loss hazards, since they are not directly connected to the ocean so the cause and likelihood of flooding are less clear.

[17] These assets were not field verified by ESA.

TABLE 4
ASSET DATA SOURCES

Category	Asset	Geometry	Source
Communications	Fiber Optic Communication Cabinets	Point	City of Santa Barbara
Communications	Fiber Optic Cables	Line	City of Santa Barbara
Critical Facilities	Fire Stations	Point	City of Santa Barbara
Critical Facilities	Police Stations	Point	City of Santa Barbara
Critical Facilities	Evacuation Routes	Line	City of Santa Barbara
Harbor Infrastructure	Concrete Breakwaters	Line	City of Santa Barbara
Harbor Infrastructure	Rip-rap Breakwaters	Line	City of Santa Barbara
Harbor Infrastructure	Boat Launch Ramps	Line	City of Santa Barbara
Harbor Infrastructure	Solid Groins	Line	City of Santa Barbara
Harbor Infrastructure	Rip-Rap Groins	Line	City of Santa Barbara
Harbor Infrastructure	Street Parking	Line	City of Santa Barbara
Recreation	Recreational Areas[1]	Polygon	BREN[2]
Recreation	CA Coastal Trail	Line	City of Santa Barbara
Stormwater	Stormwater Pipes	Line	City of Santa Barbara
Stormwater	Stormwater Channels	Line	City of Santa Barbara
Stormwater	Water Control Structures	Point	ESA[3]
Structures/Parcels	Parcels	Polygon	City of Santa Barbara
Transportation	Railroads	Line	City of Santa Barbara
Transportation	Roads	Line	City of Santa Barbara
Transportation	Public Parking Lots	Polygon	City of Santa Barbara
Wastewater	Sewer Lift Stations[4]	Point	City of Santa Barbara
Wastewater	Sewer Laterals	Line	City of Santa Barbara
Wastewater	Sewer Force Mains	Line	City of Santa Barbara
Wastewater	Sewer Gravity Mains	Line	City of Santa Barbara
Water Supply	Groundwater Wells	Point	City of Santa Barbara
Water Supply	Monitoring Wells	Point	City of Santa Barbara
Water Supply	Production Wells	Point	City of Santa Barbara
Water Supply	Water Pumps	Point	City of Santa Barbara
Water Supply	Raw Water Mains	Line	City of Santa Barbara
Water Supply	Water Mains	Line	City of Santa Barbara
Water Supply	Recycled Water Mains	Line	City of Santa Barbara
Water Supply	Recycled Water Laterals	Line	City of Santa Barbara

NOTES:

1 Recreation Areas include Stearns Wharf, though this asset is in the harbor area. The harbor and Stearns Wharf are addressed in more detail in Section 4.4.1 and 4.4.2.

2 The recreational areas dataset from Bren provides more data than the layer provided by the city, but covers fewer areas. This dataset was augmented with any areas in the city-provided dataset that were exposed to one or more of the hazard layers.

3 ESA identified two tide gates and one pump station that were not in the data provided by the City and created a layer to identify these in the analysis.

4 The “lift station” identified by the City represents the El Estero Wastewater Treatment Plant.

As described in Section 3.2, a hierarchy of the coastal hazard zones was used to identify hazard exposure. The hierarchy from most severe hazard to least severe hazard is as follows: erosion, tidal inundation, storm waves, storm flooding, tidal low-lying areas, and finally storm flood-prone areas. The identified hazards are mutually exclusive to prevent over estimating exposure. For example, assets exposed to erosion are not marked as exposed to tidal flooding, since they are considered lost already.

Each hazard was assessed at three timelines: existing conditions, 2060, and 2100. However, erosion is a future hazard and so was not considered for existing conditions. Future hazard zones were also considered under the "let it go" management scenario, under which the shore progresses inland without the assumption that armoring will withstand sea-level rise. Because the hazard layers are mutually exclusive, some assets are less exposed to temporary loss hazards (like storm flooding) in the future, as permanent loss hazards (like tidal flooding) cover more area.

In addition to the extent of the hazard, inundation depth for storm flooding is presented in **Figures 18** through **25**, as estimated by CoSMoS. The depth of flooding is related to the level of damage for a given asset. These are shown for only storm flooding because depth is especially important for temporary loss hazards, because assets may be abandoned or decommissioned if permanently inundated, even if the damage at that depth is relatively low.

4.3 Exposure Analysis Results by Category

The results of the exposure analysis are summarized in this section. The complete exposure tables and charts including exposure results for existing conditions, 2060 and 2100, for each subarea, are provided in Appendix F. The exposed assets were tabulated based on the geometry of the feature (**Table 4**): point assets are counted, line assets are measured in linear feet, and polygon assets are measured in square feet. **Figures 26** through **32** display exposure to hazard zones in the year 2100 by each asset category. The year 2100 results convey the greatest extent of exposure to hazards that were analyzed in this study. Many of the assets see a mild increase in hazard in 2060, followed by a sharp increase by 2100. A summary of these results is provided below by asset category.

4.3.1 Transportation

Figure 26 presents transportation assets exposed to hazards in 2100. Most of the roads and the railroad in the City show little exposure at 2060, but public parking is exposed to increased tidal flooding and wave damage, and Shoreline Drive and Cabrillo Boulevard show minor exposure to erosion. By 2100, much of the public parking and roads around the harbor are inundated regularly, and the railroad through the city is exposed to tidal and storm damage. Most of Cabrillo Boulevard is exposed to erosion or tidal inundation, and the junction of Megis Road and Shoreline Drive is exposed to erosion. Roads in the downtown area, like Gutierrez Street, Haley Street, and Milpas Street are exposed to storm flooding. This is likely to disrupt harbor and beach access. Furthermore, Highway 101 is exposed to storm flooding west of Andrée Clark Bird Refuge, potentially disrupting traffic at a regional scale.

4.3.2 Fire Stations, Police Stations, and Wildland Fire Evacuation Routes

Figure 27 presents fire stations (one of which is exposed), police stations (none of which are exposed) and wildland fire evacuation routes exposed to hazards in 2100. The City sees very little exposure in 2060. By 2100, however, Santa Barbara Fire Station 2 (south of Highway 101) could be inundated during a storm event, potentially stranding emergency response personnel or equipment. While many coastal evacuation routes are spurs, the route through Arroyo Burro connects coastal communities west of the city to inland areas and could be flooded during a storm event.

4.3.3 Stormwater Infrastructure

Figure 28 presents stormwater infrastructure exposed to hazards in 2100. In 2060, drainage channels are likely to see more tidal flooding and storm flooding. While this may not damage the channels, it could cause more flooding during rain events. Starting in 2060 and worsening in 2100, the City's water control structures are expected to be exposed to more frequent flooding. This includes the Laguna Channel Tide Gate system and the tide gates at Andrée Clark Bird Sanctuary, both of which would be expensive to replace. These are described in more detail in Section 4.4. Water flowing into the stormwater drainage pipes could also cause stormwater backup and local ponding further inland than just tidal and storm inundation. This study did not assess whether future conditions would accelerate corrosion of stormwater infrastructure.

4.3.4 Recreational Areas

Figure 29 presents recreational areas exposed to hazards in 2100. Results indicate that many of the beaches and the parks on the bluffs – iconic features and major tourist attractions in Santa Barbara – would be at least temporarily affected by 2060 and potentially lost by 2100. In many places, beach access along the bluff-backed beach in the west half of the City is provided by stairways down the bluff to the beach, and these would be exposed to erosion by 2060 (e.g., Mesa Lane Stairs and One Thousand Steps). Other recreational opportunities could be disrupted temporarily by flooding at 2060 and then permanently impacted by tidal inundation, such as portions of the California Coastal Trail.

4.3.5 Stearns Wharf

Stearns Wharf lies at the east end of the Santa Barbara Harbor and is elevated above the water on piles. The wharf deck is not expected to be exposed to tidal inundation, even as late as 2100. However, the wharf can be damaged by storm waves under existing conditions. As larger storms become more frequent through 2060 and into 2100, damage is expected to occur more often at the wharf and to be more severe. Stearns Wharf appears in **Figure 30** with other facilities in and around the harbor.

4.3.6 Facilities at the Harbor

Figure 30 presents harbor assets exposed to hazards in 2100. Some of these assets, such as the breakwater, protect inland assets and their damage would have significant secondary effects, such as damage to the marina docks and closure of harbor businesses while the docks were repaired. The breakwater and groins around Santa Barbara Harbor protect the marina and private, commercial, and recreational facilities. Though not immediately obvious on **Figure 30**, the harbor interior shows the water beneath the floating infrastructure. While this means the floating docks may not necessarily be inundated, tidal flooding along the edge of the harbor indicates that access and use would be disrupted at the least. Damage and disruption of service happens occasionally under existing conditions and can be expected to be more frequent in 2060 and commonplace in 2100.

4.3.7 Public and Private Properties

Figure 31 presents public and private properties (assessor parcels) exposed to hazards in 2100. Exposure to permanent hazards grows by 2060 as areas that were previously only exposed to storms are more regularly inundated by tides. This trend continues by 2100 when a large number of properties are expected to be exposed to temporary flooding or permanent inundation. **Table 5** presents a count of vulnerable parcels by parcel type over time, which shows an exponential increase in the number of parcels at risk from sea-level rise over time: the number of parcels impacted by 2060 is 1.7 times greater than existing conditions, and by 2100 is 12.5 times greater than existing conditions.

TABLE 5
PARCEL COUNT BY TYPE INTERSECTING WITH HAZARD ZONES

-	Existing Conditions		2060 Conditions		2100 Conditions	
	Storm	**Tidal**	**Storm**	**Tidal + Erosion**	**Storm**	**Tidal + Erosion**
Vulnerable Parcels (Count)[a]						
Commercial	2	2	2	3	124	46
Hotels, Motels, B&Bs[b]	0	0	4	0	13	26
Industrial	3	0	4	3	151	61
Institutional[c]	6	3	0	10	24	16
Miscellaneous	2	0	4	2	5	18
Residential	22	48	9	115	495	221
Vacant	6	5	1	16	17	24
TOTAL	**41**	**58**	**24**	**149**	**829**	**412**

NOTES:
a Counts do not exclude based on if the parcel is impacted in previous conditions; rather, the parcels impacted by tide and/or erosion under 2060 conditions, for example, includes parcels that might be impacted by tide and/or erosion under existing conditions.
b B&Bs = bed and breakfast establishments
c "Institutional" assets include recreation, education, and government. Recreational here includes: golf courses, auditoriums, stadiums, and other recreational land uses.

4.3.8 Communication Infrastructure

Figure 32 presents communication infrastructure exposed to hazards in 2100. The major fiber optic lines and associated cabinets running along the waterfront could experience temporary inundation in 2060 and could be inundated during tidal conditions in 2100. While these assets are underground and not likely to be destroyed during temporary inundation, permanent flooding will preclude access and maintenance, making them unusable in the long run.

4.3.9 Water Supply and Wastewater Infrastructure

Water supply and wastewater infrastructure exposed to coastal hazards were also considered, but they are not shown on maps included in this study for security reasons. The water and wastewater assets considered include the recycled water distribution system. In general, most water supply assets are not significantly exposed to hazards in 2060, but many are expected to see significant temporary and permanent flooding impacts by 2100. An exception is the recycled water system, which is used for irrigation at many of the coastal parks and public areas and may see permanent erosion and tidal inundation beginning in 2060 and increasing through 2100. While temporary inundation is generally acceptable, erosion hazards may expose and damage pipelines. The loss of water supply pipelines can lead to major inconvenience.

By 2100, two wells (a groundwater well and a production well) in the City are expected to be exposed to storm flooding. By 2100 the Charles E. Meyer Desalination Plant will not be operable as it is currently designed due to tidal inundation. This study does not assess the potential impacts of saltwater intrusion on the water supply, which is a possible impact of sea-level rise on the local coastal aquifers.

Portions of the wastewater piping system (gravity mains, etc.) that are south of Cabrillo Boulevard are expected to be exposed to tidal inundation and erosion by 2060. Further analysis is being conducted to see how extensively seawater entering the piping system would impact operations at the El Estero Wastewater Treatment Plant in 2060. By 2100, tidal inundation would permanently impact several portions of the wastewater piping system, including the sewer trunk main, and El Estero Wastewater Treatment Plant will be permanently inoperable as currently designed due to tidal inundation and storm flooding in the wastewater system, at the plant itself, and to roads accessing the plant. Damage to wastewater pipelines can lead to spills and significant public health concerns.

This analysis does not consider impacts that may occur from increased rates of corrosion of water and wastewater facilities from increased salinities in groundwater.

El Estero Wastewater Treatment Plant and the Charles E. Meyer Desalination Plant are discussed in more detail in Section 4.4.5 and 4.4.6, respectively.

4.4 Other Major Built Public Assets

The analysis in Sections 4.2 and 4.3 identifies assets that may be exposed to coastal flooding from a high level. While this is sufficient for many interchangeable assets in the city (e.g. fiber optic cabinets), Santa Barbara has several important assets that deserve more detail. These assets and their vulnerability to SLR are described below.

4.4.1 Stearns Wharf

Stearns Wharf is located on the Santa Barbara waterfront immediately east of the Santa Barbara harbor. Stearns Wharf is an important asset to the City and community, drawing large numbers of visitors and serving important services to the local tourism industry: approximately 1 million pedestrians and 250,000 cars use Stearns Wharf every year.[18] Although the location of Stearns Wharf is generally sheltered from the large north Pacific swells, it is still exposed to storm waves.

Under existing conditions, Stearns Wharf is vulnerable to extreme storms with high water levels and large waves. Damage to a structure located on Stearns Wharf occurred in March 2014 during storm conditions with a particularly large wave event from the west. This suggests that a moderately extreme event is likely to cause minor damages and disrupt operations of businesses and public use of the Wharf. Under an extreme 100-year coastal event with existing sea levels, damages to the Wharf are expected to be much greater, potentially requiring temporary closure and significant structural repairs.

In the future with sea-level rise, events that trigger minor damage and operational impacts will become more frequent due to the increased proximity of the wave crest to the deck of the Wharf (approximately elevation 19.5 feet NAVD). The wave crest elevation (not including wave runup on a structure) for the 100-year event was estimated using the water level and wave output from CoSMoS in the vicinity of the seaward end of Stearns Wharf: 18.5 feet NAVD, 21 feet NAVD, and 25 feet NAVD at existing, 2060, and 2100, respectively. Therefore, although typical tidal conditions are not likely to pose risk of damage to Stearns Wharf, damaging events will become much more frequent.

4.4.2 Harbor

The Santa Barbara harbor area includes the marina (about 1200 slips), commercial uses, parking, industrial areas, and the City Pier, also known as the “harbor pier,” which supports the Coast Guard, an ice house, a NOAA tide station, and the fuel dock. There is also a commercial area located west of the City Pier that includes restaurants and several marine-related businesses. The commercial area on the west side of the harbor is located at about the same elevation as the north side of the harbor (located farthest from the open ocean). However, much of the south and west sides of the harbor are built up since they are potentially more exposed to waves. This includes the sidewalk located along on the south side of the harbor, which is about two feet higher than the sidewalk on the north side of the harbor (generally along the water’s edge).

[18] Personal communication, August 17, 2018, Karl Treiberg, Waterfront Facility Manager, City of Santa Barbara

Under existing conditions, portions of the harbor are vulnerable to high water levels and to large wave events. Damage to harbor assets, including dislocation of pile caps due to the upward movement of floating docks, has occurred due to high water levels resulting from storm surge or even from astronomically high tides (e.g., perigean spring tides or "King" tide). Large wave events overtop the harbor breakwater forcing closure of the public path on an approximately annual basis. Through current management practice, the harbor accommodates these relatively minor impacts. Under an extreme 100-year coastal event with existing sea levels, damages to the harbor would likely be severe. Several different damaging storm combinations are possible, but the worst may be a storm approaching from the southeast, from which direction the harbor entrance is most exposed to waves. Moderately sized wind waves entering the harbor combined with high water levels have caused damage to the floating infrastructure of the harbor in the past.

In the future, these impacts are expected to occur more frequently with sea-level rise. With one foot of sea-level rise, harbor functions could likely be managed, but more than two feet would likely induce impacts to several major assets that allow the harbor to function. With over 6 feet of sea-level rise by 2100, the harbor would not be usable in its existing configurations without major modifications through adaptation.

The fuel dock at the City Pier is of particular concern due to the potential for spill and fire hazards. The dock is connected to underground supply tanks on the shore by double-walled pipelines running beneath the dock. These lines have shutoff valves, but the valves are located under the dock, at the base of the pier and are only accessible by boat. This means that even small amounts of sea-level rise could make these valves inaccessible during a storm, when water levels could be too high to allow a boat under the pier. Increased sea-level rise would expose the pipelines and valves directly to waves or even periods of inundation, both of which could result in pipe damage and leakage.

4.4.3 Laguna Channel and Tide Gate/Pump System

The Laguna Channel Tide Gate structure plays an important flood management role in the City. Located at the southern terminus of the low-lying Laguna Channel drainage, the tide gates prevent the waters from the Mission Creek Lagoon from extending landward. **Figure 15** presents a photo of the Laguna Channel Tide Gate structure during a period of high lagoon water levels, when the lagoon mouth is closed[19]. The Mission Creek Lagoon is managed such that it forms a joint lagoon with the Laguna Channel discharge. During precipitation events, a significant portion of the City's downtown area drains to the Laguna Channel, which can only drain through the tide gates during periods when the Mission Creek Lagoon is open[20].

[19] Mission Creek Lagoon closes when waves build the beach to an elevation that separates the Laguna Channel from the ocean, allowing water to build up behind the beach. Mission Creek Lagoon opens when water levels are high enough to breach the high beach, generally during a storm when runoff in Laguna Channel rapidly increases the water level in the Mission Creek Lagoon. (ESA, 2013)

[20] If the Mission Creek Lagoon is closed during a large rain event, the closed tide gates cause water to gather upstream of the Laguna Channel Tide Gate structure. When the water ponded upstream of the gates (on the north side) is higher than the Mission Creek Lagoon water level, the tide gates are opened and the ponded water flows into the Mission Creek Lagoon, causing the lagoon to open. (ESA, 2013)

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: ESA

Figure 15
Laguna Channel Tide Gate Looking North (Upstream) During Period of Closed Lagoon with High Water

The Laguna pump station is located immediately north (upstream) of the Laguna Channel Tide Gate structure. When there are low flows in the Laguna Channel, the pump station uses low-flow pumps to move nuisance flows from the Laguna Channel into the Mission Creek Lagoon. When the Laguna Channel fills with stormwater runoff during large rain events, high-flow pumps are activated and pump water from Laguna Channel into the Mission Creek Lagoon. **Figure 16** shows a photo of the Laguna pump station on the right side of the Laguna Channel.

Prior studies indicate that the Laguna Channel flood control system can convey up to approximately the 10-year recurrence flowrate without flooding (ESA, 2013). At higher flowrates, flooding occurs in the low area downstream of Highway 101. Also, the culvert under Highway 101 impedes drainage and increases flooding upstream of Highway 101. With sea-level rise, it is expected that the flood performance for Laguna Channel will decrease because the higher ocean water levels will prevent the gates from discharging water from Laguna Channel more often than under existing conditions (ESA, 2013; 2014). This means that the flood flow capacity will become progressively less than the 10-year event, and flooding will become frequent and more extreme. The seaward location of the tide gates also exposes them to the forces of wave impacts, which will become greater in the future with sea-level rise.

City of Santa Barbara Sea-level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: ESA

Figure 16
Laguna Pump Station and Laguna Channel
Looking North (Upstream)

The hazards in this vulnerability study are based on coastal water levels migrating up Laguna Channel, and do not include rainfall runoff. The hazard zones indicated that this facility will be exposed to tidal inundation or erosion between 2060 and 2100.

4.4.4 Mission Creek

Mission Creek is a major regional drainage that runs through Santa Barbara. The flood conveyance was recently improved by adding a bypass culvert, and the expected conveyance capacity without flooding is approximately the 20-year recurrence flowrate (ESA, 2013). The water level in the creek during low flows is elevated due to backwater from the elevated beach berm. Mission Creek flowrates are high enough to rapidly fill the lagoon and breach the beach berm, and hence the beach berm is not considered a significant flood-control impediment for existing sea levels (ESA, 2014). The hazards in this vulnerability study are based on coastal water levels migrating up Mission Creek, and include representative creek discharge and precipitation during a coastal storm but not severe rainfall runoff events that are likely to impact the creek.

4.4.5 El Estero Wastewater Treatment Plant

The El Estero Wastewater Treatment Plant is an important asset located immediately east of the Laguna Channel. According to this analysis, the plant itself would not be exposed to storm flooding or tidal inundation by 2060. However, portions of the wastewater piping system located south of Cabrillo Boulevard would be impacted by storm flooding and tidal inundation. Potential inundation of the sewer trunk main that runs along the beach south of Cabrillo Boulevard could require extended shutdowns of the plant. Additional analysis is needed to determine if the anticipated level of inundation of the wastewater system piping would significantly impact the operations of the plant by 2060.

By 2100, portions of the plant itself, as well as significant portions of the wastewater piping system south of highway 101 connected to the plant are located in the tidal inundation zone. Regular tidal inundation into manholes, pipelines, the sewer trunk main, and the plant area itself will make the plant and associated affected wastewater systems as they are currently designed permanently inoperable. This is partially due to the level of salinity of the water reaching the plant, the hydraulics associated with the gravity flow wastewater system, and water regularly inundating the plant facilities themselves. Additionally, access to the plant facilities will be limited. Future storm flood depths in the vicinity of the wastewater treatment plant at 2100 are expected to be approximately 1 to 4 feet depending on the ground elevation. CoSMoS output for the extreme storm indicates a future flood elevation of 14.2 feet NAVD at 2100. The facility's outfall is located offshore. An additional, more detailed study would need to consider whether erosion of the coastal profile would expose portions of the outfall pipeline and supports, and how sea level rise may impact sediment deposition and seafloor configurations that could affect the outfall. In addition, saltwater intrusion and salinity- corrosion to underground utilities has not been studied.

The potential exposure of the facility indicates a need for subsequent detailed study of the vulnerability of the wastewater treatment plant and its assets to climate change and sea-level rise.

4.4.6 Charles E. Meyer Desalination Plant

The Charles E. Meyer Desalination Plant is a valuable and important asset north of El Estero Wastewater Treatment Plant along the east side of Laguna Channel, directly south of Highway 101. According to this analysis, the plant site is not likely to be exposed to coastal hazards under existing conditions or by 2060, but is likely to be exposed by 2100. Some of the site is exposed to tidal inundation at 2100 and some is exposed to storm flooding, but operations would likely be impacted, since some facilities or activities would need to be moved away from the permanent loss hazard (tidal inundation). Future storm flood depths in the vicinity of the desalination plant at 2100 are expected to increase be approximately 1 foot or more, depending on the ground elevation. CoSMoS output for the extreme storm indicates a future flood elevation of 14.1 feet NAVD at 2100. The facility's intake and outfall are both located offshore. An additional, more detailed study would need to consider whether erosion of the coastal profile would expose portions of the intake and outfall pipelines and supports, and how sea level rise may impact sediment deposition and seafloor configurations that could affect the intake and outfall.

The potential exposure of the facility indicates a need for subsequent detailed study of the vulnerability of the desalination plant and its assets to climate change and sea-level rise.

4.4.7 Ortega Groundwater Treatment Plant

The Ortega Groundwater Treatment Plant is located north of Highway 101, and was designed to treat high levels of naturally occurring iron and manganese in the groundwater pumped from nearby wells. The treated groundwater is used to augment the City's drinking water supply. The treatment plant is located just outside the projected future flood hazard zone at 2100. CoSMoS output for the extreme storm indicates a future flood elevation of 17.4 feet NAVD at 2100 near the plant. While the plant itself may not be impacted, portions of the groundwater system, including two groundwater wells, that feed water into the plant may be affected by storm flooding and additional study in the future is needed to assess how this might impact the operations of the plant. A subsequent study is also needed to investigate the potential for sea-level rise-driven saltwater intrusion of the coastal aquifer that could affect the salinity levels of groundwater.

4.4.8 Public Works Replacement Costs in Place as Currently Designed

Table 6 presents approximate replacement costs for various public works assets in the City. These costs assume replacement-in-place (no relocation) and as currently designed and represent a rough order of magnitude cost in 2018 dollars for planning purposes only. The values were developed with input from the City of Santa Barbara Public Works Department. It should be noted that actual replacement costs for these facilities in the future would likely be much higher due to inflation and the high likelihood that either the facility would need to be relocated, redesigned, or the site altered as part of replacement. The wastewater lift station near Arroyo Burro is known as the Braemar Lift Station. The Laguna Pump Station is for stormwater. Costs of these assets and the others are in the table below.

Cost of complete replacement of the Santa Barbara Harbor was estimated to be on the order of $50-60 million dollars, based on review of damages documented at Crescent City and Santa Cruz harbors during earthquakes in 2006 and 2011[21]. However, it is possible that only portions of the Harbor could be affected.

[21] Damages at Crescent City and Santa Cruz were converted to 2018 dollars and scaled based on the larger size of Santa Barbara Harbor.

TABLE 6
APPROXIMATE 2018 REPLACEMENT COSTS FOR PUBLIC WORKS ASSETS IN PLACE AS CURRENTLY DESIGNED

Asset	2018 Replacement Cost in Place as Currently Designed
Water Main	$250/LF
Communications	$100/LF
Wastewater - Gravity	$200/LF
Wastewater – Force Main	$300/LF
City Street Reconstruct	$365/LF
Braemar Lift Station	$3-5M
Laguna Tide Gates	$3M
Laguna Stormwater Pump Station	$10M
Harbor	$50-60M
Stearns Wharf	$59M[a]
El Estero Wastewater Treatment Plant	$200-250M[a]
Charles E. Meyer Desalination Plant	$72M

NOTES:
[a] Costs estimated using assessed values per 2015 Property Schedule provided by the City

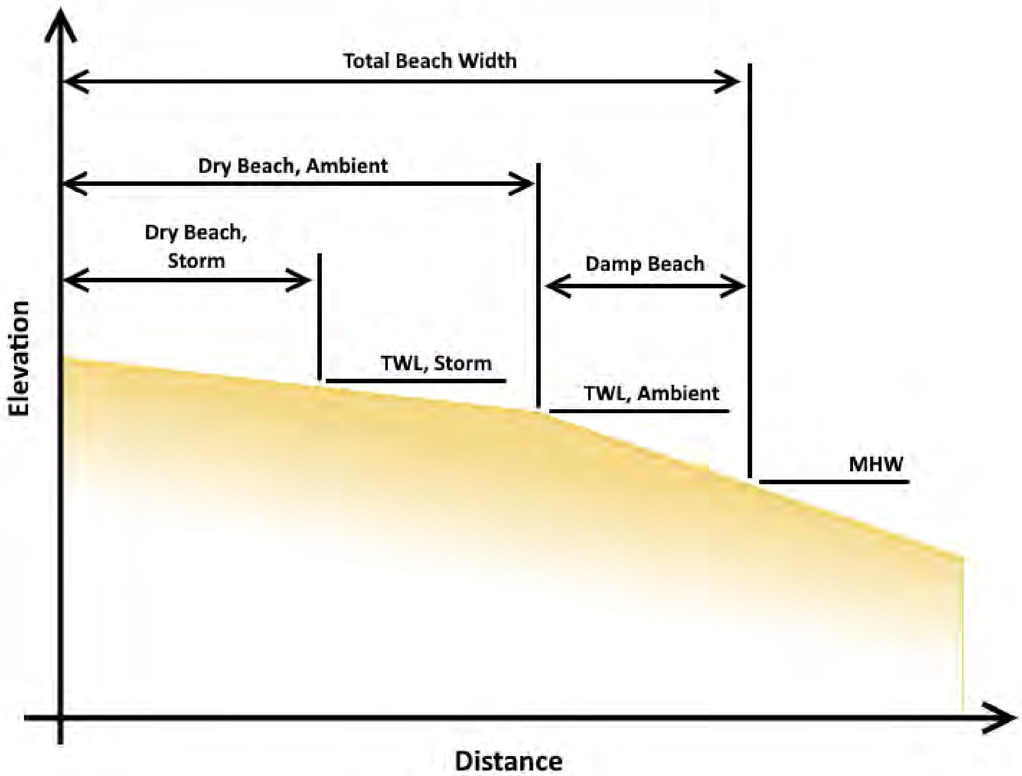
4.5 Beach Widths

Beach access is one of the defining characteristics of the City, both culturally and economically. Without action, sea-level rise is expected to drive beaches to shrink, squeezing them against existing bluffs or infrastructure on the backshore. Since beaches are a major recreational asset for the City, they were analyzed in additional detail. The beach width analysis employed a 2-line shoreline evolution model developed by ESA that tracks the shoreline and backshore erosion and thus beach width through time. Details on the shoreline evolution modeling are discussed in Appendix G. The beach widths from the shoreline evolution model were divided into zones based on the mean high water elevation[22], ambient or daily typical wave runup elevation[23], and the annual storm wave runup elevation[24]. **Figure 17** presents a schematic of the beach width zones.

[22] Mean high water is the high point on the beach that is completely underwater at each high tide during a normal day. (MHW in Figure 17)

[23] Ambient wave runup elevation is the point on the beach reached by waves on a normal day. The water level including waves is called the “Total Water Level.” (TWL, Ambient in Figure 17)

[24] Storm wave runup elevation is the point on the beach reached by waves under storm conditions. The water level including waves is called the “Total Water Level.” (TWL, Storm in Figure 17)



City of Santa Barbara Sea-level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: ESA

Figure 17
Definition of Beach Zones used in the Ecological and Economical Vulnerability Analysis

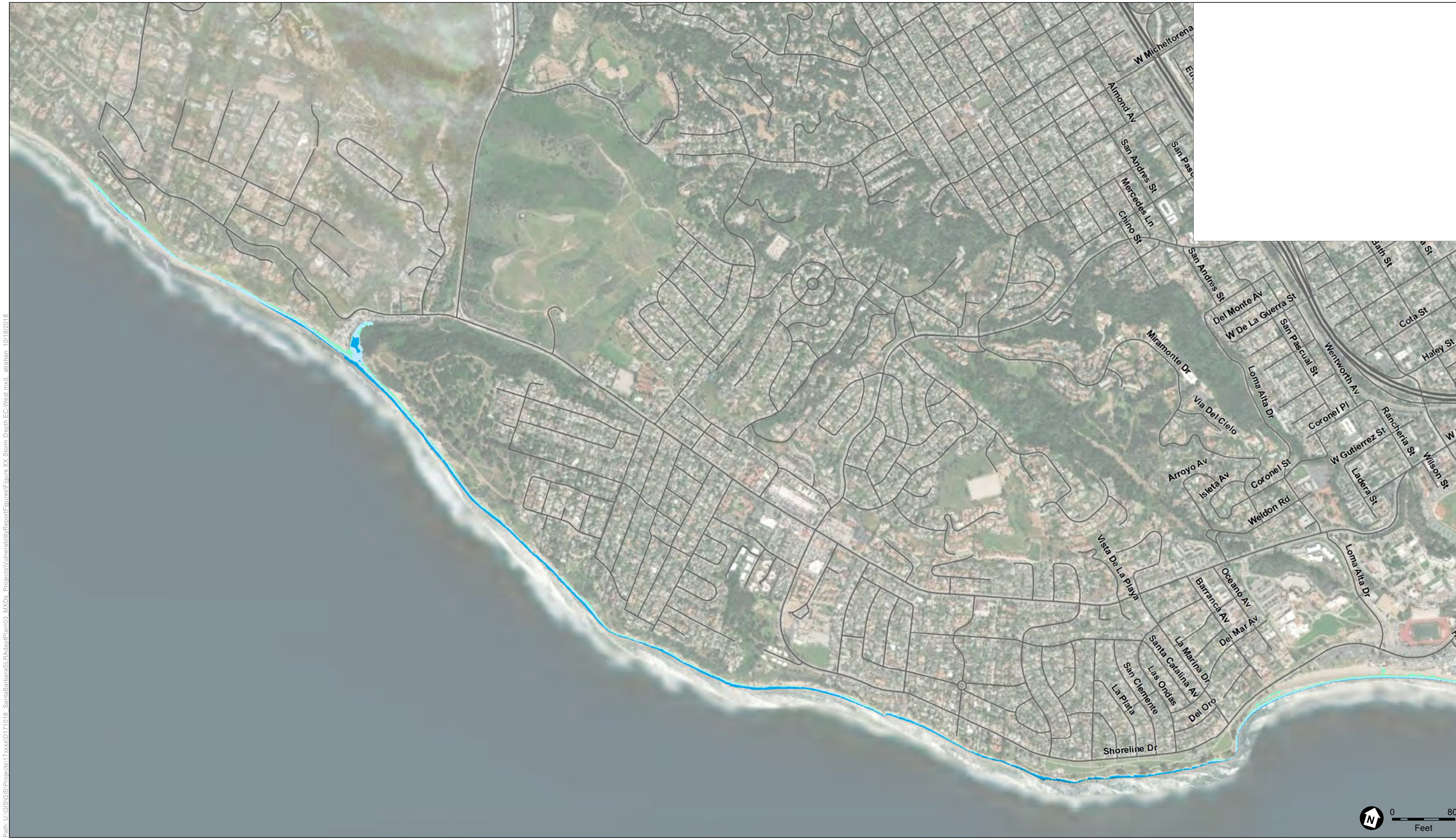
The existing beach widths were determined manually in GIS by measuring the representative distance between the mean high water (MHW) shoreline (extracted from the CoSMoS DEM) and the backshore location (either development line or the toe of dune/bluff). The Santa Barbara Area Coastal Ecosystem Vulnerability Assessment (CEVA) (Myers et al. 2017) provides a description of the sandy beach ecosystems in Santa Barbara County and divides beach width into the areas that are generally damp (“damp beach”), those that are dry during normal conditions (“dry beach, ambient”), and those that are dry even during storm conditions (“dry beach, storm”).

The beach width projections from Arroyo Burro (bluffs) and East Beach (sandy beach) were used to estimate the percent of the total existing beach width made up by the dry beach and the damp beach for each type of shoreline. The dry and damp widths at each of the other beaches in the City were determined based on the type of beach; bluffs were assumed to be similar to Arroyo Burro and sandy beaches were assumed to be similar to East Beach. As the shoreline evolution model proceeds and beaches narrow, the portion of dry beach (storm and ambient) are lost first, then the damp beach narrows when the dry beach is completely eroded. The results for dry beach (ambient daily), dry beach (annual storm), damp, and total beach width in each subarea are presented in **Table 7**. Total beach width is equal to the dry ambient plus damp beach widths.

TABLE 7
BEACH WIDTHS WITH SEA-LEVEL RISE IN THE CITY OF SANTA BARBARA

Subarea	Description	Length of Shore (ft)	Beach Width (ft) Existing Conditions	2060	2100
A	**Arroyo Burro (Bluffs) Total**	**3781**	**94**	**33**	**0**
	Damp Beach		*60*	*33*	*0*
	Dry Beach, Ambient		*34*	*0*	*0*
	Dry Beach, Storm		*8*	*0*	*0*
B	**Douglas Family Preserve (Bluffs) Total**	**3427**	**65**	**7**	**0**
	Damp Beach		*41*	*7*	*0*
	Dry Beach, Ambient		*24*	*0*	*0*
	Dry Beach, Storm		*6*	*0*	*0*
C	**Residential (Bluffs) Total**	**3537**	**50**	**10**	**0**
	Damp Beach		*32*	*10*	*0*
	Dry Beach, Ambient		*18*	*0*	*0*
	Dry Beach, Storm		*4*	*0*	*0*
D	**Lighthouse & Open Space (Bluffs) Total**	**1116**	**40**	**18**	**22**
	Damp Beach		*25*	*18*	*22*
	Dry Beach, Ambient		*15*	*0*	*0*
	Dry Beach, Storm		*4*	*0*	*4*
E	**Residential (Bluffs) Total**	**2442**	**35**	**0**	**0**
	Damp Beach		*22*	*0*	*0*
	Dry Beach, Ambient		*13*	*0*	*0*
	Dry Beach, Storm		*3*	*0*	*0*
F	**Shoreline Park (Bluffs) Total**	**3415**	**30**	**0**	**0**
	Damp Beach		*19*	*0*	*0*
	Dry Beach, Ambient		*11*	*0*	*0*
	Dry Beach, Storm		*3*	*0*	*0*
G	**Leadbetter Beach (Sandy) Total**	**2734**	**120**	**95**	**69**
	Damp Beach		*76*	*76*	*69*
	Dry Beach, Ambient		*44*	*19*	*0*
	Dry Beach, Storm		*11*	*0*	*0*
H	**West Beach (Sandy) Total**	**2646**	**430**	**396**	**344**
	Damp Beach		*273*	*273*	*273*
	Dry Beach, Ambient		*157*	*157*	*105*
	Dry Beach, Storm		*38*	*4*	*0*
I	**Chase Palm Park (Sandy) Total**	**4001**	**170**	**44**	**0**
	Damp Beach		*108*	*44*	*0*
	Dry Beach, Ambient		*62*	*0*	*0*
	Dry Beach, Storm		*15*	*0*	*0*

Subarea	Description	Length of Shore (ft)	Beach Width (ft) Existing Conditions	2060	2100
J	**East Beach (Sandy) Total**	**2847**	**280**	**183**	**32**
	Damp Beach		*178*	*178*	*32*
	Dry Beach, Ambient		*102*	*5*	*0*
	Dry Beach, Storm		*25*	*0*	*0*
K	**Residential (Bluffs) Total**	**1075**	**95**	**32**	**0**
	Damp Beach		*60*	*32*	*0*
	Dry Beach, Ambient		*35*	*0*	*0*
	Dry Beach, Storm		*8*	*0*	*0*



SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 18
Existing Conditions Storm Inundation Depth (West)

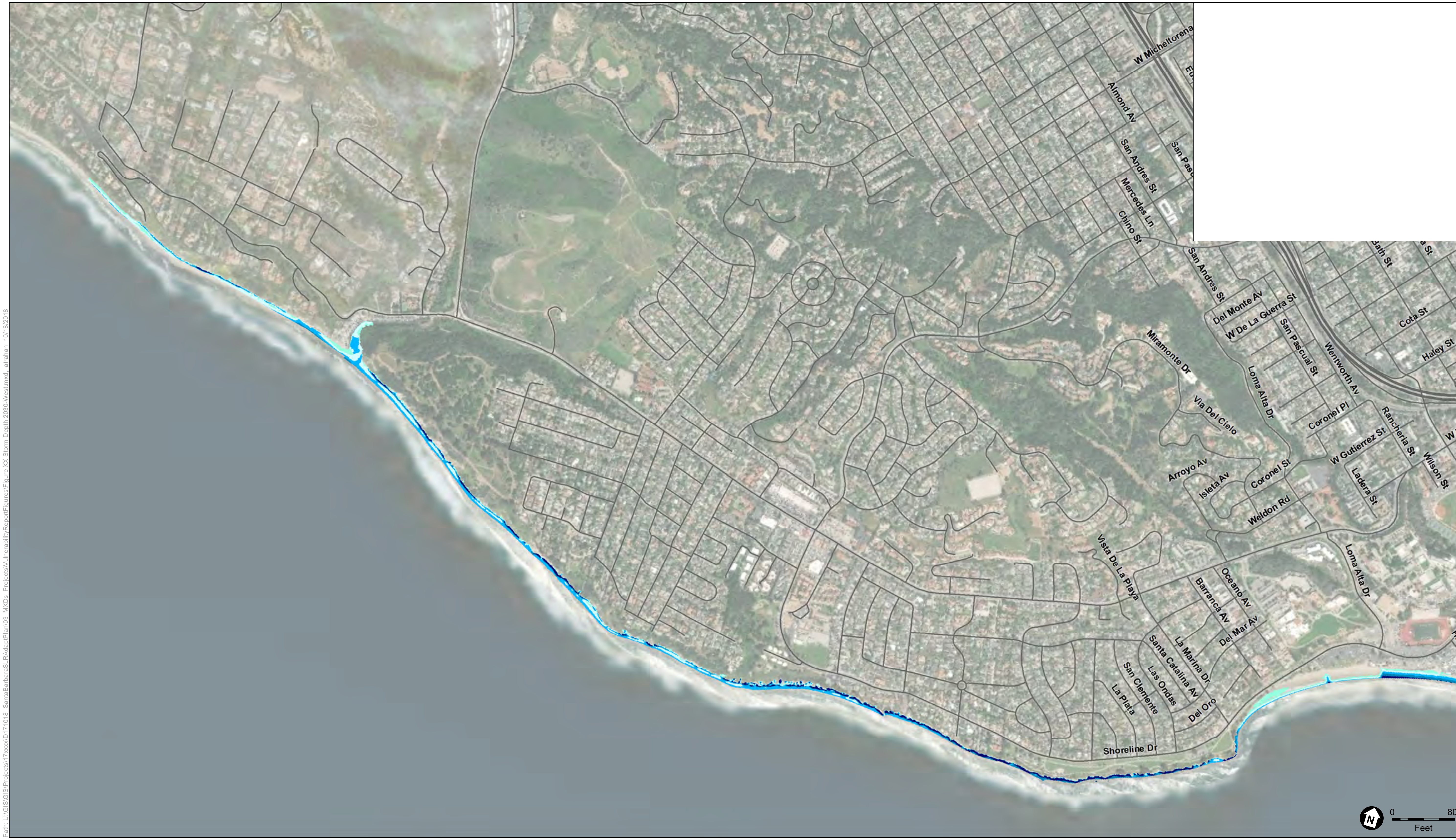
ESA

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 19
Existing Conditions Storm Inundation Depth (East)

ESA



SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 20
2030 Storm Inundation Depth (West)

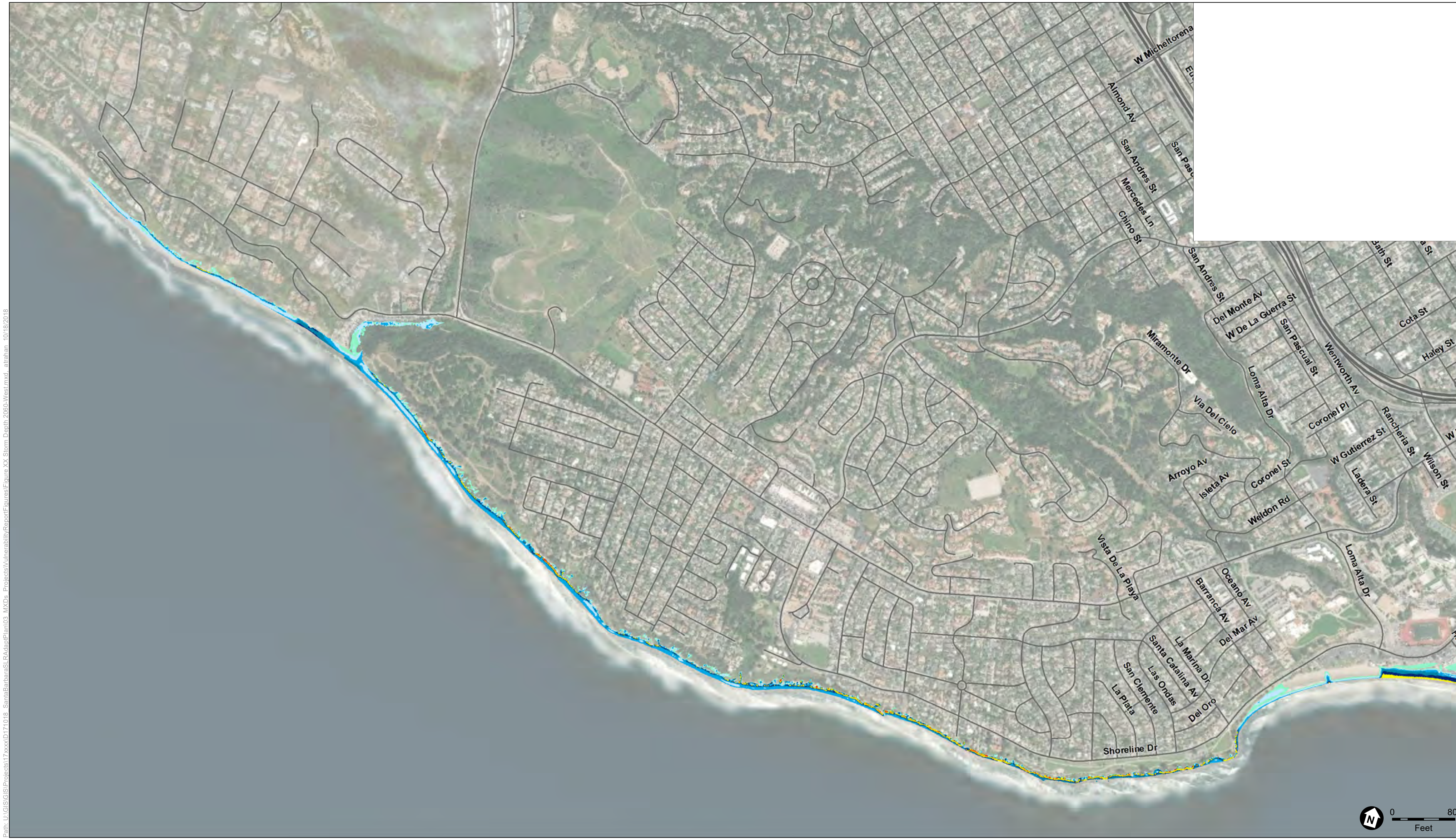
ESA

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 20
2030 Storm Inundation Depth (East)

ESA



SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 22
2060 Storm Inundation Depth (West)

ESA

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 23
2060 Storm Inundation Depth (East)

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

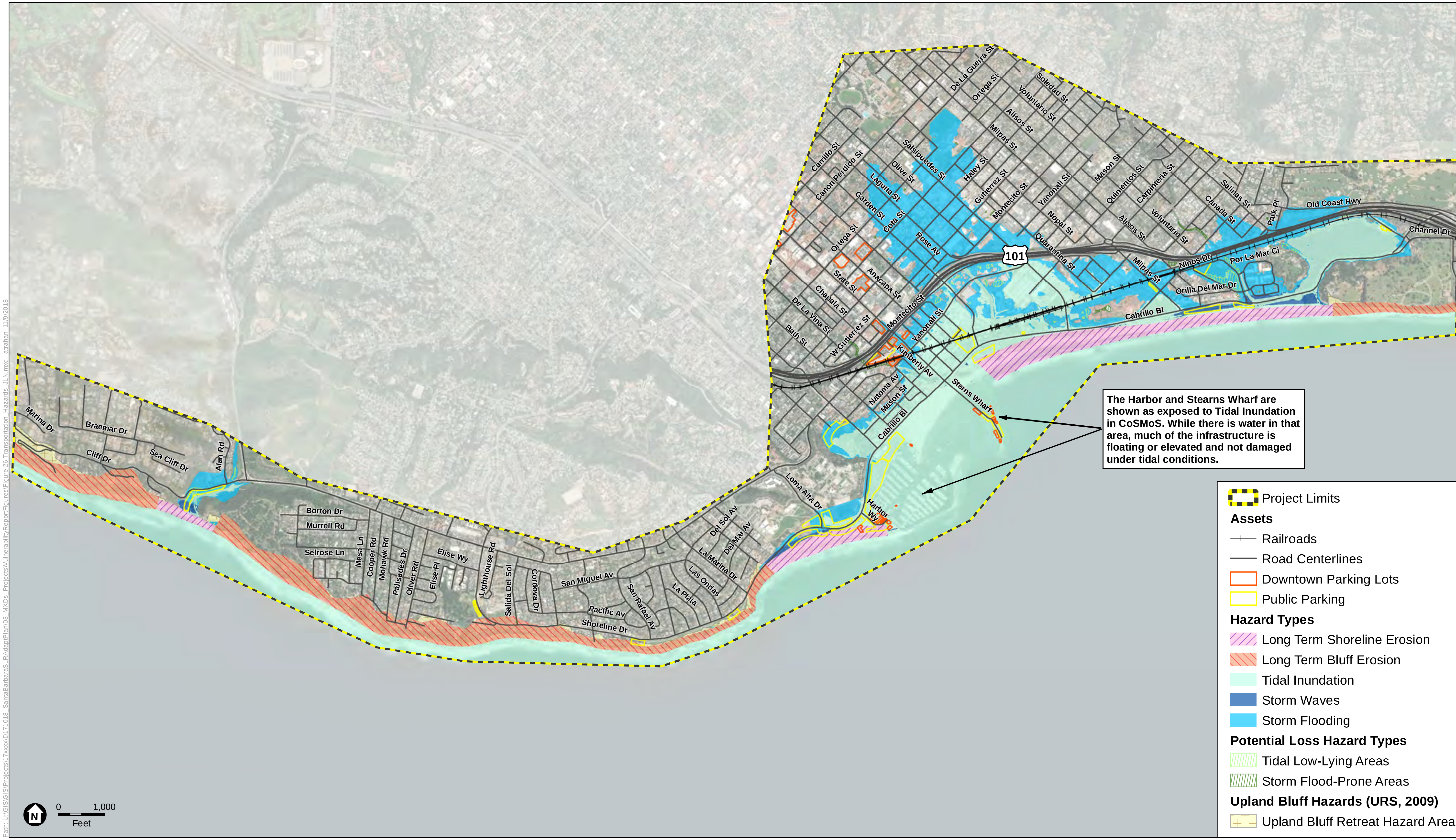
Figure 24
2100 Storm Inundation Depth (West)

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 25
2100 Storm Inundation Depth (East)

ESA

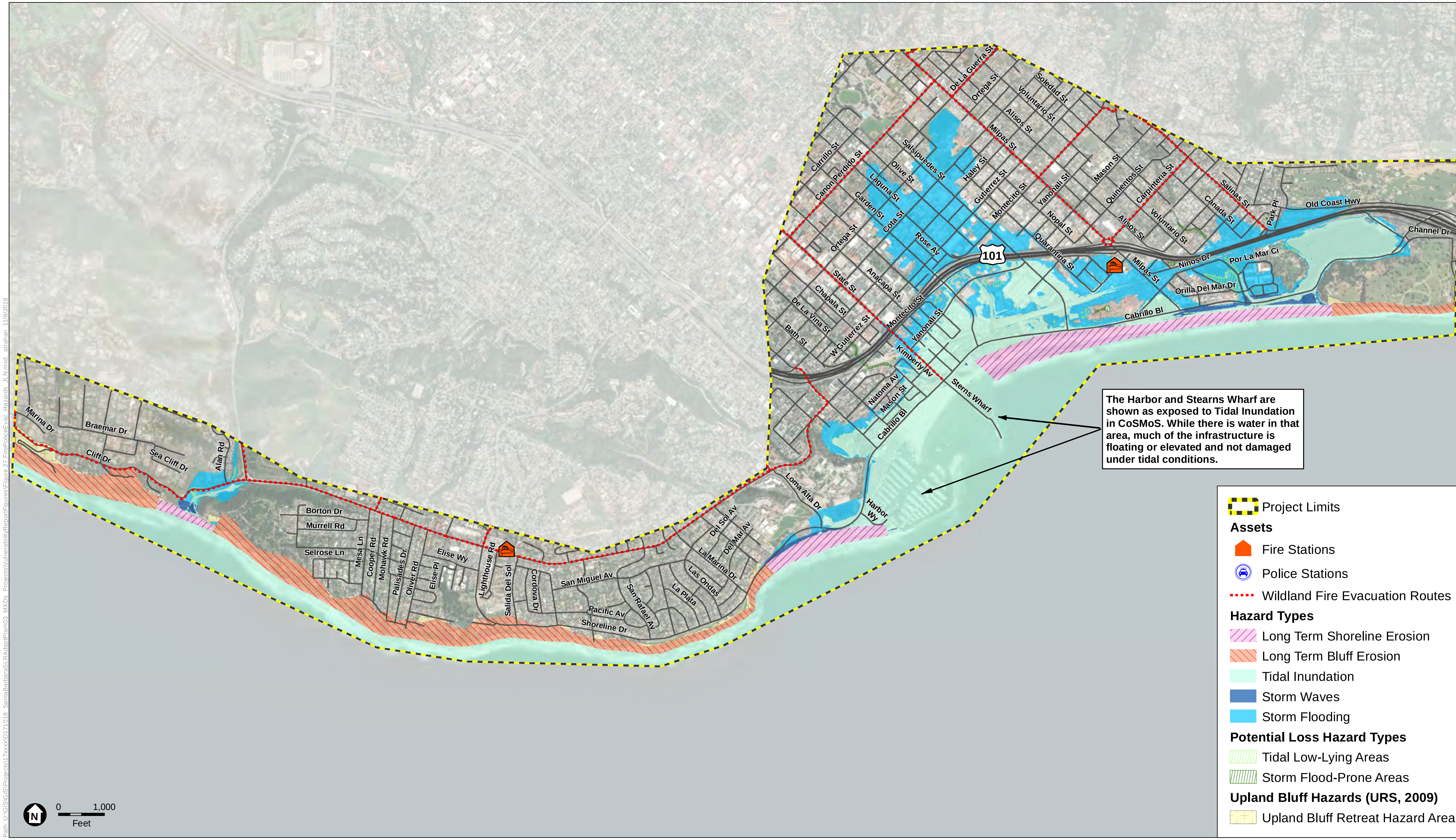


SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbra, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 26
Asset Hazard Map:
Transportation Hazards with 6.6 ft SLR

ESA

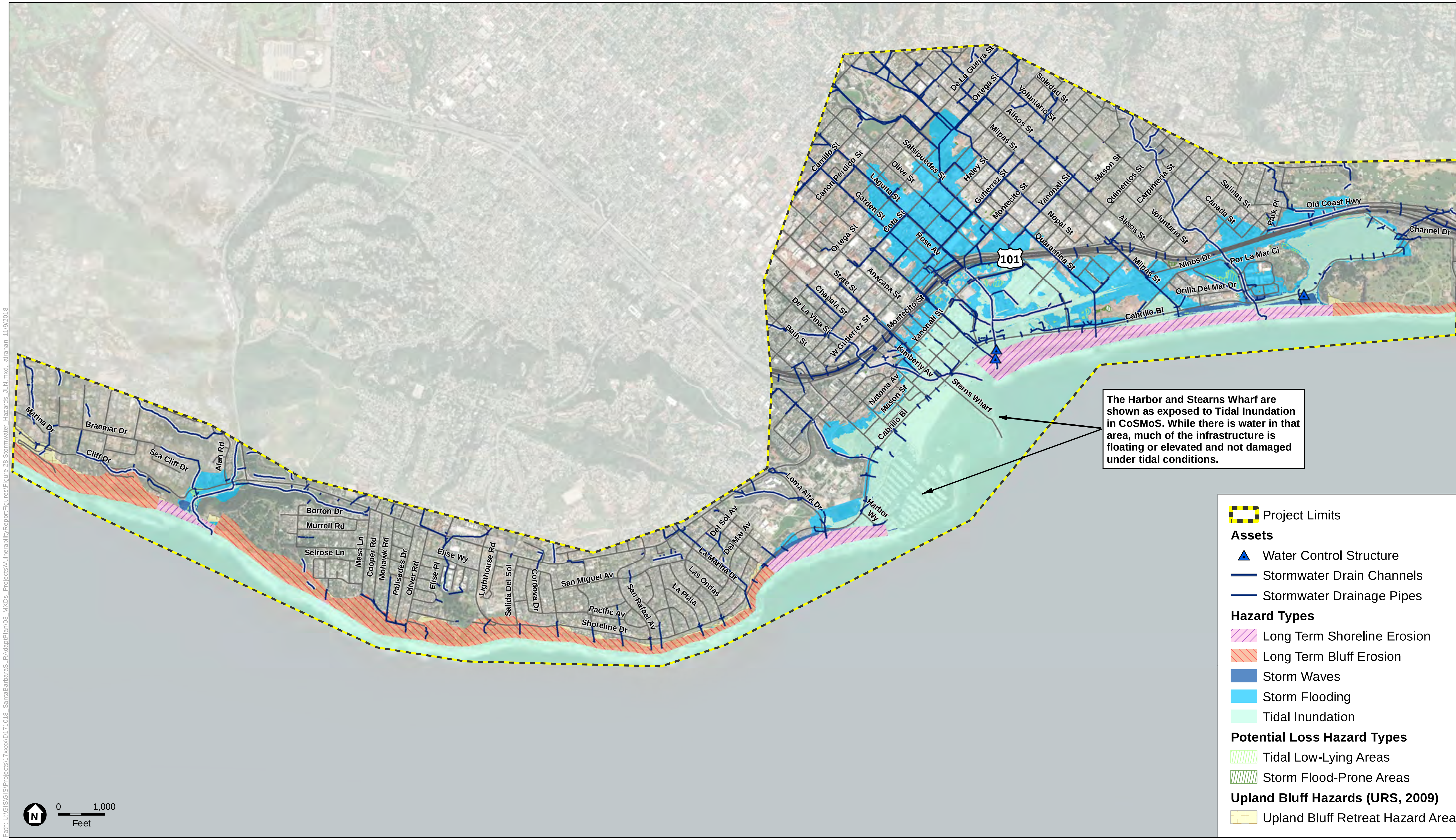


SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

ESA

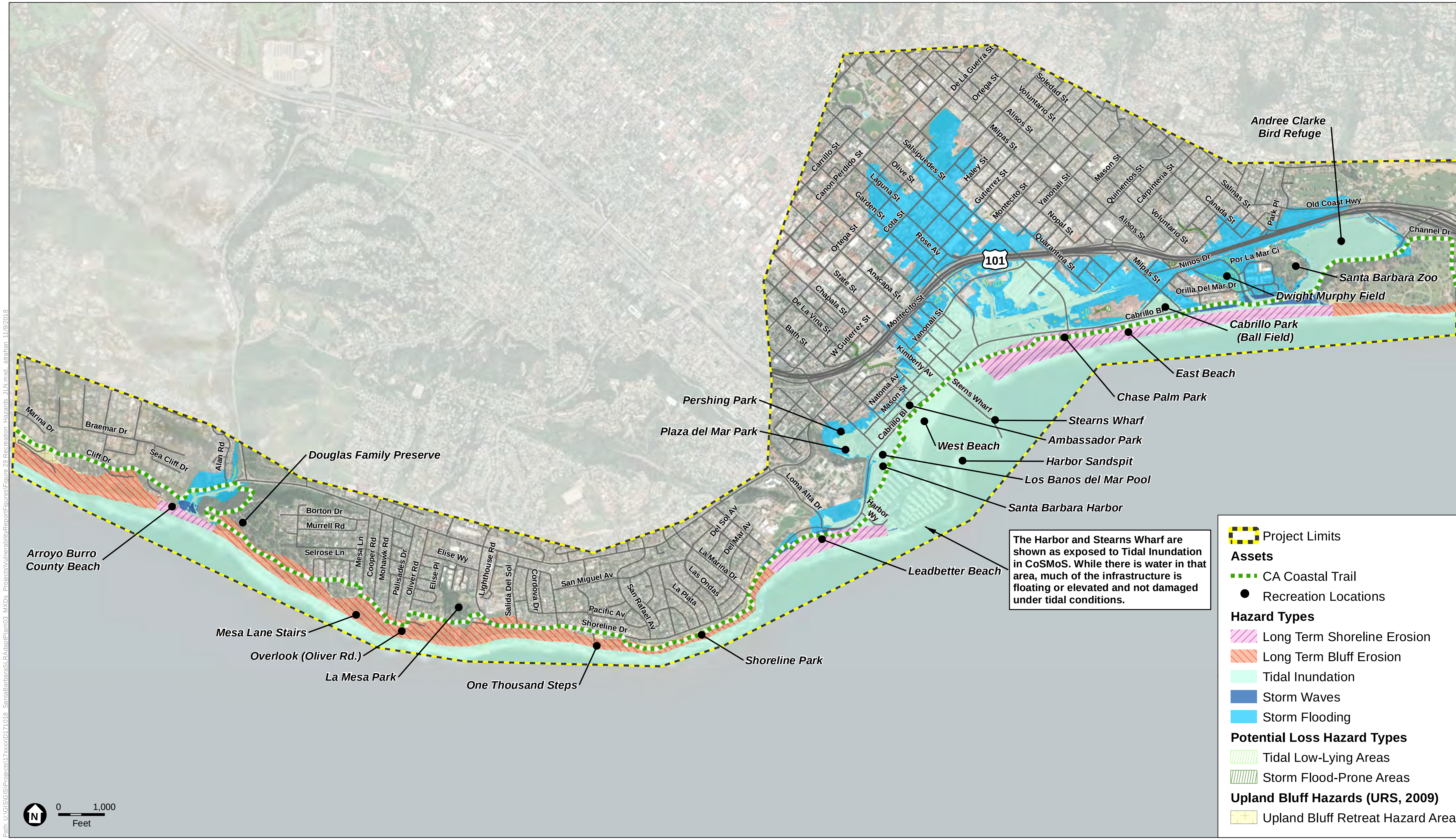
Figure 27
Asset Hazard Map:
Fire Stations, Police Stations, and Evacuation Routes
Hazards with 6.6 ft SLR



SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018.

Figure 28
Asset Hazard Map:
Stormwater Hazards with 6.6 ft SLR

ESA



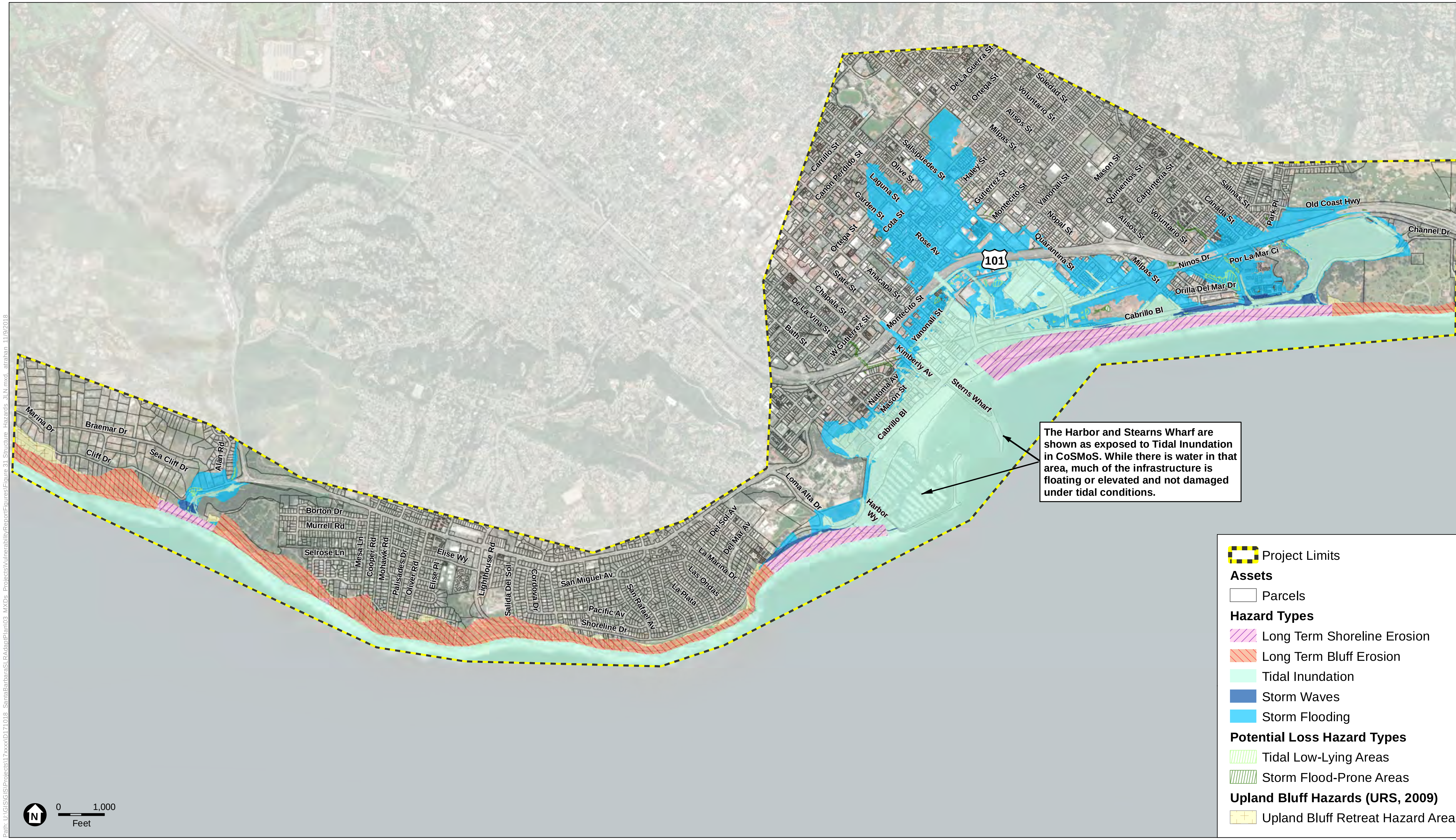
SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbra, 2018.

Figure 29
Asset Hazard Map:
Recreation Areas Hazards with 6.6 ft SLR

ESA

SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbra, 2018.

Figure 30
Asset Hazard Map:
Harbor Assets Hazards with 6.6 ft SLR

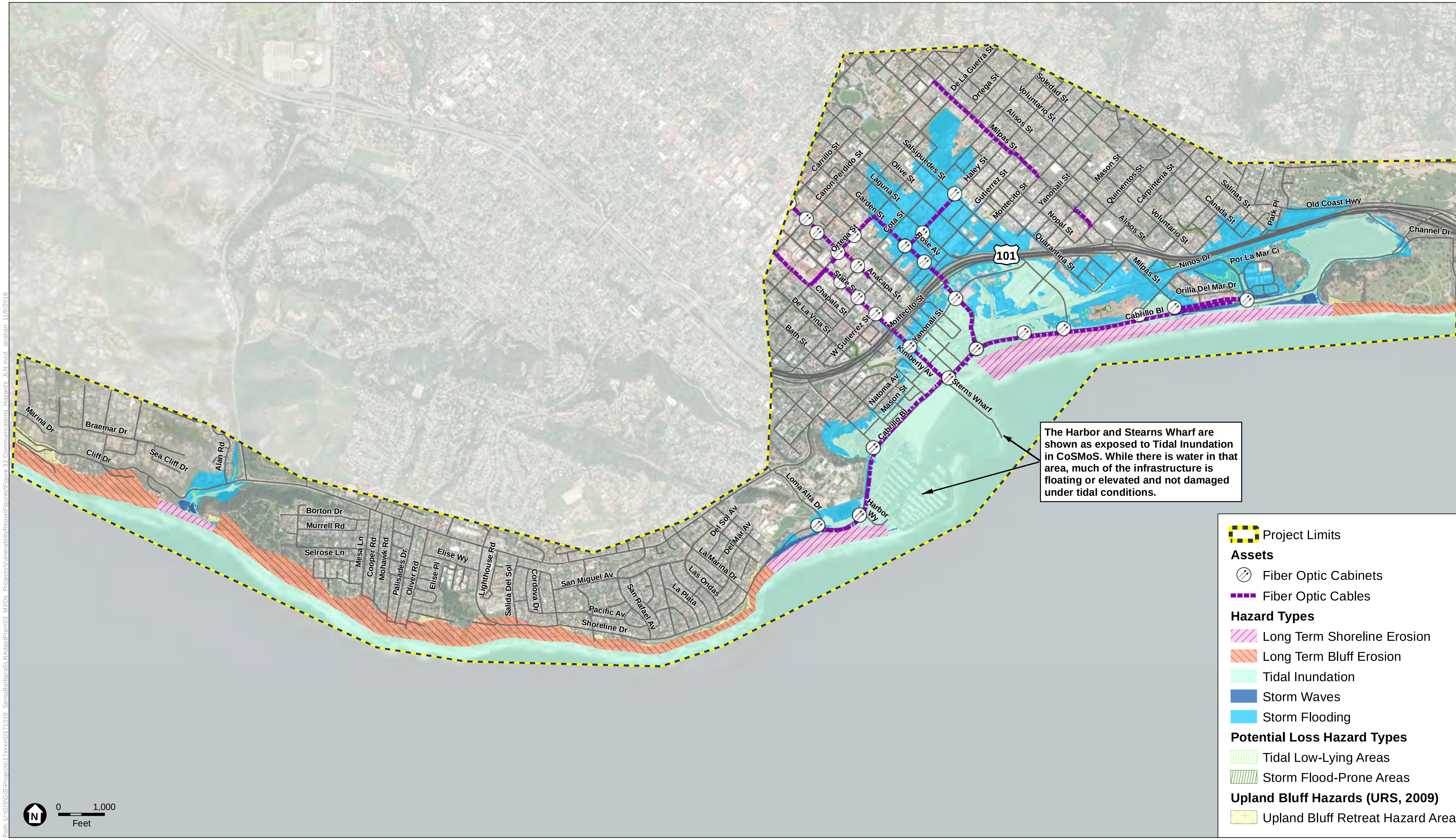


SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbra, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 31
Asset Hazard Map:
Public and Private Properties
Hazards with 6.6 ft SLR

ESA



SOURCE: ESRI, 2018, ESA, 2018, City of Santa Barbara, 2018.

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update

Figure 32
Asset Hazard Map: Communications
Hazards with 6.6 ft SLR

ESA

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5 Ecological Vulnerability of Shoreline Habitats to Sea-level Rise

Dave Hubbard of Coastal Restoration Consultants prepared the following section, which summarizes the ecological vulnerability of natural habitats to sea-level rise within the study area in the City of Santa Barbara.

5.1 Background

The ecological vulnerability of the study area was assessed by analyzing sea-level rise impacts to shoreline features and bluff erosion impacts to other habitats. The vulnerability of habitats to these mechanisms is linked as increasing sea levels will intensify bluff and shoreline erosion rates. The largest losses are projected to occur along the immediate coast with sea-level rise.

Beaches are dynamic edge habitats that lie on the interface between land and ocean. They are on the front line of climate change because they are sensitive to changes in sea level. In many places, beaches will be caught in a coastal squeeze as rising water on the ocean side pushes them toward fixed property lines, bluffs, and seawalls on the inland side.

Beaches provide a broad range of ecosystem services including water filtration and nutrient processing, habitat for diverse and abundant invertebrate species, food and habitat for shorebirds and other bird species, feeding resources for fish including species important for sport fishers, habitat for egg laying by grunion (**Figure 33**), and roosting areas for seabirds (Dugan and Hubbard 2016). The ecological resources of sandy shorelines depend on the ability of plants and animals to move with changing conditions as sand erodes and accretes[25] (Dugan et al 2013). The ecological zones of sandy shores can be broken roughly into zones by moisture content and effective tide level (although these change on daily and longer time scales):

1. Dune- above the reach of extreme tides, supports vegetation and wind-driven sand transport processes
2. Dry sand zone, between elevations of total water levels experienced spring tides and extreme water levels, can support coastal strand vegetation, also good for towel space and recreation
3. Damp sand zone, high intertidal high value for beach invertebrates
4. Saturated sand, low intertidal, high value for beach invertebrates, shorebird and fish foraging.

Beaches that have a full suite of zones will provide more ecosystem services than those that have fewer. The simplest way to assess the status and trends of ecosystem values of beaches is to understand the extent of the resource. This requires a description of the distribution of beach widths or acreage along the shore and an understanding that the shore is constantly changing. A greater understanding can be developed with a description of the distribution of functional zones along the coast. The locations and extents of the zones are determined by the interaction of waves and tides with sand on the shoreline. Generally, this requires more sophisticated modeling to

[25] Accretion is the opposite process of erosion, through which sand is naturally added to a beach rather than being removed.

generate a three dimensional representation of the habitat and an overlay describing typical wave and tide runup patterns.

City of Santa Barbara Sea-level Rise Adaptation Plan for the LCP Update / D171018.00

Figure 33
Grunion nests near the high tide line in the morning after a spawning event at Arroyo Burro Beach, Santa Barbara, July 1, 2017. These fish lay their eggs in wet sand at night during extreme tides during spring and summer full and new moons.

5.2 Analysis

The analysis of beach ecosystem vulnerability presented here is based on the status and predicted trends in the area of the shoreline including damp, dry and high beach habitat in several shoreline segments for current conditions and two sea-level rise scenarios: 2.5 feet by 2060 and 6.6 feet by 2100 (see **Table 7**). We have summarized the results by shoreline type (bluff-backed beaches primarily in the western part of the study area and beaches backed by low lying topography in the eastern area). Bluff-backed beaches in the study area are narrow with an average total width of 63 feet (range from 30 to 95 feet) with little upper shore (see **Table 7**). The other segments in the eastern area, including Leadbetter Beach, West Beach, Chase Palm Park, and East Beach, have broader beaches with an average width of 250 feet (range 120 to 430 feet), and have more extensive dry sand zones backed by low topography. Average beach widths for current and future conditions (with 2.5 and 6.6 feet of sea-level rise) in the City of Santa Barbara were estimated for upper total width, damp beach, dry beach (ambient), and dry beach during storm conditions. Habitat data for Arroyo Burro and East Beach are from the Santa Barbara Area Coastal Ecosystem Vulnerability Analysis (Myers et al. 2017, Barnard et al. 2017, Dugan et al. 2017).

5.3 Beach Habitats and Sea-level Rise

In current conditions, the broad beach segments in the eastern area account for 39% of the shoreline length and 87% of the area in this analysis. There are 62 acres, and 2.3 miles in the eastern segments out of a total of 94 acres, and six miles of beach in the study area.

5.3.1 Upper Beach

The eastern segments contain 66% of the upper beach habitat in the study area. This upper shore is important for ecosystem services because it generally supports about 40% of the biodiversity on southern California's sandy beaches. The highest levels, above the reach of typical storms, and shown in **Table 7** as widths above "Dry beach, storm" can support coastal strand vegetation and dunes. High beach habitat supports plants, rare species, grunion nesting during extreme tides (see **Figure 33**), and all species during storm conditions (as a refuge). Upper beach habitat width and acreage is also a good indicator of towel space (dry sand), lateral access along the beach during any tide, and easy and predictably accessible areas for general recreational use.

5.3.2 Damp Beach

The non-bluff-backed segments currently have about 66% of the damp beach habitat in the study area. The damp shore currently accounts for 63% of the total beach area. The lower zone of the beach supports very large numbers and a high diversity of invertebrates. These are important food sources for both shorebirds and near shore fish. Some beaches in the region still support harvestable populations of Pismo clams in this zone.

5.3.3 Sea-level Rise Projections

In the analysis, beaches in the study area are projected to shrink substantially under all combinations of sea-level rise scenario, habitat zone and shoreline segment. We calculated the changes in area for damp, dry beach and high dry beach (above typical storm levels) habitats compared to current conditions using two sea-level rise projections for 2.5 feet and 6.6 feet for the shoreline segments in the study area (**Table 7**) and summarized them by shoreline type.

5.3.4 Conditions at 2060: 2.5 feet of Sea-level Rise

A rise of 2.5 feet in sea level is projected to eliminate 42 acres of beach for the study area (44% of the current beach area). The projections suggest that the losses would be proportionately greater for the upper shore (59%) than the lower shore (41%), and more rapid along bluff-backed beaches (76%) than beaches backed by low topography (25%). Losses are projected to be greatest for the highest zone, the dry beach during storm conditions. Projected average upper beach widths for the western segments in this scenario are zero, indicating loss of the upper beach. These zone widths will not support upper beach ecological communities and functions and would be vulnerable to storm events and larger disturbances.

The impacts of a 44% loss in beach area would be substantial, but the system will probably lose more than that amount of ecological capacity. As the narrow, bluff-backed beaches erode toward widths of averages of 0 to 35 feet from current conditions with averages of 30 to 95 feet, they will be less able to recover from disturbances and deliver ecosystem services.

5.3.5 Conditions at 2100: 6.6 feet of Sea-level Rise

A rise of 6.6 feet in sea level is projected to reduce the beach habitat zones under consideration in this study by 70%. The projections indicate that about 66 acres of beach will be lost by 2100 in the study area. Bluff-backed beaches are likely to convert to other habitat types (bedrock, cobble or inundated) for substantial periods as they transition toward this loss because conversion will typically be driven by episodic events that punctuate climate change trends. The beaches backed by low topography are projected to lose 56% of their area. Beach ecosystem services will be greatly reduced in this scenario, as would beach recreation.

5.4 Other Habitats and Bluff Erosion

The analysis of the vulnerability of habitats further inland to climate change used existing habitat mapping **(**Figure 34) along with bluff erosion modeling (this report) to estimate changes in the extent of major habitat types in the study area (**Table 8**). As the bluffs erode inland, current bluffs will be destroyed and new bluff faces will be created from current bluff top habitats. The sandy shorelines assessed in this study either did not fully erode by 2100 or are backed by managed park area, thus having little effect on upland habitats, so this analysis focused on bluff areas.

Three habitat types (Coastal Sage Scrub, Eucalyptus Grove and Annual Non-native Grassland) are projected to lose at least one acre of area each for a total of 36.5 acres by 2060, and 42.8 acres by 2100. These losses range from 2 to 7% of the current acreage. Three other habitat types are projected to lose smaller areas: Ruderal (1 acre by 2100, 0.9%), Riparian and Wetland (0.9 acre by 2100, 0.3%), and Coast Live Oak Woodland, Savanna, or Forest (0.1 acre by 2100, 0.0%).

Two other cover classes (Urban, and Ornamental Trees- Landscape) are projected to lose substantial area to bluff erosion, but are not analyzed as habitat.

TABLE 8
PROJECTED AREAS AND PERCENTAGE OF COASTAL AND UPLAND HABITATS LOST TO BLUFF EROSION

Habitat Type	Full City (Acres)	Area Lost to Bluff Erosion (Acres)		Percent of Habitat Lost to Bluff Erosion	
		2060	2100	2060	2100
Annual Non-native Grassland	202.9	3.8	4.8	1.9%	2.4%
Chaparral	97.0	0.0	0.0	0.0%	0.0%
Chaparral/Coastal Sage Scrub	77.9	0.0	0.0	0.0%	0.0%
Chaparral/Oak Woodland	130.4	0.0	0.0	0.0%	0.0%
Coast Live Oak Woodland, Savanna, or Forest	820.5	0.0	0.1	0.0%	0.0%
Coastal Sage Scrub	468.9	27.9	32.6	6.0%	6.9%
Coastal Sage Scrub/ Grassland	16.8	0.0	0.0	0.0%	0.0%
Coastal Sage Scrub/Oak Woodland	20.4	0.0	0.0	0.0%	0.0%
Eucalyptus Grove	112.0	4.8	5.4	4.3%	4.8%
Native Perennial Grassland	5.5	0.0	0.0	0.0%	0.0%
Open Water	27.5	0.0	0.0	0.0%	0.0%
Orchard	227.7	0.0	0.0	0.0%	0.0%
Ornamental Trees - Landscape	2,423.9	7.4	16.3	0.3%	0.7%
Riparian and Wetland	283.8	0.7	0.9	0.2%	0.3%
Ruderal	119.5	0.5	1.0	0.4%	0.9%
Undetermined Grassland	12.3	0.0	0.0	0.0%	0.0%
Urban	2,419.5	36.0	51.9	1.5%	2.1%

5.5 Summary

This analysis predicts significant losses in several habitat types in the study area. Coastal Sage Scrub habitat is projected to have the greatest loss of native habitats due to bluff erosion. The largest habitat losses in terms of acreage and proportion of current resources will be for beaches. The highest sensitivity for losses is for bluff-backed shores and upper beach habitats. The results of this analysis are consistent with other recent studies of sandy beaches in the study area: (two sections from Myers *et al*. 2017- Barnard *et al*., 2017 and Dugan *et al*. 2017). This is not surprising because the analytical methods were quite similar. In addition, Vitousek *et al*. 2017 used the same model to analyze future trends for beaches throughout southern California. Their results predict major losses in beach widths, but also the total losses of beaches across a considerable proportion of the coast. Projections of major losses of beach habitat in southern California with sea-level rise in each of these studies indicate that the areal extent of sandy beach ecosystems and the ecosystem services they provide will decline precipitously in the coming decades.

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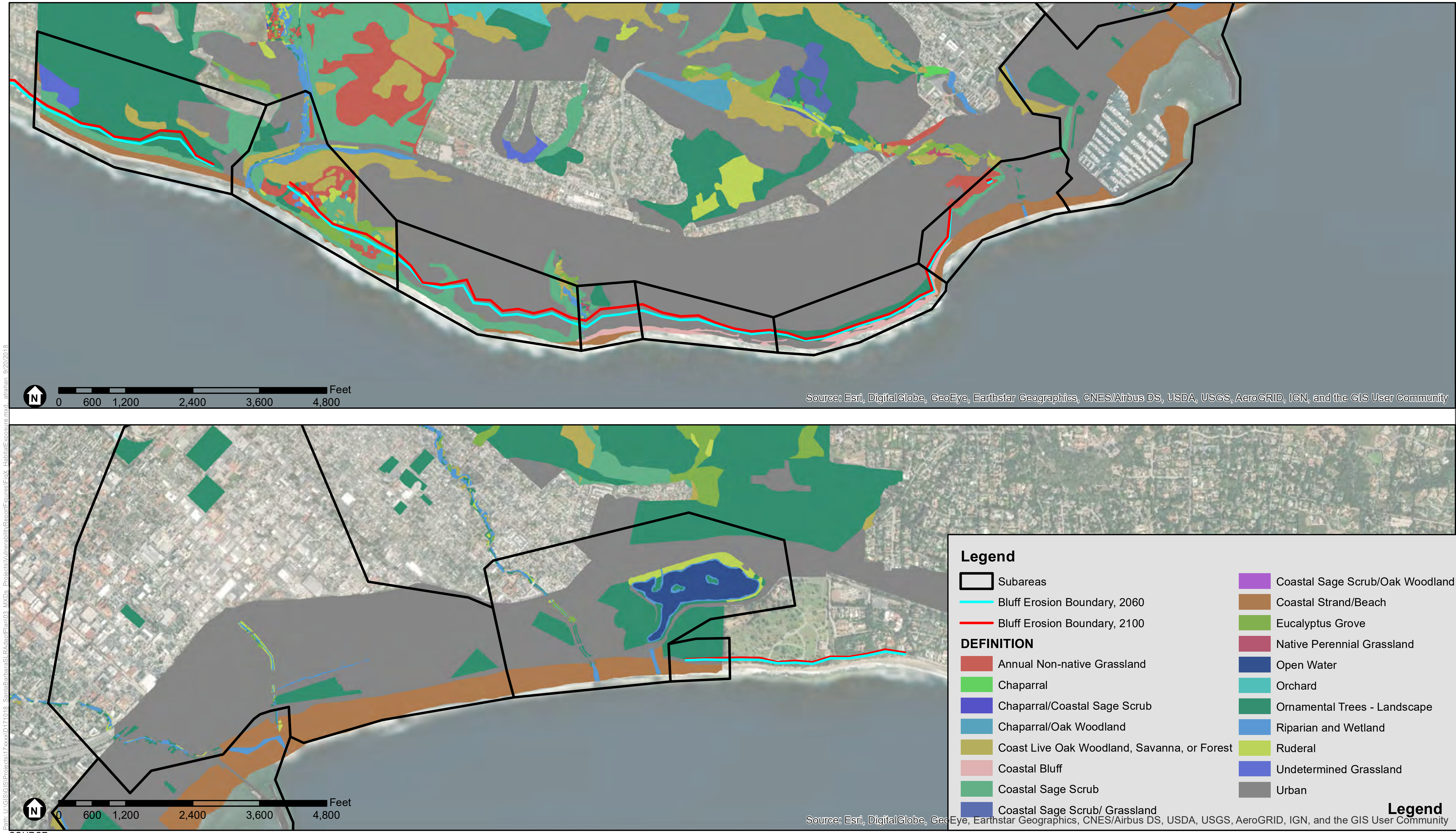

SOURCE:
Erosion: USGS CoSMoS, 2017
Habitats: City of Santa Barbara, 2018

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Figure 34
Habitat Areas Exposed to Bluff Erosion

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6 Conclusions

The purpose of the City of Santa Barbara Vulnerability Assessment Update was to identify and quantify the vulnerability of coastal assets in the City to SLR. As an update, this assessment aimed to fill gaps in previous studies for the City and County of Santa Barbara by:

- Using updated data about the City's assets
- Using the most recent hazard zones from USGS (CoSMoS v3.0), augmented by wave hazard zones from Coastal Resilience Santa Barbara
- Performing a focused study of local geology and erosion risk
- Investigating the ecological impacts of beach loss in the City

The study evaluated the vulnerability of assets in nine categories (Transportation, Critical Infrastructure, Stormwater, Recreational, Harbor, Public and Private Property (Parcels), Communications, Water Supply, and Wastewater). These assets were analyzed for vulnerability to six hazards (bluff erosion, shoreline erosion, tidal inundation, storm waves, storm flooding, and low-lying areas). These hazards and the City's vulnerability to them were evaluated under existing conditions and under two SLR scenarios (2.5 feet and 6.6 feet). These scenarios represent the high greenhouse gas emissions scenario from the OPC (2018) guidance with Medium/High risk aversion in 2060 and 2100, respectively. A near-term 2030 condition was reviewed, but was similar enough to existing conditions that a detailed analysis was not performed. The higher value, 6.6 feet of SLR, also represents the extreme risk aversion case from OPC (2018) in the year 2080.

The conclusions of this assessment are summarized as general conclusions and SLR vulnerability by subarea.

6.1 General Conclusions

6.1.1 Bluff Areas

Rising sea levels are expected to increase the coastal hazards that are currently impacting the City of Santa Barbara. Much of the westerly portion of the City's coastal zone is situated on bluffs overlooking the beach. Bluff areas in the City include subareas A –F, from approximately Sea Edge Lane at the west end of the City of Santa Barbara to approximately Santa Barbara Point, as well as subarea K at the far easterly portion of the City by the Bellosguardo Estate.

These bluffs are currently eroding with exposure to waves, and as sea level rises, they will be exposed to more extreme waves more often. This is expected to increase bluff erosion rates to about 1.5 times current rates by 2060 (40% increase) and to more than twice current rates by 2100 (140% increase). By 2060 the City could lose 78% of its bluff-backed beaches to erosion, and by 2100, the City could lose 98% of its bluff-backed beaches. In locations where these beaches are lost, the bluffs behind them will be more exposed to waves and are expected to erode more quickly. The extent of the hazards in these areas are expected to reach bluff-top infrastructure, including roads and utility infrastructure and public and private properties by 2100.

6.1.2 Low-Lying and Waterfront Areas

The low-lying areas of the City include the City's Waterfront, lower downtown area, and Arroyo Burro County Beach Park. In these areas, sandy beaches and low-lying areas in the City are also expected to see a change in exposure with sea-level rise, predominantly due to increased tidal inundation and storm flooding. Under current conditions and through 2060, impacts from erosion, tidal inundation, and storm waves are generally limited to the area south of Cabrillo Boulevard. However, by 2100 these hazard zones are expected to reach north of Cabrillo Boulevard, exposing more assets in the City. Furthermore, by 2060 the City could lose 32% of its sandy beaches in these low-lying areas to erosion, and by 2100, the City could lose 60% of its sandy beaches in low-lying areas.

There may also be changes in the direction from which waves come during different seasons, which may affect sand movement and erosion patterns at sandy beaches and in the harbor. In addition to rising sea level, a changing climate may also alter storm frequencies and patterns, bringing more severe storms more often or at different times.

6.1.3 Harbor and Stearns Wharf

The Santa Barbara Harbor and Stearns Wharf are valuable and important assets in the City. Under existing conditions, Stearns Wharf is exposed to wave damage during large storms and a 100-year coastal event is expected to require temporary closure and significant structural repairs. As sea level rises through 2060 and into 2100, events large enough to damage Stearns Wharf are expected to become more common, though non-storm tidal conditions are not likely to pose a risk of damage for the wharf deck.

The harbor includes the marina, commercial uses, parking, industrial areas, and the City Pier (sometimes called the "harbor pier"), which supports the Coast Guard and houses a fuel dock. Under existing conditions, storm events and especially high tides (e.g. "King Tides") can dislocate pile caps at the floating docks, and waves can overtop the harbor breakwater and reduce public access. More than two feet of sea-level rise (for example, the 2060 case) is expected to regularly impede normal harbor functions, and the harbor in its current configuration would be unusable by 2100, with over six feet of sea-level rise.

6.1.4 Storm Flooding Area

Flooding from coastal storms is expected to significantly increase in extent and frequency, particularly by 2100. FEMA flood insurance rate maps (FIRMs) are another hazard map generally used to assess exposure and vulnerability, so there is interest in how these relate to the results of this study. FEMA FIRMs are used to assess flood insurance rates and for regulatory purposes. For instance, the City's current Flood Plain Management Ordinance (Municipal Code Section 22.24) requires certain development standards, including floodproofing and raised foundations, based on the extent of flood hazard areas and the base flood elevations shown on the FEMA FIRMs. FEMA FIRMs do not include future conditions, future sea-level rise, or erosion hazards, so they indicate less severe coastal hazards than the hazard zones in this assessment in coastal areas. The FIRMs do, however, include extreme fluvial (river) events. The coastal and river flood events are mapped together on the FIRM, though they are not expected to occur simultaneously. Note that the FIRM flood hazard extent includes areas that are subject to river flooding that are not including in the Vulnerability Assessment's coastal flood hazard extent since the Vulnerability Assessment does not include extreme river flood hazards. The Vulnerability Assessment does, however, consider the degree of river flow that has historically occurred concurrent with extreme coastal storm events.

Some of the flood hazard areas currently mapped in the FIRMs are expected to experience more frequent flooding with sea-level rise, and in some areas the water levels are expected to change. The future hazard zones in areas dominated by coastal flooding that are near the waterfront and downtown south of Highway 101 are expected to experience higher water levels and more severe flooding than FEMA (water levels up to 2-3 feet higher than current base flood elevations). Some areas south of Highway 101 that are not currently mapped in any flood hazard zone on the FEMA FIRMS right now are projected to experience flooding by 2100. However, further inland (for example, downtown north of Highway 101), fluvial flooding is expected to be more extreme than coastal flooding, so the FEMA FIRM (existing conditions) represent more extreme conditions than the hazard zones from this assessment (future conditions). These areas would likely experience more frequent flooding events by 2100 due to sea-level rise, but the flood depths from sea-level rise alone would likely not be more than the base flood elevations currently shown on the FEMA FIRMs.

Other changing climatic factors, such as increasing precipitation intensity, could increase the fluvial hazard and flood extents and depths, but would require further study and analysis outside the scope of this vulnerability study to fully understand.

6.1.5 Major Infrastructure Facilities

Major infrastructure facilities, including the El Estero Wastewater Treatment Plant, the Charles E. Meyer Desalination Plant, and several major roads including Highway 101 are expected to experience increased flood risk by 2100. While they are expected to be exposed, facility-specific vulnerability assessments are recommended to better understand the adaptive capacity to flood proof these facilities and the actual risk to these facilities.

The vulnerability assessment identifies shows the El Estero Wastewater Treatment Plant partially in the tidal inundation and storm flooding hazard zones by 2100 and the Charles E. Meyer Desalination Plant, at least partially exposed to the tidal inundation and storm flooding hazard zones by 2100. However due to tidal inundation of the infrastructure associated with these plants, as well as portions of the plants themselves, both the El Estero Wastewater Treatment Plant and Desalination Plant will be permanently inoperable by 2100 if no action is taken. Tidal inundation of some of the wastewater piping system flowing into the plant will occur by 2060 if no action is taken. Additional analysis is needed to determine how much this will interrupt operations of the plant., In addition, by 2100 much of Cabrillo Boulevard is exposed to erosion or tidal inundation, and Highway 101 may experience storm flooding near Andrée Clarke Bird Refuge, and Shoreline and Cliff Drive could be threatened by shoreline and bluff erosion.

6.2 Conclusions by Subarea

Each of the subareas in **Figure 1** contains different assets (see **Table 1**), exposed to different coastal hazards at different time horizons. The following sections describe the subareas and how exposure is expected to change with sea-level rise.

6.2.1 Subarea A

Subarea A covers the area from Sea Ledge Lane at the west end of the City of Santa Barbara to the west side of Arroyo Burro Beach County Park. It consists of a bluff-backed beach, with an ancient landslide at the west end and residential neighborhoods running along the bluff for much of its length. Under existing conditions, Subarea A has extensive recreational area (the bluff-backed beach) exposed to tidal flooding hazards and storm wave hazards. Projected bluff erosion in this area is being investigated further due to geologic complexities, so results at 2060 and 2100 are not yet available.

6.2.2 Subarea B

Subarea B stretches from the west end of Arroyo Burro Beach County Park to the east edge of the Douglas Family Preserve. It consists of a bluff-backed beach with bluff-top open space (Douglas Family Preserve) and a coastal lagoon with extensive low-lying drainage (Arroyo Burro and Arroyo Burro Creek) and beach area (Arroyo Burro Beach County Park and associated parking area). Under existing conditions, Subarea B has large recreational and natural areas and some stormwater drainage channels exposed to tidal flooding, storm waves, and storm flooding, particularly surrounding the coastal lagoon (Arroyo Burro). In 2060, the erosion hazard zone begins to affect the bluff-top open space (including access roads) and the bluff-backed beach. Some areas exposed to storm flooding under current conditions become exposed to tidal flooding, and some areas exposed to tidal flooding become exposed to erosion. In 2100 storm flooding becomes a significant concern, causing temporary loss of service for sewer infrastructure, water supply infrastructure, roads, and evacuation routes. In addition, more of the bluff-backed beach area is exposed to tidal inundation, and large areas of both bluff-backed beach and bluff-top open space are exposed to erosion.

6.2.3 Subarea C

Subarea C covers the area from the west end of Medcliff Road to the east end of El Camino de la Luz. It consists of a bluff-backed beach with bluff-top residential neighborhoods. There is a modern landslide at El Camino de la Luz and beach access at Mesa Lane. Under existing conditions this subarea only has minor exposure to coastal hazard zones; however, by 2060 erosion is likely to damage sewer lines, stormwater drainage pipes, roads, and properties in the bluff-top residential neighborhoods. This trend continues into the future, with more roads, properties, and infrastructure in the bluff-top residential neighborhoods exposed to erosion by 2100.

6.2.4 Subarea D

Subarea D covers the area surrounding the Santa Barbara Lighthouse. It consists of a bluff-backed beach with bluff-top open space surrounding the lighthouse itself. Under existing conditions this subarea only has minor exposure to coastal hazard zones, which increases into 2060, at which point some of the roads, trails, sewer lines, and water supply lines supporting the lighthouse and associated open space are exposed to erosion. This trend continues into the future, with more roads and infrastructure around the lighthouse exposed to erosion by 2100. Shoreline drive will be impacted by erosion by 2060 and 2100.

6.2.5 Subarea E

Subarea E spans from the edge of the lighthouse open space area where Meigs road becomes Shoreline Drive to the west edge of Shoreline Park. It consists of bluff-backed beach with bluff-top residential neighborhoods and includes beach access for 1,000 Steps Beach. Under existing conditions, several properties in the subarea are exposed to tidal flooding and storm flooding, but by 2060 these properties, along with roads, beach access, open space areas, sewer lines, and water lines in the bluff-top neighborhoods are exposed to erosion. This trend continues into the future, with more roads, properties, and infrastructure in the bluff-top residential neighborhoods exposed to erosion by 2100. Shoreline Drive will be impacted by erosion by 2100.

6.2.6 Subarea F

Subarea F covers Shoreline Park and the area east of the park to Santa Barbara Point. It consists of bluff-backed beach with bluff-top open space, primarily Shoreline Park, with associated parking and beach access. Under existing conditions, the beach areas at Shoreline Park are exposed to tidal flooding and storm flooding. By 2060, much of this area is exposed to tidal flooding, and bluff-top segments of Shoreline Park are exposed to erosion, along with associated trails and irrigation infrastructure. This grows more severe by 2100, when the beach and more of the bluff-top park area are exposed to erosion or tidal flooding. Shoreline drive will be impacted by erosion by 2060 and 2100.

6.2.7 Subarea G

Subarea G encompasses Ledbetter Beach and properties behind it. It consists of Ledbetter Beach itself, with associated park area and parking lot, neighboring bluff recreation area to the west, Santa Barbara Community College, and several commercial establishments. Under existing conditions, some of the beach is exposed to tidal inundation, and much of the beach is exposed to storm waves, along with some sewer and stormwater lines. By 2060, portions of the beach area and neighboring bluff-top recreation area are exposed to erosion, and sewer and irrigation systems in the bluffs are exposed to erosion. Portions of the beach and sewer and stormwater lines continue to be exposed to storm waves. Erosion continues through 2100, eventually affecting all of the bluff recreation area and most of the beach, along with roads, communication infrastructure, sewer lines, and irrigation water supply lines. Some of these systems are also exposed to tidal flooding inland of the erosion hazard, and they are all exposed to storm waves. Shoreline Drive will be impacted by tidal inundation by 2100.

6.2.8 Subarea H

Subarea H covers the area in and around Santa Barbara Harbor, reaching as far east as the Laguna Tide Gates. The subarea consists of harbor and wharf region, with its breakwater, Waterfront Department offices, US Coast Guard facilities, marinas, and the harbor pier (City Pier). It also includes West Beach, the Sand Spit (a popular surf spot), a yacht club and boat yard, and Stearns Wharf. The low-lying areas around the harbor are home to parking lots, recreational facilities, park areas, commercial establishments, residential development, and a coastal trail. Subarea H also includes the Mission Creek Lagoon (which is also connected to Laguna Creek).

Under existing conditions, Subarea H has significant recreational areas (generally beaches), roads, and drainage infrastructure exposed to tidal flooding and storm flooding, with more exposure to storm waves. There are also launch ramps and harbor protection infrastructure (i.e. breakwater elements and rock groins) exposed to tidal and storm flooding. By the year 2060, parts of the beach and some drainage infrastructure in the recreational areas are exposed to erosion. Many recreational areas, stormwater infrastructure, and harbor protection infrastructure that were exposed to storm waves and tidal flooding under existing conditions are exposed to tidal flooding by 2060. Sewer infrastructure, particularly gravity mains, are also exposed to tidal and storm inundation by 2060, along with some irrigation lines in the recreational areas. Between 2060 and 2100, most assets that were exposed to storm waves and storm flooding become exposed to tidal flooding. Some of the drainage and irrigation infrastructure associated with recreational areas, along with sections of West Beach, are exposed to erosion, though much more is exposed to tidal flooding. By 2100, storm flooding and storm waves are lesser concerns in Subarea H because most of the low-lying assets are exposed to tidal flooding instead. Cabrillo Boulevard and State Street will be impacted by tidal inundation by 2100.

6.2.9 Subarea I

Subarea I covers Chase Palm Park and Downtown Santa Barbara. Much of this area is beach (East Beach) and low-lying backshore (Chase Palm Park and Downtown Santa Barbara). The park and beach include recreational facilities, a waterfront coastal trail, and parking areas. Inland, this subarea includes Downtown Santa Barbara with commercial and residential areas. The subarea also contains a segment of Highway 101, a railroad station (and the railroad), segments of Laguna Channel and Mission Creek, and El Estero Wastewater Treatment Plant.

Under existing conditions, the recreational areas in Subarea I (East Beach and Chase Palm Park) are primarily exposed to storm waves, with some of the beach exposed to tidal flooding. There are also some sewer lines exposed to tidal flooding and several sewer, drainage, and irrigation lines exposed to storm waves. By 2060, recreational areas (the beach and park) along with segments of the coastal trail and some drainage and irrigation infrastructure are exposed to erosion. As the erosion hazard zone increases, less recreational area is exposed to flooding and waves, but more properties are exposed to both tidal flooding and storm flooding. Tidal flooding also begins to impact drainage and irrigation infrastructure by 2060. By the year 2100, much of the beach area and some of the park area are exposed to erosion (including the coastal trail, drainage, and irrigation), and most of what remains is exposed to tidal or storm flooding. Storm waves play a lesser role in Subarea I by 2100 because many assets are exposed to erosion or flooding by that point, including many of the properties and facilities south of Highway 101, including El Estero Wastewater Treatment Plant, which is within the storm flooding hazard zone and which will not be operable due to tidal inundation into key components of the wastewater system. North of Highway 101, many private and public parcels in the Downtown Santa Barbara area are exposed to storm flooding, with many more considered flood-prone (i.e. below the storm flooding elevation but not directly connected to the ocean). Along with private and public parcels, this means that extensive sewer and water supply infrastructure in Downtown Santa Barbara is exposed to storm flooding, and infrastructure south of Highway 101 is exposed to tidal or storm flooding. Cabrillo Boulevard will be exposed to tidal inundation by 2100.

6.2.10 Subarea J

Subarea J covers the region from South Milpas Street to Andree Clark Bird Refuge. It consists of a beach (East Beach) with waterfront coastal trail and low-lying backshore with some residential and commercial development. The Santa Barbara Zoo, Cabrillo Boathouse, Sycamore Creek, and Sycamore Creek Lagoon, and Andree Clark Bird Refuge are all located within Subarea J. Under existing conditions, much of the beach recreational area, a portion of the coastal trail, and some of the surrounding roads are exposed to storm waves. In 2060, some segments of the beach recreation area are exposed to erosion, others to tidal flooding. Storm waves continue to be a concern, with roads, communications infrastructure, stormwater lines, and some properties and sewer lines exposed. Between 2060 and 2100, storm flooding becomes severe enough to overrun the beach, exposing much of the infrastructure behind the beach. This includes roads, railroads, many properties, and the sewer, stormwater, and water supply systems. There is significantly less exposure to storm waves, but only because much of what was previously exposed to storm waves is exposed to erosion or tidal flooding by 2100. Cabrillo Boulevard will be impacted by tidal inundation by 2100, and Highway 101 will be impacted by storm flooding by 2100.

6.2.11 Subarea K

Subarea K covers the Bellosguardo Estate at the east end of the City. It consists of a bluff-backed beach with bluff-top development. Under existing conditions, the beach portion of this subarea is exposed to tidal flooding, storm flooding, and storm waves. By 2060, these beach areas are exposed to erosion, and beach and bluff areas further inland are exposed to storm waves. This progresses through 2100, at which point all of the beach and portions of the estate on the bluffs are exposed to erosion.

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Appendix A
Sea-level Rise Scenario Preliminary Recommendations and Summary of Policy Guidance (ESA, April 2, 2018)

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memorandum

date	March 26, 2018 (revised April 2, 2018)
to	Melissa Hetrick, City of Santa Barbara
from	Louis White, PE
subject	Sea-Level Rise Scenario Preliminary Recommendations and Summary of Policy Guidance: City of Santa Barbara Sea-Level Rise Adaptation Plan for the Local Coastal Program Update

The purpose of this memorandum is to facilitate selection of sea-level rise scenarios for the City of Santa Barbara Sea-Level Rise Adaptation Plan for the Local Coastal Program Update project. It is Environmental Science Associate's (ESA) understanding that the City of Santa Barbara (City) and the California Coastal Commission (CCC) staff will review this memo and select the scenarios for the project. Therefore, ESA has recommended sea-level rise scenarios (Section 4, Table 5) and documented the reasons for the recommended scenarios in this memo. ESA has also included a summary of State and Federal policy guidance and other relevant information. ESA is available to discuss this document based on direction from the City including comments from the CCC staff. This document is not authorized for public release except at the discretion of the City of Santa Barbara.

1. Introduction

This memo includes recommendations for selecting sea-level rise amounts and time horizons based on different projections of sea-level rise over time as a function of greenhouse gas emissions. This memo also relates the sea-level rise scenarios used in prior work by ESA and the United States Geological Survey (USGS) to the recently updated California sea-level rise guidance. Based on this information, ESA will assist the City to select the sea-level rise scenarios to be used in the project. ESA recommends two planning horizon timeframes (i.e., 2060, 2100) and two sea-level rise scenarios that account for variable greenhouse gas emissions and risk aversion, and a third extreme emission scenario for one timeframe (H++ scenario). See Section 4 for details on the recommended scenarios. Note that a subsequent memo will be prepared that discusses the hazard map products, including assumptions on storms, shore protection, and other issues such as beach nourishment; this memo is focused on sea-level rise scenarios.

2. Summary of Prior Sea-Level Rise Hazard Mapping Studies in Santa Barbara

ESA and USGS have previously assessed the impacts of sea-level rise on the Santa Barbara coast. ESA conducted sea-level rise hazard mapping, including the erosion and flooding hazards, in collaboration with Santa Barbara County, as well as the City of Santa Barbara (ESA 2015; 2016a; 2016b). The USGS also recently released the Coastal Storm Modeling System (CoSMoS) 3.0 study (Phase 2), which includes similar hazard mapping along the Southern California coast, including the city of Santa Barbara. Although the methods used in the studies differ, both studies predict increased areas impacted by erosion and flooding with sea-level rise as compared to existing conditions. The approach in integrating sea-level rise policy differs, however, where the ESA studies present scenario-based hazard maps informed by the recommended sea-level rise policy guidance, and the USGS study presents results for a discrete range of sea-level rise amounts independent of time. How each of these studies incorporated sea-level rise is described in the following sections.

2.1 Santa Barbara County and City Coastal Hazard Mapping by ESA

ESA worked with Santa Barbara County to prepare coastal hazard maps with sea-level rise to inform the County's Local Coastal Program (LCP) update (ESA 2015; 2016b). The process involved several stakeholders and local science advisors. The sea-level rise scenarios were based on those presented in National Research Council's report *Sea-Level Rise for the Coasts of California, Oregon, and Washington* (NRC 2012), with modified rates of vertical land motion to account for the variable geology along the Santa Barbara coastline. In areas mapped within the limits of the city of Santa Barbara, a single value of vertical land motion of -1.5 mm per year (the negative value indicates subsidence) was used, which conforms with the values reported in NRC (2012), OPC (2013), and CCC (2015). Based on ESA's interpretation of the new OPC (2018) guidance described in Section 3, the prior work is also consistent with the new sea-level rise projections of OPC (2018).

The planning horizons for the project were selected by the stakeholder process, which recommended presenting hazard data for the years 2030, 2060 and 2100. The basis for selecting 2060 was that it represents a mid-century horizon that occurs prior to years where the uncertainty in the projections becomes more evident. The selection of the years 2030 and 2100 were consistent with state guidance at the time of the study (OPC 2013; see section 3.2).

Based on feedback from the City of Santa Barbara, ESA refined the hazard maps to include the effects that existing shore protection would have on the hazard extents (ESA 2016a). ESA developed a methodology for considering the protective nature of coastal structures, and assumed that the structures would be maintained throughout the forecasting period. This resulted in hazard areas that were reduced, but not eliminated, owing to overtopping of the structures that increases with the rise in sea-level.

2.2 CoSMoS Southern California 3.0

As part of the USGS effort to expand the CoSMoS along the west coast, the recent 3.0 Phase 2 study was completed for the Southern California coast, which includes the extents of the city of Santa Barbara (Barnard et al. 2015). Rather than computing the hazard extents for sea-level rise based on the current policy guidance, the CoSMoS approach computes the hazard extents for several discrete values of sea-level rise, independent of time. Sea-level rise amounts from 0 to 2 meters were used, at 0.25 meter increments. Table 1 presents a conversion of the sea-level rise amounts from metric to English units.

TABLE 1
METRIC-ENGLISH CONVERSION OF SEA-LEVEL RISE AMOUNTS SIMULATED BY COSMOS

Case	1	2	3	4	5	6	7	8	9
Meters	0	0.25	0.5	0.75	1	1.25	1.5	1.75	2
Feet	0	0.8	1.6	2.5	3.3	4.1	4.9	5.7	6.6

3. Sea-Level Rise Policy Guidance

The sections below present State and Federal guidance on sea-level rise.

3.1 State Guidance on Sea-Level Rise

The California Ocean Protection Council (OPC) first released a statewide sea-level rise guidance document in 2010 following Governor Schwarzenegger's executive order S-13-08. This interim guidance document informed and assisted state agencies to develop approaches for incorporating sea-level rise into planning decisions. The document was updated in 2013 (OPC 2013) after the NRC released its final report *Sea-Level Rise for the Coasts of California, Oregon, and Washington* (NRC 2012), which provided three projections of future sea-level rise associated with low, mid, and high greenhouse gas emissions scenarios, respectively.

The CCC adopted sea-level rise policy guidance in 2015 (CCC 2015). The document recommends using a range of climate change scenarios (i.e., emissions scenarios) at multiple planning horizons for vulnerability and adaptation planning. The guidance presents a step-by-step process for addressing sea-level rise and adaptation planning in updated LCPs (CCC 2015, p 18). This memo focuses on the first step of the CCC recommended process: Determine a range of sea-level rise projections relevant to LCP planning area/segment using best-available science. At the time of the CCC (2015) report, NRC (2012) was included in State policy by OPC (2013). Since then, California commissioned an update (Griggs et al. 2017) and released an update to the sea-level rise policy in March 2018. Consequently, a key question is how to select the "best available science" and incorporate changes in the State Policy update. Additional information is provided in the following sections of this document.

3.1.1 Guidance on Climate Change and Sea-Level Rise Scenarios

The accumulation of greenhouse gases in the Earth's atmosphere is causing and will continue to cause global warming and resultant climate change. For the coastal setting, the primary exposure will be an increase in mean sea-level rise due to thermal expansion of the ocean's waters and melting of ice sheets.

State planning guidance for coastal flood vulnerability assessments call for considering a range of emission scenarios (OPC 2013; CCC 2015). These scenarios bracket the likely ranges of future greenhouse gas emissions and ice sheet loss, two key determinants of climate whose future values cannot be precisely predicted. Scenario-based analysis promotes the understanding of impacts from a range of emission scenarios and identifies the amounts of climate change that would cause impacts.

The state guidance recommends using emission scenarios that represent low, medium, and high rates of climate change. Recent studies of current greenhouse gas emissions and projections of future loss of ice sheet indicate that the low scenario probably underrepresents future sea-level rise (Rahmstorf et al. 2012; Horton et al. 2014). Also, note that even if sea-level rise does not increase as fast as projected for the high scenario, sea-level rise is projected to continue beyond 2100 under all emission scenarios. The assumptions that form the basis for the NRC (2012) scenarios are as follows:

Low Emissions Scenario – The low scenario assumes population growth that peaks mid-century, high economic growth, and assumes a global economic shift to less energy-intensive industries, significant reduction in fossil fuel use, and development of clean technologies.

Medium Emissions Scenario – The medium scenario assumes population growth that peaks mid-century, high economic growth, and development of more efficient technologies, but also assumes that energy would be derived from a balance of sources (e.g., fossil-fuel, renewable sources), thereby reducing greenhouse gas emissions.

High Emissions Scenario – The high scenario assumes population growth that peaks mid-century, high economic growth, and development of more efficient technologies. The associated energy demands would be met primarily with fossil-fuel intensive sources.

Table 2 presents sea-level rise projections for prior State guidance of OPC (2013) based on NRC (2012). The values for relative sea-level rise[1] at 2030, 2050 and 2100 for Los Angeles[2] are relative to 2000 and includes regional projections of both mean sea-level rise and vertical land motion of -1.5 millimeters per year for the San Andreas region south of Cape Mendocino.

TABLE 2
OPC (2013) STATE GUIDANCE: SEA-LEVEL RISE PROJECTIONS FOR SOUTHERN CALIFORNIA

Scenario	2030	2050	2100
Low Range	0.2 feet	0.4 feet	1.5 feet
Mid Curve	0.5 feet	0.9 feet	3.1 feet
High Range	1.0 feet	2.0 feet	5.5 feet

Source: Table 5.3, NRC (2012)

3.1.2 Sea-Level Rise Guidance Update of 2018

The California Natural Resource Agency and OPC released 2018 guidance update (OPC 2018) to the 2013 State of California guidance document (OPC 2013). The updated guidance provides a synthesis of the best available science on sea-level rise in California, a step-by-step approach for state agencies and local governments to evaluate sea-level rise projections, and preferred coastal adaptation strategies. The key scientific basis for this update was developed by the working group of the California OPC Science Advisory Team titled *Rising Seas in California: An Update on Sea-Level Rise Science* (Griggs et al. 2017). The above mentioned studies and guidance documents are shown in Figure 1 to illustrate the relationship between these documents.

[1] The term "relative sea-level rise" indicates that the local effects of vertical land motion are included in the sea-level rise projection,
[2] Los Angeles relative sea-level rise amounts are in closest proximity to city of Santa Barbara

Figure 1
California Sea-level Rise Guidance Documents and Scientific Basis for Each

The 2018 guidance update includes the following key changes and additions to the OPC (2013) guidance:

- **For years before 2050, sea-level rise projections are provided only for the high emissions scenario (RCP 8.5).** The world is currently on the RCP 8.5 trajectory, and differences in sea-level rise projections under different scenarios are minor before 2050.

- **Includes new "extreme" sea-level rise projections associated with rapid melting of the West Antarctic ice sheet.**

- **Shifts from scenario-based (deterministic) projections to probabilistic projections of sea-level rise.** The guidance update recommends a range of probabilistic projections for decision makers to select given their acceptable level of risk aversion for a given project.

- **Provides estimated probabilities of when a particular sea-level rise amount will occur.** In addition to sea-level rise projections that are tied to risk acceptability, updated guidance provides information on the likelihood that sea-level rise will meet or exceed a specific height (1 foot increments from 1 to 10 feet) over various timescales.

The guidance update includes significant advances in the scientific understanding of sea-level rise. Compared to the ***scenario-based*** sea-level rise projections in the 2013 version of state guidance, the updated guidance incorporates ***probabilistic*** sea-level rise projections, which associate a likelihood of occurrence (or probability) with various sea-level rise heights and rates into the future and are directly tied to a range of emissions scenarios (described below). Using probabilistic sea-level rise projections is currently the most appropriate scientific approach for policy setting in California, providing decision makers with increased understanding of potential sea-level rise impacts and consequences. The guidance update also includes an extreme sea-level rise scenario that is based on rapid melting of the West Antarctic ice sheet.

The guidance update now provides a range of probabilistic projections of sea-level rise that are based on two Intergovernmental Panel on Climate Change (IPCC) emissions scenarios called representative concentration pathways (RCPs[3]), as well as a non-probabilistic projection associated with rapid West Antarctic ice sheet mass loss. These three climate scenarios are explained below:

RCP 2.6 *Scenario* – This scenario corresponds closely to the aspirational goals of the 2015 Paris Agreement, which calls for limiting mean global warming to 2 degrees Celsius and achieving net-zero greenhouse gas emissions in the second half of the century. This scenario is considered very challenging to achieve, and is analogous to the low emissions scenario in NRC (2012).

RCP 8.5 *Scenario* – This scenario is consistent with a future where there are no significant global efforts to limit or reduce emissions. This emission scenario is consistent with that used to develop the high emissions scenario in NRC (2012).

H++ Scenario – This extreme scenario was proposed by the OPC Science Advisory Team in response to recent scientific studies that have projected higher rates of sea-level rise due to the possibility of more rapid melting of ice sheets.

Table 3 presents the probabilistic projections of sea-level rise for Santa Barbara with additional probabilities for the RCPs and the non-probabilistic H++ scenario (depicted in blue on the right-hand side). High emissions scenario represents RCP 8.5; low emissions scenario represents RCP 2.6. Because differences in sea-level rise projections under the various emissions scenarios are minor before 2050, the update only provides RCP 8.5 projections of sea-level rise up to 2050. **State-recommended projections for use in low, medium-high and extreme risk aversion decisions are outlined by dark blue boxes in Table 3.** The State suggests that decision makers take a precautionary, risk-averse approach of using the medium-high sea-level rise projections across the range of emissions scenarios for longer lasting projects with low adaptive capacity[4] and high consequences[5]. The State further recommends incorporating the H++ scenario in planning and adaptation strategies for projects that could result in threats to public health and safety, natural resources and critical infrastructure such as large power plants, wastewater treatment, and toxic storage sites. The probabilities included in Table 3 do not represent the actual probabilities of occurrence of sea-level rise, but provide probabilities that the ensemble of climate models used to estimate the contributions of sea-level rise will predict a certain amount of sea-level rise (OPC 2018).

[3] Named for the associated radiative forcing (heat trapping capacity of the atmosphere) level in 2100 relative to pre-industrial levels.
[4] Adaptive capacity is the ability of a system or community to evolve in response to, or cope with the impacts of sea-level rise.
[5] Consequences are a measure of the impact resulting from sea level rise, typically quantitative.

TABLE 3
OPC (2018) STATE GUIDANCE: PROJECTED SEA-LEVEL RISE FOR SANTA BARBARA IN FEET

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds…	66% probability sea-level rise is between…		5% probability sea-level rise meets or exceeds…	0.5% probability sea-level rise meets or exceeds…	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.3	0.2 -	0.4	0.5	0.7	1.0
	2040	0.5	0.3 -	0.7	0.8	1.1	1.6
	2050	0.7	0.4 -	1.0	1.2	1.8	2.5
Low emissions	2060	0.7	0.4 -	1.0	1.4	2.2	
High emissions	2060	0.9	0.6 -	1.3	1.6	2.5	3.6
Low emissions	2070	0.9	0.5 -	1.3	1.7	2.8	
High emissions	2070	1.1	0.7 -	1.7	2.1	3.3	4.9
Low emissions	2080	1.0	0.5 -	1.5	2.0	3.6	
High emissions	2080	1.4	0.9 -	2.1	2.7	4.3	6.3
Low emissions	2090	1.1	0.6 -	1.8	2.4	4.4	
High emissions	2090	1.7	1.1 -	2.6	3.3	5.3	7.9
Low emissions	2100	1.2	0.6 -	2.0	2.9	5.3	
High emissions	2100	2.1	1.2 -	3.1	4.1	6.6	9.8
Low emissions	2110*	1.3	0.7 -	2.1	3.0	5.9	
High emissions	2110*	2.2	1.4 -	3.2	4.2	6.9	11.5
Low emissions	2120	1.4	0.7 -	2.4	3.5	7.0	
High emissions	2120	2.5	1.7 -	3.7	4.9	8.2	13.7
Low emissions	2130	1.5	0.8 -	2.6	3.9	8.0	
High emissions	2130	2.9	1.8 -	4.2	5.6	9.5	16.0
Low emissions	2140	1.6	0.8 -	2.9	4.4	9.1	
High emissions	2140	3.1	2.0 -	4.8	6.4	11.0	18.6
Low emissions	2150	1.8	0.7 -	3.2	5.0	10.5	
High emissions	2150	3.5	2.2 -	5.3	7.2	12.6	21.4

**Most of the available climate model experiments do not extend beyond 2100. The resulting reduction in model availability causes a small dip in projections between 2100 and 2110, as well as a shift in uncertainty estimates (see Kopp et al. 2014). Use of 2110 projections should be done with caution and with acknowledgement of increased uncertainty around these projections.*

Source: OPC (2018)

The H++ projection is a single scenario and does not have an associated likelihood of occurrence as do the probabilistic projections. Probabilistic projections are with respect to a baseline of the year 2000, or more specifically the average relative sea level over 1991 - 2009.

3.2 Federal Guidance

The US Army Corps of Engineers (USACE) issued circular EC 1100-2-8162 in December 2013, which provides guidance for the incorporation of direct and indirect physical effects of projected future sea-level rise (USACE 2013). This circular superseded all previous USACE-issued guidance on the subject, including the prior guidance issued (USACE 2011). According to the circular, planning studies and engineering designs should evaluate alternatives against a range of local sea-level rise projections defined by “low,” “intermediate” and “high” rates of local sea-level rise. The USACE circular suggests using three sea level curves (historic and NRC-I and NRC-III from NRC 1987) modified to reflect the increase in the present rate of global sea-level rise to 1.7 mm per year. USACE (2013) provided guidance on how to incorporate local vertical land motion into the “intermediate” and “high” projections of sea-level rise. Additional guidance can be found in USACE (2014).

In comparison to the State guidance described above, the USACE recommended curves are slightly lower for the respective emissions scenarios. Table 4 presents a summary of the sea-level rise projections at 2030, 2060, and 2100 using the USACE (2013) guidance for values associated with Santa Barbara.[6] For purposes of this study, we recommend using sea-level rise projections that comply with the State guidance. However, consideration should also be given to the Federal guidance owing to the possibility of a USACE participation in adaptation of the Santa Barbara Harbor as well as the sand management plan which includes maintenance dredging and sand bypassing by the USACE.

TABLE 4
SEA-LEVEL RISE PROJECTIONS FOR SANTA BARBARA USING USACE (2013) GUIDANCE

Scenario	2030	2060	2100
Low	0.1 feet	0.2 feet	0.4 feet
Intermediate	0.4 feet	1.0 feet	2.1 feet
High	0.8 feet	2.3 feet	5.4 feet

Note: Values computed using methods described in USACE (2013) with parameters specific to Santa Barbara area. See footnote #6 below.

3.3 Comparison and Combination of Federal and State Guidance

Sea-level rise scenarios for projects similar to the Santa Barbara Sea-Level Rise Adaptation Plan have been based on a combination of State and Federal guidance. The Coastal Resilience Ventura project used three sea-level rise projections to represent the high, medium, and low scenarios: NRC (2012) high, NRC (2012) medium, and USACE (2011) medium, respectively. The sea-level rise hazard mapping conducted in Santa Barbara was similar to the work completed for the Coastal Resilience Ventura project, but the high, medium, and low sea-level rise curves were all derived from the NRC (2012) values and adjusted for local vertical land motion to conform to the OPC (2013) guidance, which was in effect at the time of the study.

Figure 2 presents a comparison of the updated OPC (2018) sea-level rise guidance to the federal USACE (2013) guidance. The solid, colored lines represent the projections of the new OPC (2018) guidance, and the dashed, colored lines represent the USACE (2013) sea-level rise scenarios for Santa Barbara. The low curve for USACE (2013) is not shown. Figure 2 illustrates that the USACE (2013) high sea-level rise curve generally falls within the range of values for the medium-high risk aversion from the OPC (2018) guidance, while the USACE (2013) intermediate sea-level rise curve falls within the range of values for the low risk aversion from the OPC (2018). The low scenario for the USACE (2013) is lower than the recommended projections described by the current State guidance, and not recommended for evaluation in this study (see Section 4). However, the USACE often

[6] Sea-level rise projections using the USACE (2013) guidance assume a project start at 2000 to facilitate comparison to State guidance; a subsidence rate of -1.5 mm/yr based on NRC (2012); and a historic sea-level rise rate of 1.11 mm/yr based on NOAA values for Santa Barbara NOS station 9411340.

considers the USACE (2013) low curve for evaluating federal navigation channel dredging projects, and so could be used for project-specific purposes.

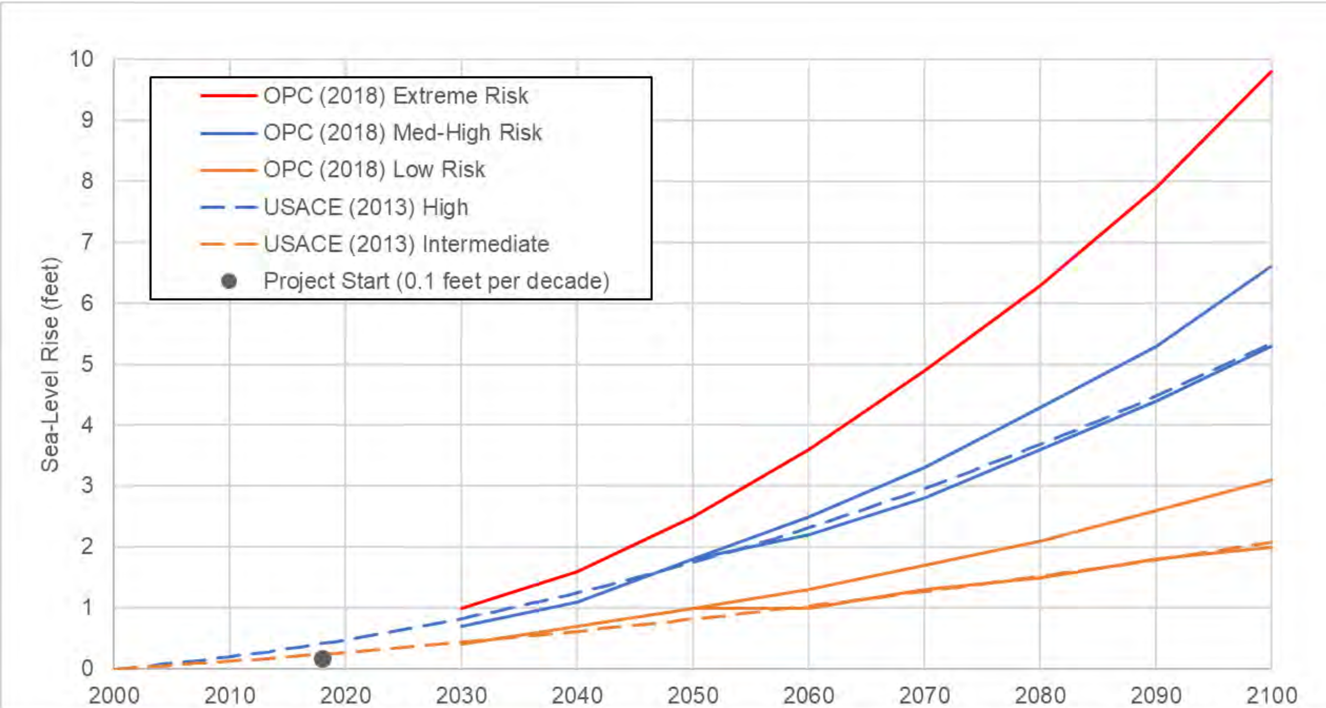

Figure 2
Comparison of Federal (USACE 2013) and State (OPC 2018) Sea-Level Rise Projections

4. Sea-Level Rise Scenarios for Santa Barbara Vulnerability Assessment

Considering the updated guidance discussed above, public webinars on the guidance update process[7], the latest science on sea-level rise and the need to use existing sea-level rise hazard data for Santa Barbara, the following planning horizons and sea-level rise scenarios are proposed for the Santa Barbara Sea-Level Rise Adaptation Plan.

4.1 Planning Horizons

ESA proposes the planning horizons of 2030, 2060, and 2100 for the purposes of the project. ESA's recommendation is based on the need to plan for short- and long-term impacts related to sea-level rise, as well as the fact that available coastal hazard maps were developed for these planning horizons (ESA 2015; ESA 2016a). Most climate models show strong agreement on the amount of sea-level rise that is likely to occur by 2050, and start to diverge after 2050 based on the range of potential emissions scenarios (OPC 2013). Therefore, it is important to consider a range of sea-level rise scenarios for future planning and projects with timeframes and to look beyond 2050.

[7] More information can be found here: http://www.opc.ca.gov/climate-change/updating-californias-sea-level-rise-guidance/

The proposed planning horizons are consistent with sea-level rise policy guidance documents and consistent with recent hazard mapping performed for Santa Barbara (ESA 2015; ESA 2016a). Years 2060 and 2100 will be used to evaluate vulnerability, adaptation, and associated economic impacts, while the year 2030 will be assessed in a qualitative manner without an economic and asset-level impact analysis. An extreme sea-level rise scenario will be assessed by considering the impacts associated with the medium-high risk level occur earlier, approximately between 2075 and 2080. The updated guidance introduces planning horizons beyond 2100 but these projections are presented with caution by the authors. As described in OPC (2018), most climate model experiments do not extend beyond 2100, which results in a large increase in uncertainty. Therefore, ESA has not presented sea-level rise amounts projected beyond 2100.

The 2060 and 2100 planning horizons are recommended so that decisions about land use can be matched to the timeframe for project lifespans and to facilitate the identification of triggers for adaptation measures. By using the planning horizons of 2060 and 2100, we can assess a range of sea-level rise that could occur at Santa Barbara in the mid and long-term whether or not the amounts of sea-level rise are realized at, before or after these years. These planning horizons (years) will determine the amounts of sea-level rise that are used to assess vulnerability to coastal flooding hazards and the timeframes over which coastal erosion hazards and consequent impacts are evaluated. These dates also correspond to existing hazard mapping products prepared for the city of Santa Barbara.

4.2 Sea-level Rise Scenarios

The sea-level rise scenarios proposed for this study were selected to be consistent with the latest guidance and to utilize available coastal hazard maps for Santa Barbara. Recent studies conducted for Santa Barbara County (ESA 2015) and the City of Santa Barbara (ESA 2016) applied the regional sea-level rise projections from NRC (2012), which were modified to incorporate local rates of vertical land motion (see Section 2). As shown in Section 3, these scenarios are consistent with the new OPC (2018) guidance.

Now that the State guidance update is in-effect, ESA proposes that this study consider the probabilistic projections of sea-level rise for low risk and medium-high risk aversion scenarios, as well as consideration of the H++ scenario. For comparison, the low and medium-high risk categories relate to the medium and high scenarios of NRC (2012), respectively, and therefore the low curve of NRC (2012) is not considered. To account for uncertainties in sea-level rise over time, and a range of assets at risk (e.g., high risk assets include critical community facilities, such as a wastewater treatment plant; low risk assets could include recreational assets and non-critical assets), ESA proposes to utilize the probabilistic projections for each Risk Aversion level from Table 3. A total of six sea-level rise scenarios are proposed to perform the vulnerability assessment and adaptation plan, including existing conditions (no sea-level rise) as well as future sea-level rise at 2060 and 2100. Table 5 below presents the proposed future sea-level rise scenarios based on the State-recommended projections for each Risk Aversion level. The implications of sea-level rise impacts to assets and possible adaptation for the 2030 timeframe will be considered at a high level without conducting an asset inventory and economic analysis, but will be described to provide context and for completion.

TABLE 5
PROPOSED SEA-LEVEL RISE SCENARIOS FOR PROJECT

Scenario	2030	2060	2075	2100
Low Risk Aversion[1]	0.4 feet	1.0 to 1.3 feet	--	2.0 to 3.1 feet
Med-High Risk Aversion[2]	0.7 feet	2.2 to 2.5 feet	--	5.3 to 6.6 feet
Extreme Risk Aversion	--	--	5.3 to 6.6 feet	--

1 Low Risk Aversion approximately equal to NRC (2012) Medium Curve
2 Med-High Risk Aversion approximately equal to NRC (2012) High Curve

In order to conduct the vulnerability assessment, ESA will rely on the available coastal hazard maps from the USGS CoSMoS effort and ESA's prior work for the County and City of Santa Barbara. Hazard maps will be selected that best match the sea-level rise scenarios presented in Table 5 above. While the CoSMoS and ESA coastal hazards selected for the vulnerability assessment do not exactly match the proposed sea-level rise scenarios in Table 5, the differences are acceptable given the uncertainties associated with sea-level rise. A subsequent memo will present the hazard mapping information and facilitate a decision by the City for how to consider erosion and flood hazards.

Figure 3 presents a chart of the sea-level rise projections based on the current OPC (2018) guidance and the available hazard maps that can be used for vulnerability and adaptation planning. The available maps were produced by ESA for the City and County of Santa Barbara, and by USGS as part of the CoSMoS 3.0. Although maps were not evaluated at the exact sea-level rise amounts of OPC (2018) tabulated in Table 3, they are representative of the new guidance within a reasonable amount of uncertainty.

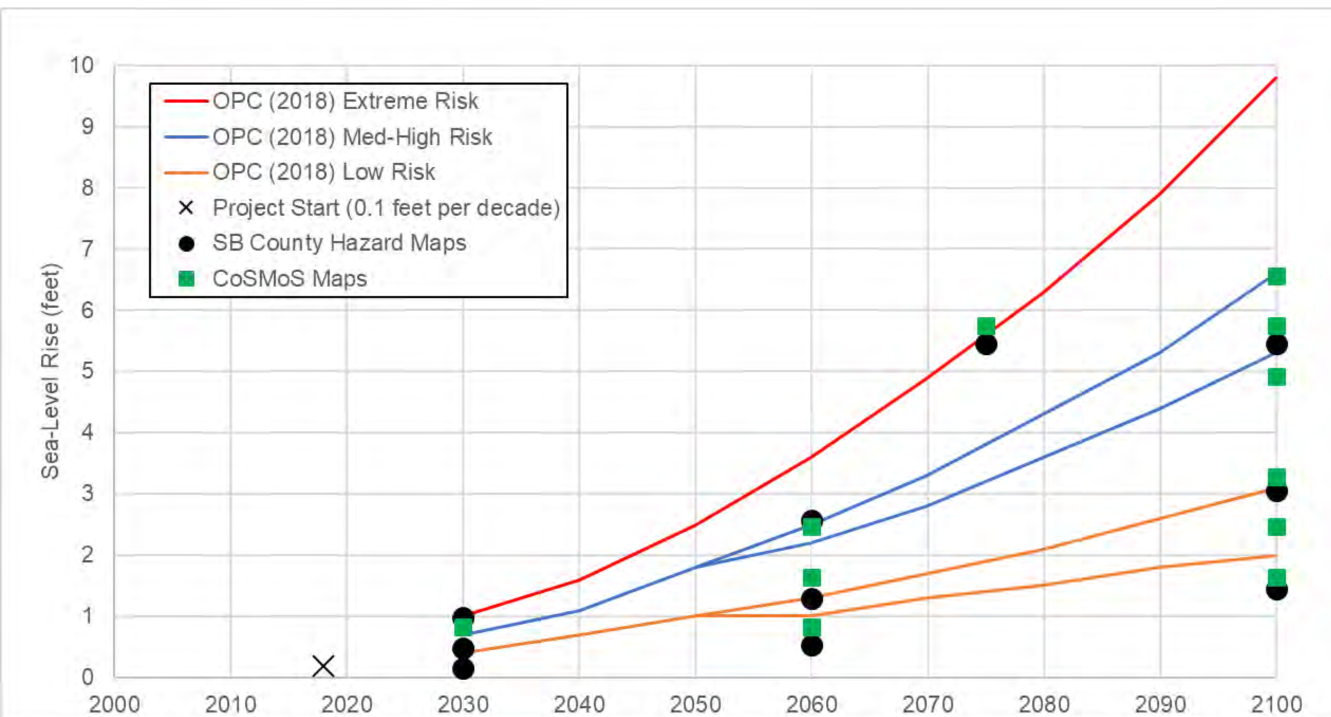

Figure 3
Comparison of Available Hazard Maps to Updated OPC (2018) Sea-Level Rise Guidance Curves

The Extreme Risk sea-level rise scenario of 9.8 feet at 2100 is not well represented in the available coastal hazard maps. This scenario will be evaluated by considering that the highest sea-level rise scenario modeled will occur at the time indicated in the Extreme Risk Aversion sea-level rise projection shown in Figure 3. Table 5 summarizes the potential sea level rise scenarios to be modeled, including the extreme H++ scenario that occurs at approximately 2075. These values can be modified based on review by the City and the CCC.

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Appendix B
Coastal Hydrology

1 COASTAL HYDROLOGY

The City of Santa Barbara lies along the Pacific coast of California, at the north end of the Southern California Bight. It is exposed to regular tidal variation and wave action from local and distant storms. The following sections summarize the tidal elevations, wave climate, typical wave runup conditions, and extreme water levels that have been reported for the project area in existing studies.

1.1 Tides

The tides in Santa Barbara exhibit mixed semi-diurnal characteristics, with two high tides and two low tides of unequal height occurring approximately every 24 hours. The tide range along the project site varies from approximately 4 feet during neap tides to approximately 9 feet during spring tides. Table 1 presents the published tidal datums for the Santa Barbara tide gage (NOAA NOS Station 9411340), located at the end of the City Pier in the Santa Barbara harbor.

TABLE 1
TIDAL DATUMS FOR SANTA BARBARA AND OTHER RELEVANT WATER LEVELS

Datum	Description	feet NAVD
Max	Highest Observed Tide (12/13/12)	7.54
HAT	Highest Astronomical Tide (12/2/90)	7.14
SHT	Spring High Tide (11/6/10)	6.80
MHHW	Mean Higher High Water	5.31
MHW	Mean High Water	4.55
MTL	Mean Tide Level	2.72
MSL	Mean Sea Level	2.70
MLW	Mean Low Water	0.89
MLLW	Mean Lower Low Water	-0.09
LAT	Lowest Astronomical Tide (1/1/87)	-2.09

Source: NOAA NOS Sta.9411340

Typical “high tide” flooding is projected using the monthly Extreme Monthly High Water (EMHW). This value was computed by averaging the maximum monthly water level for every month recorded at the Santa Barbara tide gauge (EMHW = 2.0 meters (6.6 ft) NAVD88) (ESA, 2016, ESA, 2015). This water level can therefore be thought of as the “monthly return period” ocean water level. This water level is identified as a frequency of inundation (about 12 times a year) that would impact land use: Similar thresholds but with different elevations and frequencies have become prevalent in recent years (e.g. about 26 times a year "high tide" [1] and once to twice a year "King Tide"[2]).

1.2 Waves

The incident wave climate at the City of Santa Barbara is highly seasonal, with the greatest exposure to long-period winter swells from the west. The Santa Barbara coast is generally sheltered by the summer south swells generated in the South Pacific. Shorter period storm waves from the southeast have caused significant impacts, particularly when combined with elevated water levels typical of El Niño winters.

The shore orientation and sheltering by the Channel Islands results in a narrow primary swell window from the west, and a second window from the southeast that can be occasionally quite damaging due to strong winds (e.g. March, 1983) and rare nearby tropical storm (Hurricane Marie, August 2014) Additional information can be found in the Coastal Resilience Santa Barbara technical reports (ESA, 2015; 2016; 2016b).

1.3 Extreme Water Levels

Santa Barbara is exposed to extreme water levels during storms, which can cause extensive if temporary flooding in the city. The Rincon Island tide gauge[3], an offshore gauge maintained by NOAA, is between the city of Santa Barbara and Ventura. Based on recorded water levels from this gauge, NOAA estimates an offshore still water level of 8.13 feet NAVD88. While this value is not identical to the CoSMoS data, the "storm" data reported by CoSMoS is described as the "near 100-year" event and is thus similar. More information can be found in the memo titled "Summary of Selected Methodology for Hazard Mapping – City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update" (ESA, 2018). Additional information can be found in the Coastal Resilience Santa Barbara technical reports (ESA, 2015; ESA, 2016; ESA, 2016b).

1.4 Relevant Features of FEMA Hazard Mapping

The FEMA map shows flooding due to rainfall and ocean sources that recur on average about once in 100 years. However, the extent of flooding shown is not expected to occur all at once because the 100-year rainfall event and the 100 –year ocean event do not occur at the same time. Also, a particular location may be exposed to flooding by multiple 100-year events: For example, Andree Clark Reserve can flood when high rainfall results in the 100-year flowrate on Sycamore Creek and water flows overland, with flooding also projected on US 101. The Andree Clark area can also flood when large ocean waves break during high ocean levels and the residual wave runup overtops the road and deposits water into the wetland basin. When an area is projected to flood from more than one source, the more extreme flood depth or elevation is mapped.

Another nuance in flood mapping is that each creek and each section of shore may flood differently and during different events. For example, the Mission Creek watershed is much larger than the Arroyo Burro

[1] https://tidesandcurrents.noaa.gov/publications/techrpt86_PaP_of_HTFlooding.pdf
[2] https://oceanservice.noaa.gov/facts/kingtide.html
[3] Rincon Island tide gage NOAA Sta. 9411270: http://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=9411270

watershed, requiring different rainfall durations and intensities to achieve the 100-year flowrate. Hence it is possible to have one drainage experience a 100-year flowrate and flood while a nearby drainage experiences a flowrate with a lower or higher recurrence interval (e.g. 50-year or 150-year). Similarly, shores in Santa Barbara are more or less exposed to particular wave events. The primary wave exposure is from westerly swell albeit reduced in intensity due to the oblique angle between westerly waves and the south-facing Santa Barbara shore. The western and eastern portions of Santa Barbara are more exposed to these west swells due to their more westerly shore orientation, while Leadbetter Beach and West Beach are more exposed to waves from the southeast which are typically generated by local storms (Moffatt & Nichol, 1987).

Flood and erosion events are partly correlated with storms that occur during the El Nino phase of the El Nino – Southern Oscillation (ENSO) climatic fluctuation which occurs about every five to seven years with widely ranging intensity: High intensity El Nino conditions occurred in 1982-83 and 1997-98, with moderate intensity more recently in 2010 and 2016 (Seymour, 1983; Barnard et al, 2017). El Nino intensity may be elevated during the "warm" phase of the Pacific Decadal Oscillation (PDO) that is estimated to have a periodicity of about 30 to 50 years, also with varying intensity (Bromirski et al, 2012). During strong El Nino conditions, the storm tracks drop to lower latitudes closer to southern California, resulting in high precipitation, larger breaking waves and storm surge (NRC, 1984). El Nino also temporarily perturbs the circulation in the Pacific Ocean which results in higher ocean levels on the entire west coast (OPC, 2015). Therefore, Santa Barbara is more likely to flood from both rainfall and ocean sources during El Nino conditions. However, the timing of high rainfall and high ocean levels and waves are not completely correlated, and their "joint probability" of simultaneous occurrence at the 100-year or other extreme level is low. From an engineering perspective, the partial correlation is often represented by assuming a peak river flowrate occurs during a moderately elevated ocean level: For example, a 100-year creek flowrate may be modeled with an ocean level with a 1 year to 10-year recurrence, and a 100-year coastal event may be modeled with a 1 year to 10 year creek flowrate where pertinent. The treatment of partial correlation and joint probability in flood mapping is further explained in Garrity et al, 2016 and FEMA, 2015.

In summary, the FEMA flood map shown in Appendix D is a compilation of 100-year flood events computed for Arroyo Burro Creek, Mission Creek, Laguna Channel, Sycamore Creek and the Pacific Ocean for the dominant flood source and worst conditions. Additional information can be found in the Flood Insurance Study (FIS) reports that accompany the Flood Insurance Rate Map (FIRM).

Appendix C

Geologic Review of Seacliff Areas (Campbell Geo, Inc.)

CAMPBELL GEO, INC.
ENGINEERING AND ENVIRONMENTAL GEOSCIENCE

Sea Level Rise Adaption Plan for the LCP Update
Geologic Review of Seacliff Areas
City of Santa Barbara, California

August 17, 2018

Submitted to

Environmental Science Associates
550 Kearny Street, Suite 800
San Francisco, CA

Prepared by

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C A M P B E L L G E O, I N C.
Engineering and Environmental Geoscience

August 17, 2018

Environmental Science Associates
550 Kearny Street, Suite 800
San Francisco, CA

Attention: Mr. Louis White, PE

Subject: Sea Level Rise Adaption Plan
for the LCP Update – Geologic Review of Seacliff Areas
City of Santa Barbara, California

Dear Louis:

INTRODUCTION

This letter report summarizes the results of our geologic review of the sea level rise (SLR) hazard information provided by ESA, including the projected erosion resulting under various SLR scenarios in two current sets of hazard maps: the USGS Coastal Storm Modelling System (CoSMoS 3.0; Erikson et al. 2017) and the Santa Barbara County Coastal Resilience (ESA, 2015). The purpose of our work was to evaluate the geologic and seacliff conditions in the City of Santa Barbara relative to the future bluff top erosion or retreat predicted by the two approaches. We have reviewed and photo documented evidence of active or dormant erosion, relative exposure to wave runup and wave attack, and current (spring/summer 2018) beach sand profiles.

Our comments draw on Campbell·Geo's experience and site specific investigations of numerous coastal bluff properties in the City and County of Santa Barbara. In addition, regional geologic maps (Dibblee, 1966 and 1986; Hoover, 1978; Gurrola, 2002; Minor, 2009; and City of Santa Barbara General Plan, 2013) were reviewed during the course of this evaluation. Among the regional geologic maps we reviewed, the 1999 USGS Landslide Hazard Map (Bezore and Wills) also noted the existence of some landslides at the coastal bluffs, including at El Camino de la Luz and at Sea Ledge Lane.

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GEOLOGY

Regional Setting

The south coast of Santa Barbara County is located on the southern flank of the Santa Ynez Mountains, which make up a portion of the Transverse Range Province of California. The regional geologic structure consists of generally south dipping sedimentary rocks uplifted from the north by tectonic movement, including regional tectonic compression of the Santa Barbara Channel. In the coastal area of the City of Santa Barbara, tectonic movement is evident along the Mesa Fault and the Lavigia Fault, among other east to west trending structures. The uplifted Tertiary age rocks underlying the Mesa area of Santa Barbara are moderately to highly deformed by folding and faulting in the seacliff exposures between Leadbetter Beach and Hope Ranch. The coastal bluff at the Bellosguardo property (the former Clark Estate) is underlain by a Pleistocene debris flow deposit that shows some stratigraphy and is gently folded.

Site Geology: Lithology

The geologic units exposed is the coastal bluff areas are described by Dibblee (1966 and 1986) and Minor (2009), and include the Miocene-age Monterey formation and the Quaternary-age Casitas and marine terrace deposits. Holocene landslides and beach sand is also mapped. Artificial fill was not mapped by Dibblee or Minor, due to the regional nature of their work. Each geologic unit is described below from oldest to youngest.

Monterey Formation (Tm)

The Monterey formation is a white to gray marine siltstone and mudstone that is locally siliceous or cherty, diatomaceous and/or petroliferous. Some sections are moderately to highly fractured and con be accompanied by weathered material. The Monterey outcrop is well exposed at most areas of the seacliff.

Casitas Formation (Qca)

The Pleistocene-age Casitas formation is a moderately consolidated terrestrial alluvial fan (debris flow) deposit composed of pebbles, cobbles and boulders in a matrix of sand, silt and clay (minor). The unit is matrix supported in most locations exposed at the site but some areas are clast supported or are more indurated (hard) due to cementation of the matrix. The Casitas crops out along the lower portion of the seacliff near the Bellosguardo (former Clark Estate) property.

Marine Terrace Deposits (Qmt)

Unconsolidated sand and silt deposits are identified collectively as the marine terrace deposits, which unconformably overlie the Monterey and Casitas formations in roughly 10 to 20-foot thick sections.

Landslide Deposits (Qls)

This unit typically consists of fractured shale, sand, and sticky silt. Many of the shale fragments within the slide masses are relatively soft. Some of the slides are massive failures along daylighted bedding planes (such as the El Camino de la Luz landslide) and deep seated rotational slides. The slope failures at the coastal bluff adjacent to Bellosguardo are rather shallow erosional features.

Artificial Fill (Qaf)

Various amounts of artificial fill are found in the coastal bluff areas, typically associated with leveling building pads. A significant amount of artificial fill was noted at the area seaward of El Camino de la Luz, consisting of broken and regraded shale fragments. That fill is associated with grading of the landslide area that occurred after the 1978 landslide.

Beach Sand (Qbs)

Transitory deposits of beach sand are located from the toe of the seacliffs, typically in areas that extend 20 to as much as 150 feet oceanward. The amount of coverage varies by season and by wave and tidal conditions and is sometimes absent during winter months after high surf and tide events. Beach sand deposits near the eastern edge of the area (at the Bellosguardo revetment and jetties) are currently more stable, based on our observations over the last 15 to 20 years and as evidenced by the development of vegetation near the beach house.

Geologic Structure

The key feature of the seacliffs west of Leadbetter and Santa Barbara Point is the structurally complex folding of the Monterey formation that has resulted exposed sedimentary rock bedding planes with various orientations and angles of dip. In some portions of the coastal bluff in the Santa Barbara area, beds are dipping toward the ocean at an angle that is flatter or less steep than the angle of the slope face. This is called "daylighted" bedding, where the unsupported bedding plane surfaces can form landslides. Where daylighted bedding plane angles are relatively uniform and extensive, slope failures have developed, such as the 1978 landslide at El Camino de la Luz, located to the east of Edgewater Way. At that location, the bedding dips toward the ocean at angles measured to be from 10 to 35 degrees (PML/Weaver, 1978), resulting in a significant daylight condition since those angles are flatter (less steep) than the coastal slope. The western and eastern limits of the 1978 landslide are coincident with geometric changes in the bedding orientation of the Monterey formation planes.

Where the bedding is steeper, and does not exhibit a daylight condition in the bluff face, the slopes are generally more stable over the short term, with wave attack at the toe creating relatively steep slope angles. Bedding angle changes inland of the cliff face, for example where the bedding appears to flatten towards the hinge of an anticline in some areas, may result in daylighted bedding and an increased risk of slope failure and accelerated rate of erosion as the seacliff retreats.

The structure of the Casitas formation in the seacliff at Bellosguardo is a gently folded monocline where the sediments do not exhibit significant stratigraphic differentiation and do not present a significant hazard by failure from translational landslides along bedding planes.

The contact between the Monterey formation, the Casitas formation and the overlying terrace deposits is an angular unconformity. This term means that, in the time period between the deposition of the Monterey and the deposition of the terrace unit, tectonic deformation and erosion of the Monterey occurred before the terrace materials were deposited.

REVIEW OF CURRENT CONDITIONS AND THE SLR HAZARD MAPS

A reconnaissance level examination of current coastal bluff/seacliff conditions was made in May and June, 2018. Selected site photographs annotated with location and the location of the closest CoSMoS model transect number are appended to this letter. The purpose of this field effort was to review current geologic conditions, wave exposure and beach width, and, in combination with previous site specific geologic evaluations, assess the range in projections of future erosion and seacliff retreat presented in the CoSMoS and Coastal Resilience hazard maps.

Our comments are provided on Table I, organized by five separate lateral segments of the seacliff in the City of Santa Barbara from Sea Ledge Lane at the western edge of the city to the Bellosguardo (former Clark Estate) on the east.

The Coastal Resilience bluff erosion hazard maps were based on modeling the interaction of the wave runup elevation with the bluff morphology (ESA 2015). The approach utilizes a threshold approach, where the bluff toe is considered the elevation threshold for wave runup impacts on the bluff. The model estimates the increase in the erosion rate using the following steps: (1) correlate the historic erosion rate to the cumulative occurrence that wave runup elevations (i.e., total water level) exceeds the bluff toe threshold, (2) compute the increase in cumulative occurrence that the wave runup elevations exceed the bluff toe threshold for future conditions with sea level rise, (3) estimate the future erosion rate by scaling the historic erosion rate by the ratio of the future cumulative wave runup exceedance of bluff toe to the existing cumulative wave runup exceedance of the bluff toe. The model generally results in greater increases in the erosion rate for bluffs that are likely to be impacted by waves in the future, but may be less exposed to waves for existing conditions. The model is less sensitive to conditions where the relative change of bluff exposure to waves is small (e.g., bluffs impacted by waves for existing and future conditions). The Coastal Resilience model block-averages transects over sections of shore to account for variations of the erosion rates resulting from locations in different phases of bluff morphology (i.e., steep bluffs prone to erosion, or flatter bluffs that are less prone to erosion – see Young 2017).

In the areas immediately west and east of Arroyo Burro Beach County Park, based on our observations, and reported wave modeling and runup, it appears that the area to the west is less exposed to wave attack under current conditions, where the beach is somewhat wider. On the east, the beach is narrower and there is more wave contact with the toe of the seacliff. As sea level rise accelerates, the seacliff on the west, which now only occasionally is subject to wave attack, will be exposed to a greater change in conditions than the seacliff to the east, which is more frequently contacted by wave runup. In theory, the erosion rate on the west will, therefore, accelerate faster, resulting in a greater response and retreat of the seacliff. This variation is evident in the erosion maps.

Based on our discussions with one of the authors of the USGS CoSMoS model (Dr. Patrick Limber), the CoSMoS bluff recession model is very sensitive to the input parameter of the historic retreat rate. The CoSMoS bluff erosion projections are based on calculations of five different models that are dependent on historic erosion rates, water levels from tides and wave runup, and the shore and bluff morphology (Limber et al. 2018). These models range from simple Bruun-type calculations to more detailed interactions of these parameters. The CoSMoS modeling includes a wave exposure approach that is similar to that used for the Coastal Resilience bluff modeling. Where historic estimated erosion rates are high, the model predicts a much higher future rate and total erosion distance. Conversely, where historic erosion rates are low, the model predicts a relatively low future rate and lower total erosion distance. However, the historic retreat rates are estimated over a large number of locations in Southern California and there is a significant level of uncertainty as would be expected for a regional study. Site specific historic retreat rates (discussed below) are considered to be more accurate.

THREE CASE STUDIES – SITE SPECIFIC INVESTIGATIONSAND COMPARISON TO CURRENT SLR MODELS

We have reviewed the analysis and determination of structure foot print setbacks conducted at three selected sites in the city, based on site specific investigations conducted at various times by Campbell Geo between 2002 and 2012. The investigations were conducted in general conformance with the California Coastal Commission guideline (Johnsson, 2002) and made use of the analysis of historical/current aerial photographs, historical/current surveys, subsurface investigation, geotechnical lab analysis of soil and rock samples and slope stability modelling. The purpose of these studies was to evaluate seacliff retreat and slope stability to determine an appropriate development setback line to accommodate 75 years of retreat. The increase in future retreat rates from the measured historical retreat rate was, at the time of these studies, assumed to be insignificant for the 75 year (or less) project design life. Two of the site specific studies prepared by this office were submitted by private property owners to the City of Santa Barbara to support residential remodeling projects (Medcliff Road and Edgewater Way), both of which were reviewed and approved by the city. We have compared the results of the site specific investigations with the projections of seacliff erosion derived by the CoSMoS and Coastal Resilience models. A summary of the comparison is presented on Table II.

In general, the site specific measurement of seacliff retreat at the toe or the top of the bluffs are lower at the two seacliff areas (Medcliff and Edgewater sites) described above than the CoSMoS top pf bluff historic retreat estimates. At the Bellosguerdo site, the historic rate of retreat based on survey data at the top of the bluff is still significantly higher than the CoSMoS estimate.

CONCLUSIONS

Although the projected future coastal bluff erosion is subject to a great deal of variation based on a wide range of Sea Level Rise scenarios, it is clear that in response to an accelerated rate of rising sea level, the rate of seacliff erosion (retreat) will also increase as the seacliff is exposed to higher wave energies for longer periods of time. The USGS CoSMoS model and the Coastal Resilience Model are sensitive to estimated historical rate of retreat. The CoSMoS model determines the historical rate using regionally mapped shoreline and bluff edge locations, with data that is only accurate to 10 meters (33 feet). That analysis may generate a conservatively high future rate of retreat, and thereby generate unrealistically high future total erosion and retreat of the seacliff edge. Where historic retreat rates are low, the model may generate a lower future rate of retreat. For example, at the Bellosguardo site, the CoSMoS model has used a historic retreat rate that is lower than site specific measurement made after the construction of the rock revetment in the 1980's, which has greatly reduced erosion at the toe temporarily since that time. The top of the bluff has retreated, primarily due to erosional "flattening" of the slope angle, rather than erosion at the toe of the slope, as shown on one of the photos in the appendix to this report.

The variation between site specific historic retreat and the same parameter used in the CoSMoS and Coastal Resilience Models indicates they are useful tools for adaption planning at the regional to community scale. Sea level rise hazard mapping, such as the CoSMoS or Coastal Resilience products, should be periodically updated as actual sea level rise data is measured in the future to check the assumptions of low, medium, and worst case scenarios. To track actual seacliff retreat at the top and the toe, the city may wish to consider establishing a monitoring program based on a handful of survey transect locations (for example at city owned properties such as the Douglas Family Preserve/Wilcox property, Shoreline Park and the

Bellosguardo site) to have a licensed surveyor create detailed profiles on an annual basis or some other interval at the same location(s).

If you have any questions concerning this report, please do not hesitate to contact us.

Sincerely,
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Attachments: Tables (2)
Appendices

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TABLE I
SUMMARY AND COMMENTS FOR SEACLIFF EROSION PROJECTIONS
USGS COSMOS AND SB COUNTY RESILIENCE MODELS
City of Santa Barbara, California – August 2018

SEACLIFF AREA	**1. West of Arroyo Burro to Sea Ledge Lane**	**2. East of Arroyo Burro to Loyola Drive**	**3. East of Loyola Drive to Santa Barbara Point**	**4. Leadbetter Seacliff and Beach**	**5. Clark Estate / Bellosguardo**
Geologic Units and Structure	Monterey formation (Tm) overlain by thin marine terrace (Qmt); Tm bedding is daylighted in some areas; large ancient landslide at Sea Ledge Lane	Monterey formation (Tm) overlain by thin marine terrace (Qmt); Tm bedding is daylighted in some areas; large modern landslide at El Camino de la Luz	Monterey formation (Tm) overlain by thin marine terrace (Qmt); Tm bedding is daylighted in limited areas	Monterey formation (Tm) overlain by thin marine terrace (Qmt); Tm bedding is daylighted in some areas; rock revetment and artificial fill slope on east side protecting Shoreline Drive	Casitas formation (Qca) overlain by thin marine terrace (Qmt); rock revetment at toe of slope and two old sheet pile groins trapping beach sand
Wave Exposure at Toe	HIGH	HIGH	HIGH	LOW TO MODERATE	LOW
Beach Width	MODERATE TO NARROW	NARROW	NARROW	NARROW TO WIDE	MODERATE TO WIDE
CoSMoS to SB County Projected Erosion Model Comparisons for the Years 2060 and 2100	2060 - Projections are in fairly good agreement for both models with and w/out armoring	2060 - Projections are in fairly good agreement for both models (except between SB Lighthouse and Loyola Drive)	2060 - Projections are in fairly good agreement for both models with and w/out armoring	2060 - Projections are in fairly good agreement for both models with and w/out armoring	2060 - Projections are in fairly good agreement for both models with and w/out armoring
	2100 - Coastal Resilience hazard maps show greater erosion than CoSMoS	2100 - Coastal Resilience hazard maps show greater erosion between Arroyo Burro and SB Lighthouse but CoSMoS shows greater erosion between Lighthouse and Loyola	2100 - Projections are in fairly good agreement for both models with and w/out armoring	2100 - Projections are in fairly good agreement for both models with and w/out armoring; erosion boundaries east of La Marina Drive need to be considered for accuracy	2100- Projections show zero erosion for both models with armoring, which may not be accurate; the projection without armoring shows higher erosion with Coastal Resilience, but that prediction looks fairly reasonable with removal of the rock revetment/sheet piles

TABLE I
SUMMARY AND COMMENTS FOR SEACLIFF EROSION PROJECTIONS
USGS COSMOS AND SB COUNTY RESILIENCE MODELS
City of Santa Barbara, California – August 2018

SEACLIFF AREA	**1. West of Arroyo Burro to Sea Ledge Lane**	**2. East of Arroyo Burro to Loyola Drive**	**3. East of Loyola Drive to Santa Barbara Point**	**4. Leadbetter Seacliff and Beach**	**5. Clark Estate / Bellosguardo**
Additional Comments	CoSMoS transects 4030, 4031, and 4032 show the 2010 cliff edge at locations on ancient landslide at Sea Ledge Lane. The CoSMoS predicts zero erosion with armoring at Sea Ledge Lane. Area just west of Arroyo Burro showing very high future total erosion may be due to high historic rate estimated in CoSMoS model and the the absence of the Coastal Resilience block averaging method	Predicted retreat inland of Mesa Lane steps by CoSMoS may be high due to high historic rate estimated in CoSMoS model and the the absence of the block averaging method		Top of pre-SB Harbor seacliff, inland of Leadbetter Beach, Shoreline Drive, and two parking lots needs to be considered for accuracy at CoSMoS transects 3973 and 3975. Much of this area is not subject to wave attack under current conditions, but SLR will cause increased wave contact and accelerated erosion rates	Most of this area is not subject to wave attack under current conditions, but SLR will cause increased wave contact and accelerated erosion rates

TABLE II
COMPARISION OF SEACLIFF EROSION PROJECTIONS
SITE SPECIFIC INVESTIGATIONS, USGS COSMOS, AND COASTAL RESILIENCE MODELS
City of Santa Barbara, California – August 2018

LOCATION AND CLOSEST COSMOS TRANSECT NUMBER	**Medcliff Road – Transect No. 4010**	**Edgewater Way – Transect No. 4002**	**Clark Estate / Bellosguardo – Transect No. 3932**
Historical Erosion Rate (CoSMoS)	0.51 ft/yr	1.06 ft/yr	0.24 ft/yr
Historical Erosion Rate (Coastal Resilience)	1.02 ft/yr	1.02 ft/yr	0.43 ft/yr
Historical Erosion Rate (site specific investigation survey/aerial photos)	0.17 ft/yr (average retreat at toe from 1953 to 2011)	0.2 ft/yr (average retreat at toe from 1953 to 2012)	1.02 ft/yr (top of bluff – 1929 to 1983)[1] 0.36 ft/yr (top of bluff – 1986 to 2001)[2]
Total Future Erosion (Rate) Projected from CoSMoS[4] **2060 – 2.5 ft. SLR; 2100 – 5.5 ft. SLR**	2060 – 58 ft (1.2 ft/yr) 2100 – 102 ft (1.1 ft/yr)	2060 – 110 ft (2.2 ft/yr) 2100 – 187 ft (2.1 ft/yr)	2060 – 27 ft (0.54 ft/yr)[3] 2100 – 44 ft/ (0.49 ft/yr)[3]
Total Erosion from Projected from Coastal Resilience[4] **2060 - 2.6 ft. SLR; 2100 – 5.5 ft. SLR**	2060 – 87 ft (1.7 ft/yr) 2100 – 317 ft/ (3.5 ft/yr)	2060 – 86 ft (1.7 ft/yr) 2100 – 311 ft (3.5 ft/yr)	2060 – 41 ft (0.8 ft/yr) 2100 – 240 ft (2.7 ft/yr)
Recommended 75 Year Setback from Top of Bluff by Site Specific Study Completed in Year Noted (includes geotechnical F.S. analysis)	7 feet (2011, Campbell Geo, Inc.)	59 feet (2012, Campbell Geo, Inc.)	57 feet (2002, Campbell Geo, Inc.)

Notes: (1) rates estimated from aerial photographs in period prior to revetment installation at toe of seacliff at Bellosguardo
(2) rates estimated from site specific survey data after construction of revetment at Bellosguardo
(3) both CoSMoS projections at Bellosguardo are without armoring; the model projects zero erosion with armoring at this site
(4) Future erosion rates for CoSMoS and Coastal Resilience computed relative to year 2010

SEACLIFF FEATURES
CLARK ESTATE/BELLOSGUARDO
Santa Barbara, California
August, 2018

Seacliff Showing Revetment at Toe – View to West
(near CoSMoS Transect 3932)

Seacliff Showing Non-Marine Erosion – View to North

(near CoSMoS Transect 3932)

SEACLIFF FEATURES BETWEEN
SB CITY COLLEGE AND MESA LANE
Santa Barbara, California
May 28, 2018

- Top of Bluff at SB City College West Campus; View to Southwest toward Leadbetter Beach
(near CoSMoS Transect 3973)

- Revetment and Fill Slope at Leadbetter Beach near Santa Barbara Point; View to Southwest
(near CoSMoS Transect 3977)

SEACLIFF FEATURES BETWEEN
SB CITY COLLEGE AND MESA LANE
Santa Barbara, California
May 28, 2018

- Location of 2008 Bedding Plane Landslide at Shoreline Park (near CoSMoS Transect 3982)

- Seacliff Adjacent to West End of Shoreline Park (near CoSMoS Transect 3987)

SEACLIFF FEATURES BETWEEN
SB CITY COLLEGE AND MESA LANE
Santa Barbara, California
May 28, 2018

- Seacliff Adjacent to Thousand Steps at Santa Cruz Boulevard (near CoSMoS Transect 3990)

- Seacliff and Residential Structure West of Thousand Steps and East of SB Lighthouse
(West of CoSMoS Transect 3992)

SEACLIFF FEATURES BETWEEN
SB CITY COLLEGE AND MESA LANE
Santa Barbara, California
May 28, 2018

- Seacliff Area East of SB Lighthouse
(near CoSMoS Transect 3997)

- Daylighted Monterey Shale Bedding on East Side of El Camino de la Luz Landslide
(near CoSMoS Transect 4000)

SEACLIFF FEATURES BETWEEN
SB CITY COLLEGE AND MESA LANE
Santa Barbara, California
May 28, 2018

- Ruptured Shale at Toe of 1978 El Camino de la Luz Landslide
(near CoSMoS Transect 4001)

- Landslide located East of Mesa Lane Staircase
(near CoSMoS Transect 4005)

SEACLIFF FEATURES BETWEEN
MESA LANE AND SEA LEDGE
Santa Barbara, California
May 27, 2018

Top of Bluff Showing Daylighted Monterey shale Beds – View to East of from Mesa Lane Staircase (near CoSMoS Transect 4007)

Sea Cliff West of Mesa Lane Staircase (near CoSMoS Transect 4007)

SEACLIFF FEATURES BETWEEN
MESA LANE AND SEA LEDGE
Santa Barbara, California
May 27, 2018

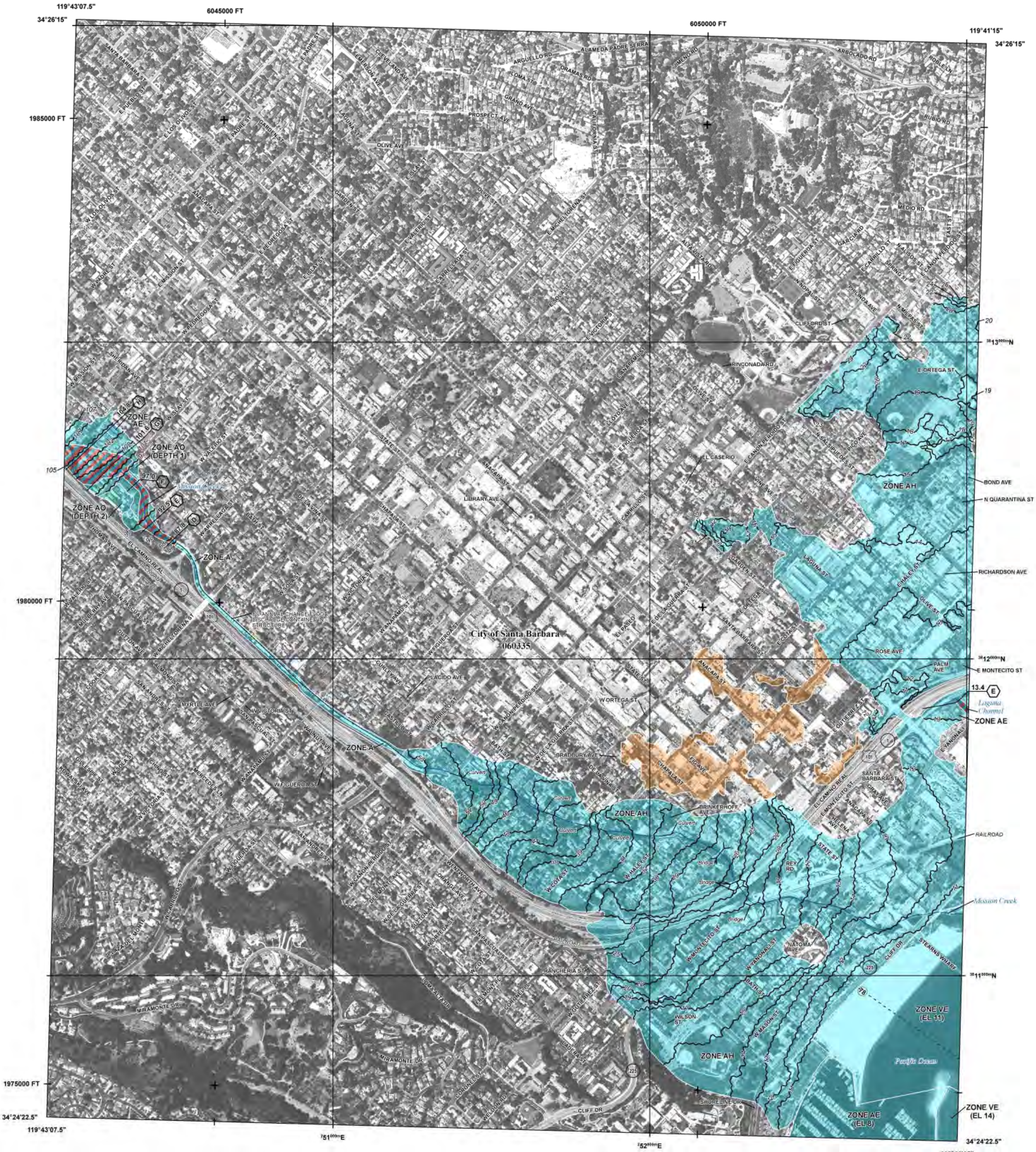
Anticline in Monterey shale West of Mesa Lane / East of Arroyo Burro (near CoSMoS Transect 4008)

Bedding Dip Slope Adjacent to Douglas Family Preserve (near CoSMoS Transect 4014)

SEACLIFF FEATURES BETWEEN
MESA LANE AND SEA LEDGE
Santa Barbara, California
May 27, 2018

Revetment Adjacent to Pre-Historic
Landslide – Sea Ledge Lane
(near CoSMoS Transect 4031)

Appendix D
FEMA FIRM Panels for City of Santa Barbara



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT HTTP://MSC.FEMA.GOV

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A, V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee See Notes *Zone X*
OTHER AREAS	NO SCREEN Areas of Minimal Flood Hazard *Zone X*
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert or Storm Sewer
	Levee, Dike or Floodwall
OTHER FEATURES	E 18.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation (BFE)
	8 Coastal Transect
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
	512 Base Flood Elevation Line (BFE)
	Limit of Study
	Jurisdiction Boundary

NOTES TO USERS

For information and questions about this Flood Insurance Rate Map (FIRM), available products associated with this FIRM, including historic versions, the current map date for each FIRM panel, how to order products, or the National Flood Insurance Program (NFIP) in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1-877-336-2627) or visit the FEMA Flood Map Service Center website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website.

Communities annexing land on adjacent FIRM panels must obtain a current copy of the adjacent panel as well as the current FIRM Index. These may be ordered directly from the Map Service Center at the number listed above.

For community and countywide map dates refer to the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your Insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

Base map information shown on this FIRM was derived from digital orthophotography collected by the Coastal Service Center and U.S. Department of Agriculture Farm Service Agency. Coastal Service Center imagery was flown in 2011 and was produced with a sub-meter ground sample distance. Department of Agriculture imagery was flown in 2014 and was produced with a 1-meter ground sample distance.

SCALE

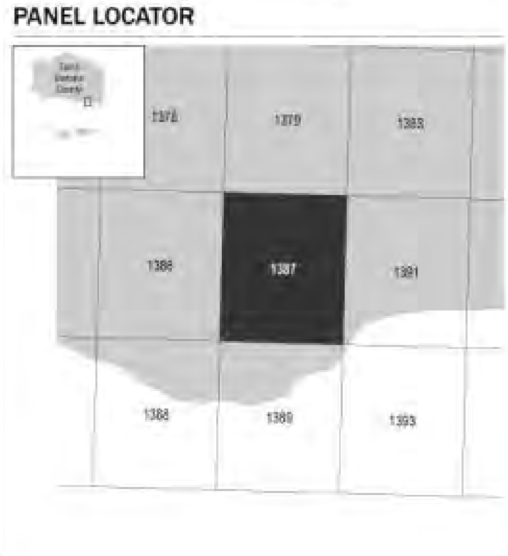
Map Projection: Universal Transverse Mercator Zone 11N; North American Datum 1983; Western Hemisphere; Vertical Datum: NAVD 88

1 inch = 500 feet 1:6,000

0 250 500 750 1,000 2,000 feet

0 125 250 500 meters

PANEL LOCATOR



National Flood Insurance Program

FEMA

NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP

SANTA BARBARA COUNTY, CALIFORNIA
and Incorporated Areas

PANEL **1387** OF **1835**

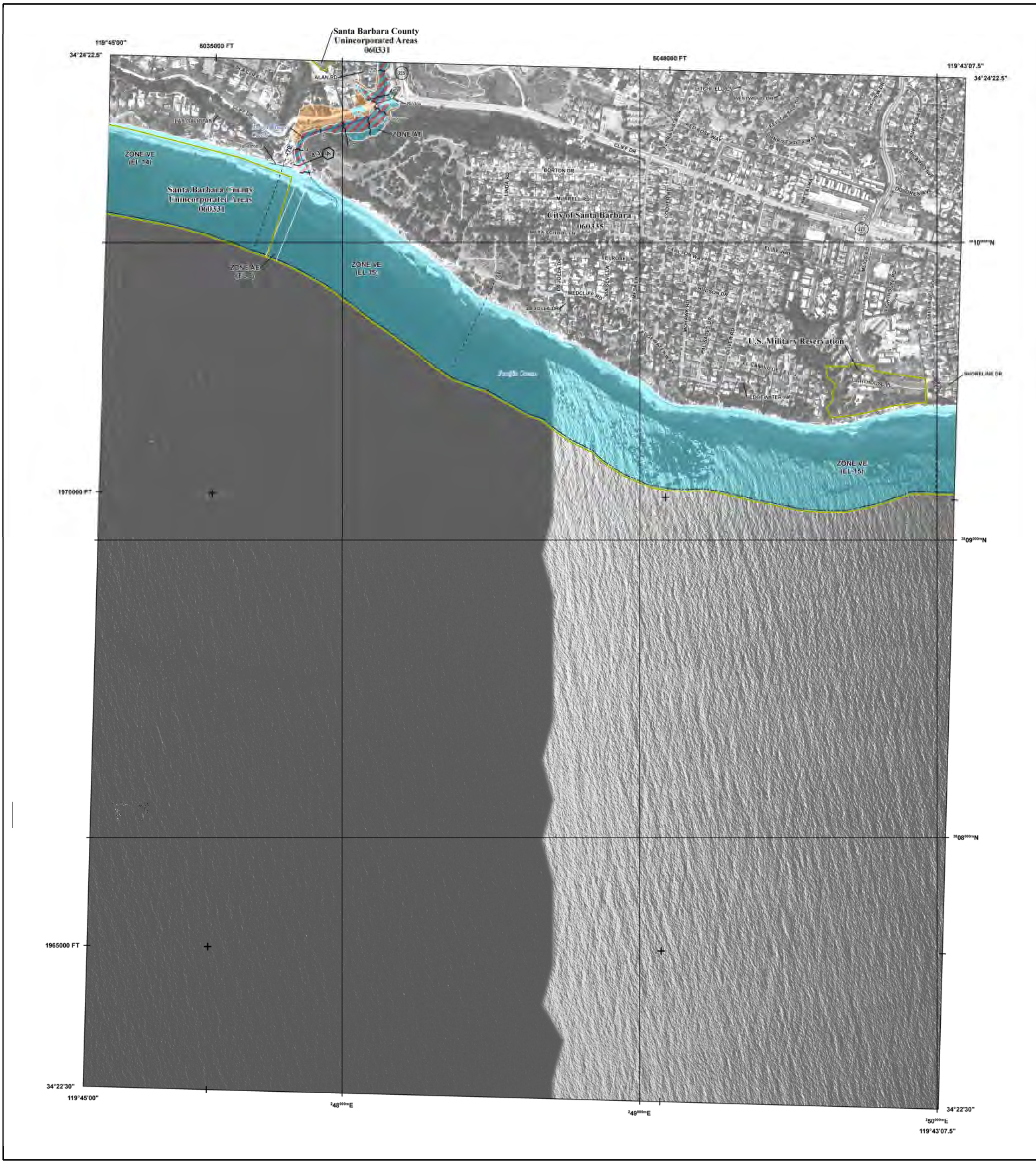
Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
SANTA BARBARA, CITY OF	060335	1387	J

VERSION NUMBER
2.3.3.3

MAP NUMBER
06083C1387J

MAP REVISED
September 28, 2018



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT HTTP://MSC.FEMA.GOV

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A, V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee See Notes *Zone X*
OTHER AREAS	NO SCREEN Areas of Minimal Flood Hazard *Zone X*
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert or Storm Sewer
	Levee, Dike or Floodwall
	(E) 18.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation (BFE)
	(8) Coastal Transect
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
	~~ 513 ~~ Base Flood Elevation Line (BFE)
OTHER FEATURES	Limit of Study
	Jurisdiction Boundary

NOTES TO USERS

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For community and countywide map dates refer to the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your Insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

Base map information shown on this FIRM was derived from digital orthophotography collected by the Coastal Service Center and U.S. Department of Agriculture Farm Service Agency. Coastal Service Center imagery was flown in 2011 and was produced with a sub-meter ground sample distance. Department of Agriculture imagery was flown in 2016 and was produced with a 1-meter ground sample distance.

SCALE

Map Projection:
Universal Transverse Mercator Zone 11N; North American Datum 1983;
Western Hemisphere; Vertical Datum: NAVD 88

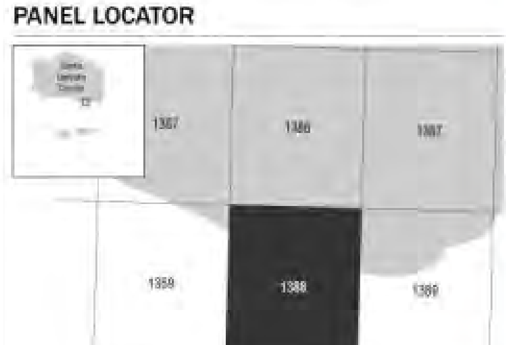
N

1 inch = 500 feet 1:6,000

0 250 500 750 1,000 2,000 feet

0 125 250 500 meters

PANEL LOCATOR



FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM

FLOOD INSURANCE RATE MAP

SANTA BARBARA
COUNTY, CALIFORNIA
and Incorporated Areas

PANEL 1388 OF 1835

FEMA

Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
SANTA BARBARA, CITY OF	060335	1388	H
SANTA BARBARA COUNTY	060331	1388	H

VERSION NUMBER
2.3.3.3

MAP NUMBER
06083C1388H

MAP REVISED
September 28, 2018

FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

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SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A, V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee See Notes *Zone X*
OTHER AREAS	NO SCREEN Areas of Minimal Flood Hazard *Zone X*
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert or Storm Sewer
	Levee, Dike or Floodwall
	18.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation (BFE)
	Coastal Transect
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
	512 Base Flood Elevation Line (BFE)
OTHER FEATURES	Limit of Study
	Jurisdiction Boundary

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SCALE

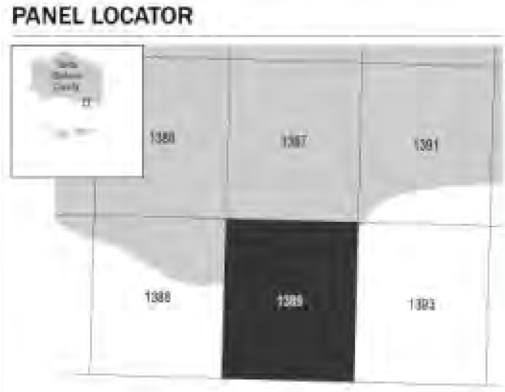
Map Projection:
Universal Transverse Mercator Zone 11N; North American Datum 1983; Western Hemisphere; Vertical Datum: NAVD 88

1 inch = 500 feet 1:6,000

0 250 500 750 1,000 2,000 feet

0 125 250 500 meters

PANEL LOCATOR



FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP

SANTA BARBARA COUNTY, CALIFORNIA
and Incorporated Areas

PANEL 1389 OF 1835

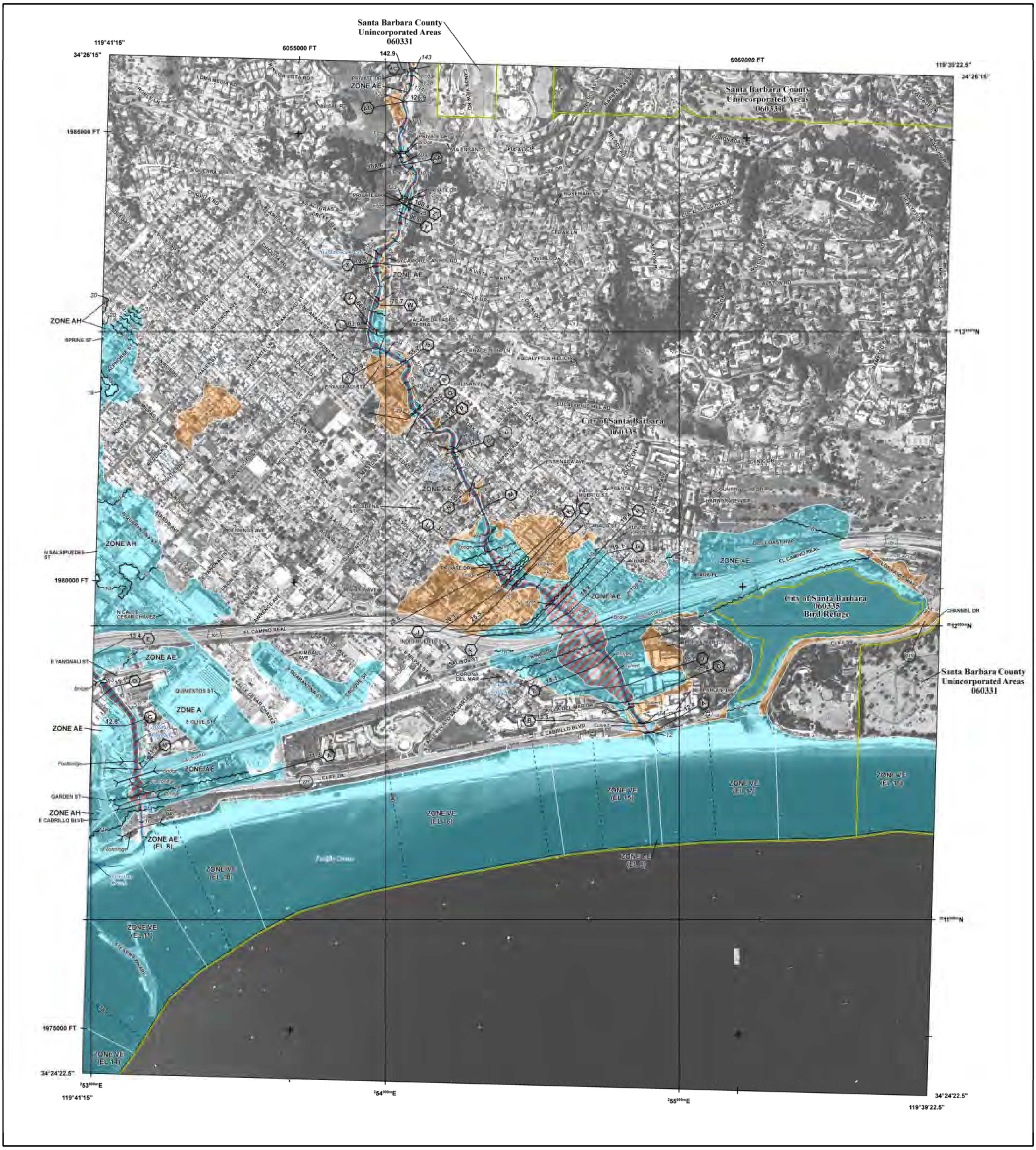
Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
SANTA BARBARA, CITY OF	060335	1389	H

VERSION NUMBER
2.3.3.3

MAP NUMBER
06083C1389H

MAP REVISED
September 28, 2018



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

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SPECIAL FLOOD HAZARD AREAS		Without Base Flood Elevation (BFE) *Zone A, V, A99*
		With BFE or Depth *Zone AE, AO, AH, VE, AR*
		Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD		0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
		Future Conditions 1% Annual Chance Flood Hazard *Zone X*
		Area with Reduced Flood Risk due to Levee See Notes *Zone X*
OTHER AREAS	NO SCREEN	Areas of Minimal Flood Hazard *Zone X*
		Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES		Channel, Culvert or Storm Sewer
		Levee, Dike or Floodwall
	(E) 18.2 / 17.5	Cross Sections with 1% Annual Chance Water Surface Elevation (BFE)
	(8)	Coastal Transect
		Coastal Transect Baseline
		Profile Baseline
		Hydrographic Feature
OTHER FEATURES	512	Base Flood Elevation Line (BFE)
		Limit of Study
		Jurisdiction Boundary

NOTES TO USERS

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SCALE

Map Projection:
Universal Transverse Mercator Zone 11N; North American Datum 1983;
Western Hemisphere; Vertical Datum: NAVD 88

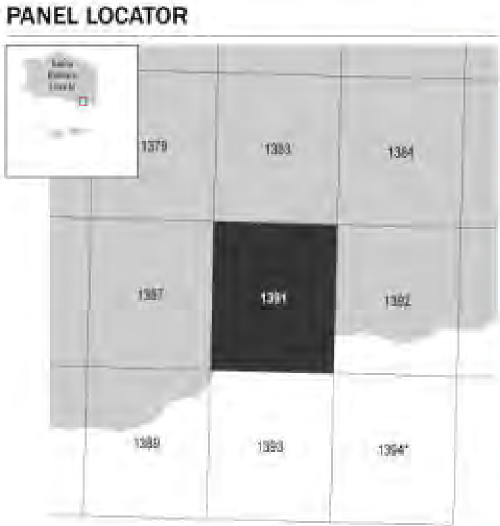
N

1 inch = 500 feet 1:6,000

0 250 500 750 1,000 2,000 feet

0 125 250 500 meters

PANEL LOCATOR



*PANEL NOT PRINTED

FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP

SANTA BARBARA COUNTY, CALIFORNIA
and Incorporated Areas

PANEL **1391** OF **1835**

FEMA

Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
SANTA BARBARA, CITY OF	060335	1391	J
SANTA BARBARA COUNTY	060331	1391	J

VERSION NUMBER
2.3.3.3

MAP NUMBER
06083C1391J

MAP REVISED
September 28, 2018

Appendix E
Sea-level Rise Hazard Maps by Hazard Type

SOURCE: USGS, ESA

Figure E-1
Erosion Hazards

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

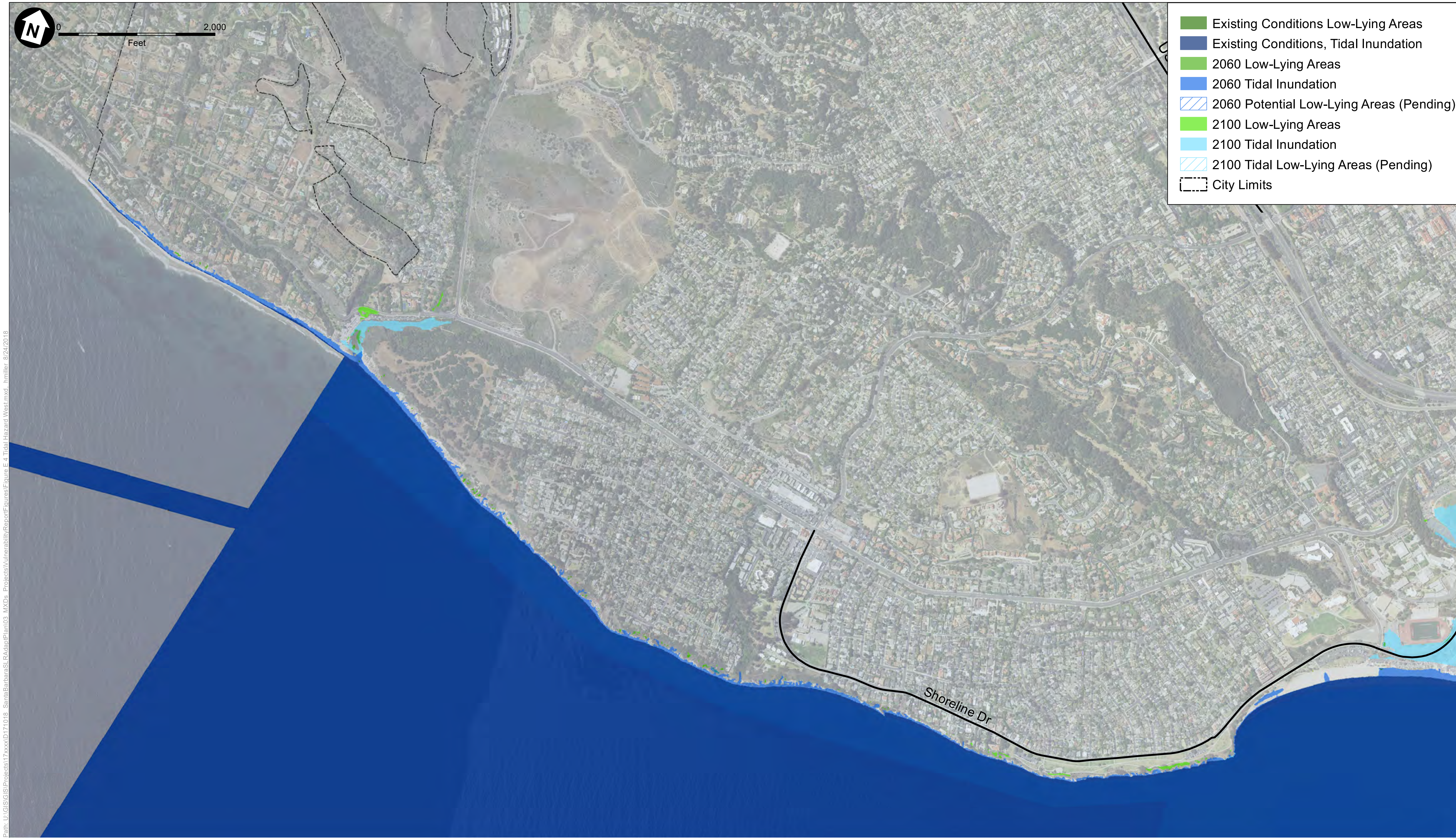
Figure E-2
Erosion Hazards

SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

Figure E-3
Tidal Inundation Hazards

ESA



SOURCE: USGS, ESA

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

Figure E-4
Tidal Inundation Hazards

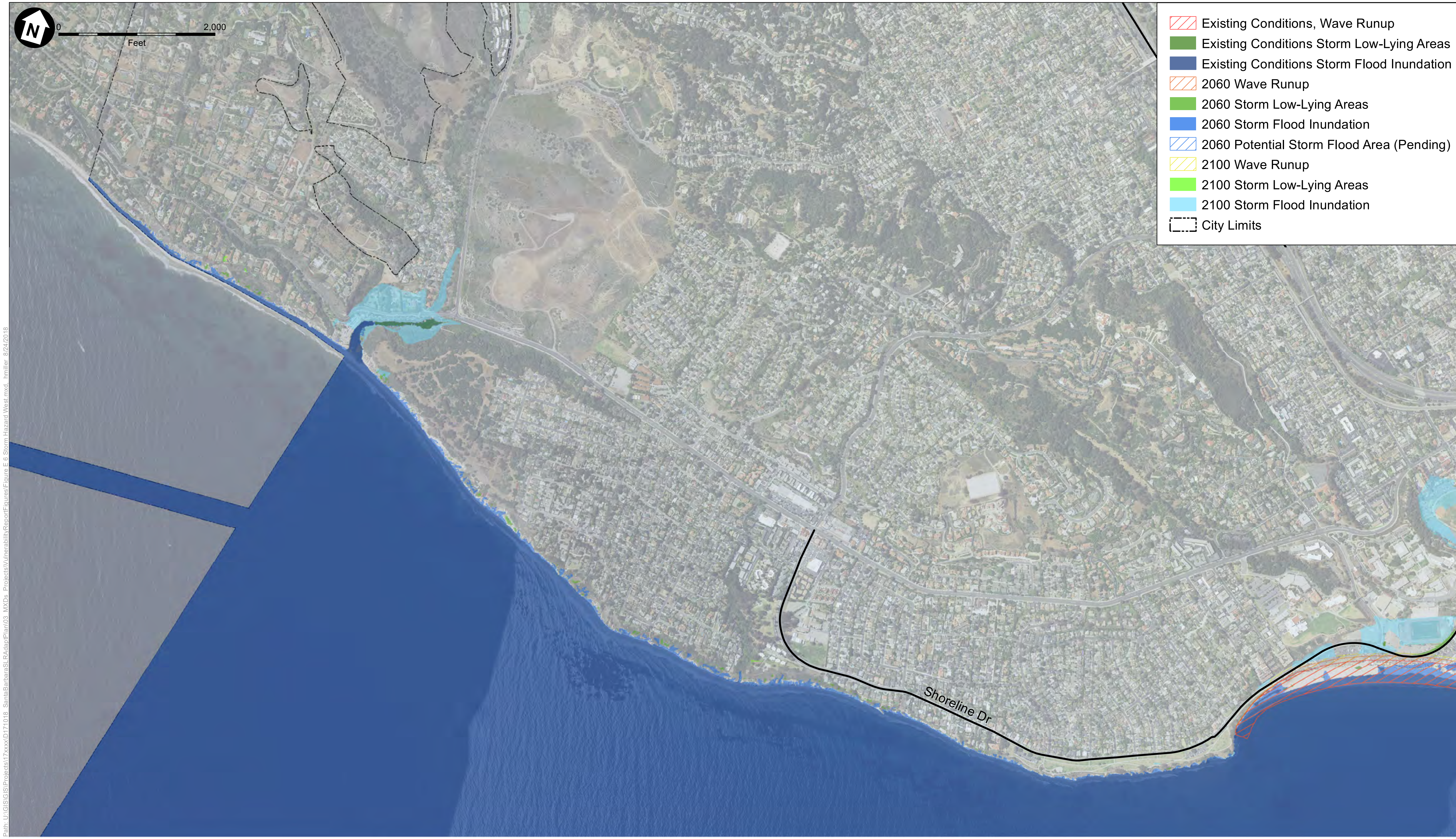
ESA

SOURCE: USGS, ESA

SCity of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

ESA

Figure E-5
Storm Inundation Hazards



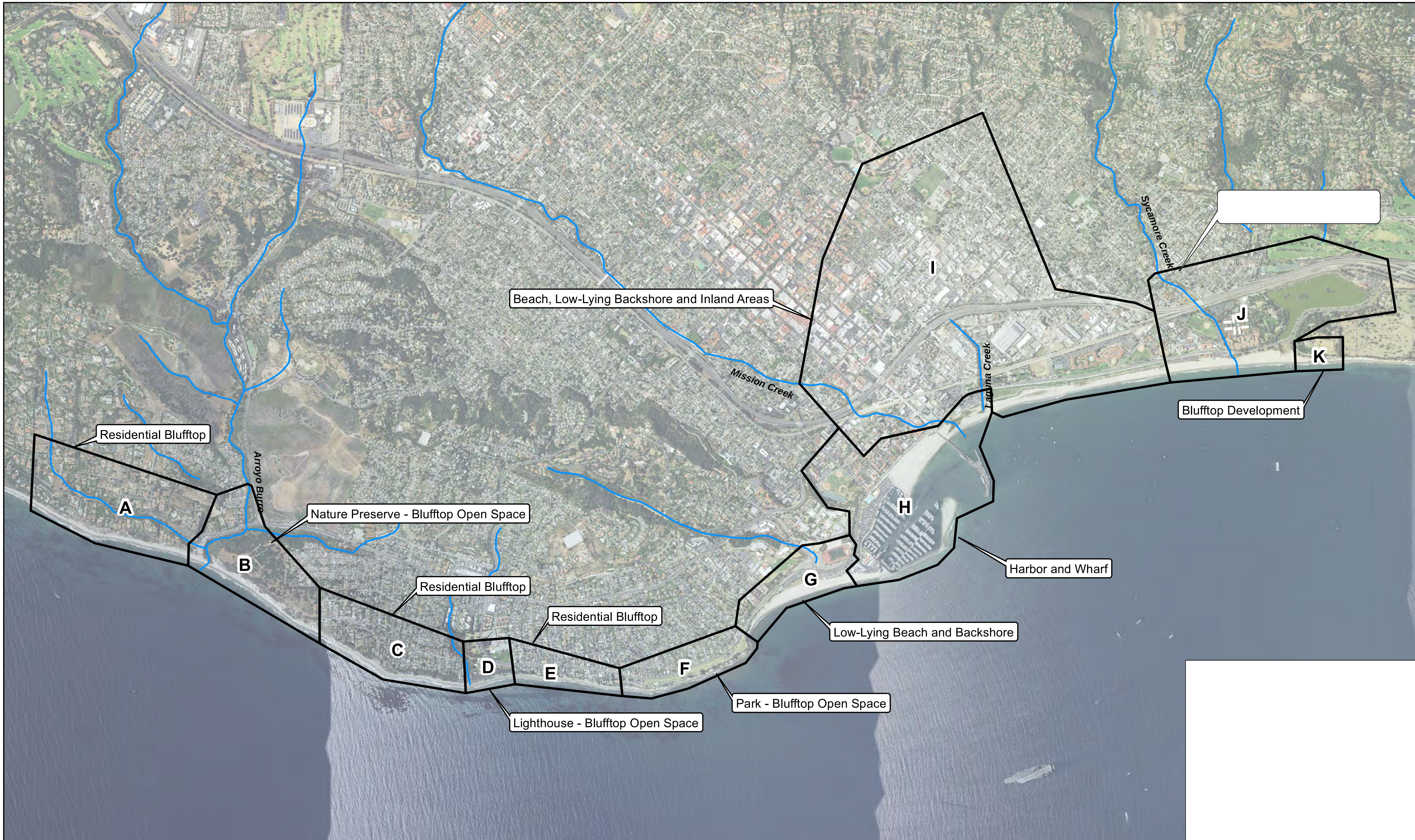
SOURCE: USGS, ESA

SCity of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update / D171018.00

Figure E-6
Storm Inundation Hazards

ESA

Appendix F
Asset Exposure Tables for City and Each Subarea



SOURCE:

City of Santa Barbara Sea-Level Rise Adaptation Plan for the LCP Update. 171018

Figure F-1

Shoreline Hazard Planning Subareas

Table F-1. Santa Barbara Exposed Public Works Assets

All Subareas

			Existing Conditions						
Category	**Assets**	**Units**	**Bluff Erosion***	**Shore Erosion***	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying***	**Flood Prone***
Tansportation	Railroads	ft	0	0	0	0	176	0	0
	Roads	ft	0	0	1,360	478	73	0	0
	Public Parking	sq ft	0	0	66,282	122,980	1,771	0	0
Communications	Fiber Optic Cabinets	ct	0	0	0	0	0	0	0
	Fiber Optic Cables	ft	0	0	0	0	67	0	0
Critical Facilities	Fire Stations	ct	0	0	0	0	0	0	0
	Police Stations	ct	0	0	0	0	0	0	0
	Evacuation Routes	ft	0	0	0	0	0	0	0
Recreation	CA Coastal Trail	ft	0	0	0	4,064	67	0	0
	Parks	sq ft	0	0	804,596	3,384,008	186,805	0	0
Parcels	Parcels	ct	0	0	62	17	100	0	0
Sewer	Lift Stations	ct	0	0	0	0	0	0	0
	Laterals	ft	0	0	0	142	0	0	0
	Force Mains	ft	0	0	0	0	0	0	0
	Gravity Mains	ft	0	0	1,215	2,052	168	0	0
Stormwater	Drainage Pipes	ft	0	0	26	835	206	0	0
	Drainage Channels	ft	0	0	499	1,309	2,359	0	0
	Water Control Structures	ct	0	0	0	2	1	0	0
Water Supply	Raw Water Mains	ft	0	0	0	0	0	0	0
	Water Mains	ft	0	0	0	0	0	0	0
	Recycled Mains	ft	0	0	0	3,516	27	0	0
	Recycled Laterals	ft	0	0	0	21	0	0	0
Harbor Infrastructu	Breakwater (Concrete)	ft	0	0	1,298	572	1,049	0	0
	Breakwater (Rip-Rap)	ft	0	0	10,168	62	408	0	0
	Launch Ramps	ft	0	0	452	0	6	0	0
	Rock Groins	ft	0	0	0	316	17	0	0
	Rock Groins (Rip-Rap)	ft	0	0	658	61	233	0	0
	Waterfront Street Parking	ft	0	0	0	533	0	0	0
Wells	Groundwater Wells	ct	0	0	0	0	0	0	0
	Monitoring Wells	ct	0	0	0	0	0	0	0
	Production Wells	ct	0	0	0	0	0	0	0

** Bluff Erosion, Shore Erosion, Low-Lying Areas, and Flood Prone Areas were not considered for Existing Conditions*

Table F-2. Santa Barbara Exposed Public Works Assets

All Subareas

			Year 2060, LIG						
Category	**Assets**	**Units**	**Bluff Erosion**	**Shore Erosion**	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tansportation	Railroads	ft	0	0	176	0	43	0	1,480
	Roads	ft	1,985	0	1,506	3,409	533	2,397	4,011
	Public Parking	sq ft	817	5,527	250,955	312,449	95,898	0	16,726
Communications	Fiber Optic Cabinets	ct	0	0	0	1	0	0	2
	Fiber Optic Cables	ft	0	0	67	3,838	1,120	0	870
Critical Facilities	Fire Stations	ct	0	0	0	0	0	0	0
	Police Stations	ct	0	0	0	0	0	0	0
	Evacuation Routes	ft	0	0	0	15	0	0	12
Recreation	CA Coastal Trail	ft	6,425	1,102	1,867	8,253	577	0	306
	Parks	sq ft	1,036,626	1,537,190	1,610,215	2,400,287	340,593	0	303,561
Parcels	Parcels	ct	135	15	44	31	35	26	135
Sewer	Lift Stations	ct	0	0	0	0	0	0	0
	Laterals	ft	676	0	253	321	646	1,609	1,533
	Force Mains	ft	0	0	0	0	0	0	0
	Gravity Mains	ft	3,278	1,335	2,073	4,477	3,465	1,976	2,986
Stormwater	Drainage Pipes	ft	2,476	193	716	2,911	859	3,049	4,112
	Drainage Channels	ft	236	719	2,607	275	3,451	0	1,318
	Water Control Structures	ct	0	1	1	1	0	0	0
Water Supply	Raw Water Mains	ft	0	0	0	0	0	0	0
	Water Mains	ft	0	0	0	25	0	0	0
	Recycled Mains	ft	1,641	1,430	1,316	4,959	570	0	1,294
	Recycled Laterals	ft	6	15	6	120	47	27	29
Harbor Infrastructu	Breakwater (Concrete)	ft	0	0	3,753	551	732	0	0
	Breakwater (Rip-Rap)	ft	0	0	11,480	24	89	0	0
	Launch Ramps	ft	0	0	458	0	0	0	0
	Rock Groins	ft	0	0	480	396	482	0	0
	Rock Groins (Rip-Rap)	ft	0	0	1,204	66	57	0	0
	Waterfront Street Parking	ft	0	0	0	2,332	1,737	0	1,807
Wells	Groundwater Wells	ct	0	0	0	0	0	0	0
	Monitoring Wells	ct	0	0	0	2	0	0	0
	Production Wells	ct	0	0	0	0	0	0	0

Table F-3. Santa Barbara Exposed Public Works Assets
All Subareas

			Year 2100, LIG						
Category	**Assets**	**Units**	**Bluff Erosion**	**Shore Erosion**	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tansportation	Railroads	ft	0	0	24,127	0	13,483	0	0
	Roads	ft	6,888	0	35,918	1,805	57,939	425	19,498
	Public Parking	sq ft	13,522	131,517	794,216	131,277	311,037	10,799	0
Communications	Fiber Optic Cabinets	ct	0	0	9	1	7	0	3
	Fiber Optic Cables	ft	0	1,421	9,746	1,268	6,685	23	2,536
Critical Facilities	Fire Stations	ct	0	0	0	0	1	0	0
	Police Stations	ct	0	0	0	0	0	0	0
	Evacuation Routes	ft	257	0	827	0	2,220	243	0
Recreation	CA Coastal Trail	ft	9,945	4,597	9,790	1,797	1,561	1,736	0
	Parks	sq ft	1,370,379	2,986,008	6,039,160	429,423	1,078,202	172,756	72,286
Parcels	Parcels	ct	184	15	328	49	1,153	260	278
Sewer	Lift Stations	ct	0	0	0	0	2	0	0
	Laterals	ft	2,304	98	10,219	279	27,998	62	13,204
	Force Mains	ft	0	0	0	0	474	0	0
	Gravity Mains	ft	7,951	2,962	30,393	1,120	56,459	460	18,401
Stormwater	Drainage Pipes	ft	4,299	791	22,308	882	42,779	419	16,282
	Drainage Channels	ft	874	1,244	10,865	246	5,598	774	2
	Water Control Structures	ct	0	1	2	0	0	0	0
Water Supply	Raw Water Mains	ft	0	0	0	0	1,571	0	424
	Water Mains	ft	0	0	25	0	0	0	0
	Recycled Mains	ft	2,768	4,305	9,458	501	9,054	65	1,171
	Recycled Laterals	ft	26	70	768	5	1,729	46	117
Harbor Infrastructu	Breakwater (Concrete)	ft	0	0	9,518	3	0	0	0
	Breakwater (Rip-Rap)	ft	0	0	12,042	0	0	0	0
	Launch Ramps	ft	0	0	458	0	0	0	0
	Rock Groins	ft	0	0	1,361	0	0	0	0
	Rock Groins (Rip-Rap)	ft	0	0	1,327	0	0	0	0
	Waterfront Street Parking	ft	0	478	16,030	251	11,203	29	150
Wells	Groundwater Wells	ct	0	0	0	0	1	0	0
	Monitoring Wells	ct	0	2	5	0	6	0	3
	Production Wells	ct	0	0	0	0	1	0	0

Table F-4. Santa Barbara Exposed Public Works Assets
Subarea A

Category	Assets	Units	Existing Conditions						
			Bluff Erosion*	Shore Erosion*	Tidal Inundation	Storm Waves	Storm Flooding	Low-Lying*	Flood Prone*
Tansportation	Railroads	ft	0	0	0	0	0	0	0
	Roads	ft	0	0	0	0	0	0	0
	Public Parking	sq ft	0	0	0	0	0	0	0
Communications	Fiber Optic Cabinets	ct	0	0	0	0	0	0	0
	Fiber Optic Cables	ft	0	0	0	0	0	0	0
Critical Facilities	Fire Stations	ct	0	0	0	0	0	0	0
	Police Stations	ct	0	0	0	0	0	0	0
	Evacuation Routes	ft	0	0	0	0	0	0	0
Recreation	CA Coastal Trail	ft	0	0	0	0	0	0	0
	Parks	sq ft	0	0	2,738	10,252	2,926	0	0
Parcels	Parcels	ct	0	0	19	1	32	0	0
Sewer	Lift Stations	ct	0	0	0	0	0	0	0
	Laterals	ft	0	0	0	0	0	0	0
	Force Mains	ft	0	0	0	0	0	0	0
	Gravity Mains	ft	0	0	0	0	0	0	0
Stormwater	Drainage Pipes	ft	0	0	0	0	0	0	0
	Drainage Channels	ft	0	0	0	0	0	0	0
	Water Control Structures	ct	0	0	0	0	0	0	0
Water Supply	Raw Water Mains	ft	0	0	0	0	0	0	0
	Water Mains	ft	0	0	0	0	0	0	0
	Recycled Mains	ft	0	0	0	0	0	0	0
	Recycled Laterals	ft	0	0	0	0	0	0	0
Harbor Infrastructu	Breakwater (Concrete)	ft	0	0	0	0	0	0	0
	Breakwater (Rip-Rap)	ft	0	0	0	0	0	0	0
	Launch Ramps	ft	0	0	0	0	0	0	0
	Rock Groins	ft	0	0	0	0	0	0	0
	Rock Groins (Rip-Rap)	ft	0	0	0	0	0	0	0
	Waterfront Street Parking	ft	0	0	0	0	0	0	0
Wells	Groundwater Wells	ct	0	0	0	0	0	0	0
	Monitoring Wells	ct	0	0	0	0	0	0	0
	Production Wells	ct	0	0	0	0	0	0	0

** Bluff Erosion, Shore Erosion, Low-Lying Areas, and Flood Prone Areas were not considered for Existing Conditions*

Table F-5. Santa Barbara Exposed Public Works Assets
Subarea A

			Year 2060, LIG						
Category	**Assets**	**Units**	**Bluff Erosion**	**Shore Erosion**	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tansportation	Railroads	ft	0	0	0	0	0	0	0
	Roads	ft	518	0	0	0	0	0	0
	Public Parking	sq ft	0	0	0	0	0	0	0
Communications	Fiber Optic Cabinets	ct	0	0	0	0	0	0	0
	Fiber Optic Cables	ft	0	0	0	0	0	0	0
Critical Facilities	Fire Stations	ct	0	0	0	0	0	0	0
	Police Stations	ct	0	0	0	0	0	0	0
	Evacuation Routes	ft	0	0	0	0	0	0	0
Recreation	CA Coastal Trail	ft	0	0	0	0	0	0	0
	Parks	sq ft	0	13,961	1,767	1,087	200	0	0
Parcels	Parcels	ct	32	3	21	1	3	8	14
Sewer	Lift Stations	ct	0	0	0	0	0	0	0
	Laterals	ft	0	0	0	0	0	0	0
	Force Mains	ft	0	0	0	0	0	0	0
	Gravity Mains	ft	0	0	0	0	0	0	0
Stormwater	Drainage Pipes	ft	0	0	0	0	0	0	0
	Drainage Channels	ft	0	0	0	0	0	0	0
	Water Control Structures	ct	0	0	0	0	0	0	0
Water Supply	Raw Water Mains	ft	0	0	0	0	0	0	0
	Water Mains	ft	0	0	0	0	0	0	0
	Recycled Mains	ft	0	0	0	0	0	0	0
	Recycled Laterals	ft	0	0	0	0	0	0	0
Harbor Infrastructu	Breakwater (Concrete)	ft	0	0	0	0	0	0	0
	Breakwater (Rip-Rap)	ft	0	0	0	0	0	0	0
	Launch Ramps	ft	0	0	0	0	0	0	0
	Rock Groins	ft	0	0	0	0	0	0	0
	Rock Groins (Rip-Rap)	ft	0	0	0	0	0	0	0
	Waterfront Street Parking	ft	0	0	0	0	0	0	0
Wells	Groundwater Wells	ct	0	0	0	0	0	0	0
	Monitoring Wells	ct	0	0	0	0	0	0	0
	Production Wells	ct	0	0	0	0	0	0	0

Table F-6. Santa Barbara Exposed Public Works Assets
Subarea A

			Year 2100, LIG						
Category	**Assets**	**Units**	**Bluff Erosion**	**Shore Erosion**	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tansportation	Railroads	ft	0	0	0	0	0	0	0
	Roads	ft	1,527	0	0	0	0	0	0
	Public Parking	sq ft	0	0	0	0	0	0	0
Communications	Fiber Optic Cabinets	ct	0	0	0	0	0	0	0
	Fiber Optic Cables	ft	0	0	0	0	0	0	0
Critical Facilities	Fire Stations	ct	0	0	0	0	0	0	0
	Police Stations	ct	0	0	0	0	0	0	0
	Evacuation Routes	ft	257	0	0	0	0	0	0
Recreation	CA Coastal Trail	ft	273	0	0	0	0	0	0
	Parks	sq ft	0	42,439	0	0	0	0	0
Parcels	Parcels	ct	35	3	1	0	0	3	7
Sewer	Lift Stations	ct	0	0	0	0	0	0	0
	Laterals	ft	0	0	0	0	0	0	0
	Force Mains	ft	0	0	0	0	0	0	0
	Gravity Mains	ft	0	0	0	0	0	0	0
Stormwater	Drainage Pipes	ft	0	0	0	0	0	0	0
	Drainage Channels	ft	535	0	0	0	0	0	0
	Water Control Structures	ct	0	0	0	0	0	0	0
Water Supply	Raw Water Mains	ft	0	0	0	0	0	0	0
	Water Mains	ft	0	0	0	0	0	0	0
	Recycled Mains	ft	0	0	0	0	0	0	0
	Recycled Laterals	ft	0	0	0	0	0	0	0
Harbor Infrastructu	Breakwater (Concrete)	ft	0	0	0	0	0	0	0
	Breakwater (Rip-Rap)	ft	0	0	0	0	0	0	0
	Launch Ramps	ft	0	0	0	0	0	0	0
	Rock Groins	ft	0	0	0	0	0	0	0
	Rock Groins (Rip-Rap)	ft	0	0	0	0	0	0	0
	Waterfront Street Parking	ft	0	0	0	0	0	0	0
Wells	Groundwater Wells	ct	0	0	0	0	0	0	0
	Monitoring Wells	ct	0	0	0	0	0	0	0
	Production Wells	ct	0	0	0	0	0	0	0

Table F-7. Santa Barbara Exposed Public Works Asses

Subarea B

Category	Asses	Units	Bluf Erosion*	Shore Erosion*	Tidal Inundation	Storm Waves	Storm Flooding	Low-Lying*	Flood Prone*
			Existig Condi tions						
Fa8skor a io8	Railroads								
	Roads								
	76li, 3Lar4i8P	su3							
nomm78i, a io8s	bi6cr3 k i, 3na6i8c s	,							
	bi6cr3 k i, 3na6lcs								
nriti, al3ba, ili ics	birc3gtatio8s	,							
	1oli, c3gtatio8s	,							
	q2a, atio83Ro cs								
Rc, rcatio8	n93hoas al3Frail								
	1ar4s	su3			eOp0CC	eepSES	vpAT		
1ar, cls	1ar, cls	,			v	A	e		
gcwcr	5i 3gtatio8s	,							
	5a crals								
	bor, c3L ai8s								
	Mra2i G3L ai8s								
gtormwatcr	y rai8aPc3Likcs								
	y rai8aPc3nDa88cls				ASC	v	h v		
	Watcr3no8 rol3g r , t rcs	, t							
Watcr3g kklG	Raw3Watcr3L ai8s								
	Watcr3L ai8s								
	Rc, G, lcd3L ai8s								
	Rc, G, lcd35a crals								
Har6or38frastr7,	Brca4watcr3(no8, rctc)								
	Brca4watcr3(Rik-Rak)								
	5a 8, D3Ramks								
	Ro, 43Mroi8s								
	Ro, 43Mroi8s3(Rik-Rak)								
	Watcrfro8 3gtrcc 3Lar4i8P								
Wclls	Mro 8dwa cr3Wclls	,							
	L o8i ori8P3Wclls	,							
	1rod, io83Wclls	,							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-8. Santa Barbara Exposed Public Works Asses
Subarea B

			Year 2060, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Oausgor a iou	Railroads								
	Roads								
	6, 3li48arPiub	sc8							
qomm, ui4a ious	i3kr8n g i48qa3iuk s	4							
	i3kr8n g i48qa3lks								
qriti4al8 a4ili iks	irk82 a ious	4							
	6oli4k82 a ious	4							
	9Fa4, atiou8Ro, ks								
Rk4rkatiou	qe8qoas al8 rail		pCpS				E		
	6arPs	sc8	E C EE	vCp7v	ECAAT	pCT5	SvCT5	TCE	TCAEv
6ar4kls	6ar4kls	4	E	p	p	p	A	A	p
2kwkr	Lift82 a ious	4							
	La krals								
	or4k8Maius								
	GraFity8Maius		5T						
2tormwatkr	Draiuabk86igks						5		
	Draiuabk8qhauukls		vv	7ES	EA		C pvv		
	Watkr8qoutrol82 r, 4 , rks	4							
Watkr82, ggly	Raw8Watkr8Maius								
	Watkr8Maius								
	Rk4y4lkd8Maius								
	Rk4y4lkd8La krals								
Har3or8ufrastr, 4 ,	BrkaPwatkr8(qou4rk k)								
	BrkaPwatkr8(Rig-Rag)								
	La, u4h8Ramgs								
	Ro4P86roius								
	Ro4P86roius8(Rig-Rag)								
	Watkrfrout82trkk 86arPiub								
Wklls	Gro, udwatkr8Wklls	4							
	Mouitoriub8Wklls	4							
	6rod, 4 iou8Wklls	4							

Table F-9. Santa Barbara Exposed Public Works Asses
Subarea B

Category	Asses	Units	Year 2100, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
vaksFor a iok	Railroads								
	Roads						76,	347	
	8Pulibc8ar ikn	sgc							
eommPkiba ioks	qiu2rc9 F ibceauik2 s	b							
	qiu2rc9 F ibceaul2s								
eritibalqabiliti2s	qir2c a ioks	b							
	8olib2c a ioks	b							
	pCabPatiokcRoP 2s						6 3	3, S	
R2br2atiok	eEceoas alcvrail		36, 7		SA		63A,	3T	
	8ar s	sgc	TS, 60T5	7S, 6S4T	70S6A0T	, 643,	7A3674T	36 1S4	
8arb2ls	8arb2ls	b		3	S	3	34		
O2w2r	Li c a ioks	b							
	La 2rals						A	, A	
	qorb2cMaiks						, S3		
	GraCitycMaiks		4A				6 TA	34T	
tormwat2r	Draikan2c8iF2s				S5		T31	A	
	Draikan2cehakk2ls		303	, 44	763 4,	3,	76ST5	357	3,
	Wa 2rceok rolc rPb Pr2s	b							
Wat2rc PFFly	RawcWat2rcMaiks								
	Wat2rcMaiks								
	R2bybl2dcMaiks						A5S	ST	
	R2bybl2dcLat2rals						T	,	
HaruordkfrastrPb P	Br2a wa 2rc(eokbr2 2)								
	Br2a wat2rc(RiF-RaF)								
	LaPkbhcRamFs								
	Rob cGroiks								
	Rob cGroiksc(RiF-RaF)								
	Wat2rfrok c tr22tc8ar ikn								
W2lls	GroPkdwa 2rcW2lls	b							
	Moki orikncW2lls	b							
	8rodPb iokcW2lls	b							

Table F-10. Santa Barbara Exposed Public Works Asses

Subarea C

Category	Asses	Units	Existig Condi tions						
			Bluf Erosion*	Shore Erosion*	Tidal Inundation	Storm Waves	Storm Flooding	Low-Lying*	Flood Prone*
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Ro es								
Recreation	CA Coastal Trail								
	Parks	sq f							
Parcels	Parcels	ct			13		23		
Sewer	Lift Stations	ct							
	Laterals								
	Force Mains								
	Gravity Mains								
Stormwater	Drainage Pipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	rodu ction Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-11. Santa Barbara Exposed Public Works Asse s

Subarea C

Category	Asse s	Units	Year 2060, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
anspor a tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	CA Coas al rail		4						
	Parks	sq f	4,388						17
Parcels	Parcels	ct	56		1			26	25
Sewer	Li S a ions	c							
	La erals		219						
	Force Mains								
	Gravi y Mains		1,267						
Stormwater	Drainage Pipes		1, 49						
	Drainage Channels		1 7						
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-12. Santa Barbara Exposed Public Works Asses

Subarea C

			Year 2100, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tanspora tion	Railroads								
	Roads		955						
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	E acua ion Rou es								
Recreation	CA Coas al Trail		339						
	Parks	sq f	4,388						27
Parcels	Parcels	ct	82		2			9	
Sewer	Li S a ions	c							
	La erals		933						
	Force Mains								
	Gra i y Mains		2 938						
Stormwater	Drainage Pipes		2 35						
	Drainage Channels		37						
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-13. Santa Barbara Exposed Public Works Asses

Subarea D

			Existig Condi tions						
Category	**Asses**	**Units**	**Bluf Erosion***	**Shore Erosion***	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying***	**Flood Prone***
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Ro es								
Recreation	CA Coastal Trail								
	Parks	sq f							
Parcels	Parcels	ct			10				
Sewer	Lift Stations	ct							
	Laterals								
	Force Mains								
	Gravity Mains								
Stormwater	Drainage Pipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	rodu ction Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-14. Santa Barbara Exposed Public Works Asses

Subarea D

			Year 2060, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tanspora tion	Railroads								
	Roads		1						
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	C Coas al Trail		3						
	Parks	sq							
Parcels	Parcels	c	4	0	0	0	0	1	1
Sewer	Li S a ions	c							
	La erals								
	Force Mains								
	Gravi y Mains		6 5						
Stormwater	Drainage Pipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		98						
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-15. Santa Barbara Exposed Public Works Asses
Subarea D

			Year 2100, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
3aesvor a ioe	Railroads								
	Roads		bc						
	knligq arFieO	spq							
Aommkeiga ioes	CinSrqE v igqAanieS s	g							
	CinSrqE v igqAanlSs								
AritigalqCagili iSs	CirSqT a ioes	g							
	oligSqT a ioes	g							
	2 agkatioeqRok Ss								
RSgrSatioe	A7qAoas alq3rail		8 1						
	arFs	spq							
argSls	argSls	g	8						5
TSwSr	9i qT a ioes	g							
	9a Srals		65						
	CorgSqL aies								
	Mra i GqL aies		bc						
TtormwatSr	y raieaOSq ivSs		1D8						
	y raieaOSqAhaeeSls								
	WatSrqAoe rolqT rkg krSs	g							
WatSrqTkvvlG	RawqWatSrqL aies								
	WatSrqL aies								
	RSgGglSdqL aies		bD						
	RSgGglSdq9a Srals								
Harnorqefrastrkg k	BrSaFwatSrq(AoegrS S)								
	BrSaFwatSrq(Riv-Rav)								
	9akeghqRamvs								
	RogFqMroies								
	RogFqMroiesq(Riv-Rav)								
	WatSrfroe qTtrSS q arFieO								
WSlls	Mrokedwa SrqWSlls	g							
	L oei orieOqWSlls	g							
	rodkg ioeqWSlls	g							

Table F-16. Santa Barbara Exposed Public Works Asses

Subarea E

Category	Asses	Units	Bluf Erosion*	Shore Erosion*	Tidal Inundation	Storm Waves	Storm Flooding	Low-Lying*	Flood Prone*
			Existig Condi tions						
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Ro es								
Recreation	CA Coastal Trail								
	Parks	sq f							
Parcels	Parcels	ct			19		26		
Sewer	Lift Stations	ct							
	Laterals								
	Force Mains								
	Gravity Mains								
Stormwater	Drainage Pipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	rodu ction Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-17. Santa Barbara Exposed Public Works Asses

Subarea E

Category	Asses	Units	Year 2060, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
Tanspora tion	Railroads								
	Roads		3						
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	C Coas al Trail		3 8						
	Parks	sq	1, 55						
Parcels	Parcels	ct	32					8	19
Sewer	Li S a ions	c							
	La erals		186						
	Force Mains								
	Gravi y Mains		5						
Stormwater	Drainage Pipes		484						
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		68						
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-18. Santa Barbara Exposed Public Works Asses
Subarea E

Category	Asses	Units	Year 2100, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
Tansporation	Railroads								
	Roads		8						
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	C Coas al Trail		8						
	Parks	sq	255						
Parcels	Parcels	ct	47						
Sewer	Li S a ions	c							
	La erals		948						
	Force Mains								
	Gravi y Mains		888						
Stormwater	Drainage Pipes		662					3	
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		67						
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-19. Santa Barbara Exposed Public Works Asses

Subarea F

			Existig Condi tions						
Category	**Asses**	**Units**	**Bluf Erosion***	**Shore Erosion***	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying***	**Flood Prone***
Tansporation	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Ro es								
Recreation	CA Coastal Trail								
	Parks	sq f			999	793	2,506		
Parcels	Parcels	ct			1	1	1		
Sewer	Lift Stations	ct							
	Laterals								
	Force Mains								
	Gravity Mains								
Stormwater	Drainage Pipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	rodu ction Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-20. Santa Barbara Exposed Public Works Asses

Subarea F

Category	Asses	Units	Year 2060, LIG Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	olice S a ions	c							
	Evacua ion Rou es								
Recreation	CA Coas al Trail		, 6						
	Parks	sq f	228,47		1,097		330	344	645
Parcels	arcels	c	2						
Sewer	Li S a ions	c							
	La erals								
	Force Mains								
	Gravi y Mains								
Stormwater	Drainage ipes		33						
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		30						
	Recycled Laterals		6						
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	roduc ion Wells	c							

Table F-21. Santa Barbara Exposed Public Works Asses

Subarea F

			Year 2100, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
anspor a tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	CA Coastal Trail		3,199				22	233	
	Parks	sq f	361,415		1,399		2,083	20,845	
Parcels	Parcels	c	4	0	1	0	1	2	0
Sewer	Li S a ions	c							
	La erals								
	Force Mains								
	Gravi y Mains		99						
Stormwater	Drainage Pipes		592					5	
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		76						
	Recycled Laterals		26						
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-22. Santa Barbara Exposed Public Works Asses

Subarea G

			Existig Condi tions						
Category	**Asses**	**Units**	**Bluf Erosion***	**Shore Erosion***	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying***	**Flood Prone***
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Ro es								
Recreation	CA Coastal Trail					82			
	Parks	sq f			55,211	454,925			
Parcels	Parcels	ct			1	5	0		
Sewer	Lift Stations	ct							
	Laterals				0	53	0		
	Force Mains								
	Gravity Mains					23			
Stormwater	Drainage Pipes					292			
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	rodu ction Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-23. Santa Barbara Exposed Public Works Asses

Subarea G

			Year 2060, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tansporation	Railroads								
	Roads		1			99	34		98
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	CA Coastal Trail		1,0	332		967			
	Parks	sq f	119,372	231,19	3,731	253,521			731
Parcels	Parcels	ct	19	2	1	3	1		2
Sewer	Li S a ions	c							
	Laterals		271			71			
	Force Mains								
	Gravity Mains		36			290	33		74
Stormwater	Drainage Pipes					24		20	136
	Drainage Channels							96	2
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		1,0			760			12
	Recycled Laterals								7
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-24. Santa Barbara Exposed Public Works Asse$_{s}$

Subarea G

Category	Asse$_{s}$	Units	Year 2100, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
Tanspor$_{a}$ tion	Railroads								
	Roads		[illegible]		204	202	247		
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables			58	505	332	91		
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	CA Coastal Trail		34	[illegible]	5	941			
	Parks	sq f	8,10 9	435,632	40,683	79,146	27,318	258	
Parcels	Parcels	ct	30	3	4	4		2	4
Sewer	Li S a ions	c							
	Laterals		351	71			73		68
	Force Mains								
	Gravity Mains		389	263	876	209	542		33
Stormwater	Drainage Pipes		614	321	526	364	737	8	23
	Drainage Channels				5				
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains		34	432	606	453	498		
	Recycled Laterals				20	5	34		
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking								
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-25. Santa Barbara Exposed Public Works Asses

Subarea H

			Existig Condi tions						
Category	**Asses**	**Units**	**Bluf Erosion***	**Shore Erosion***	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying***	**Flood Prone***
Tanspora tion	Railroads								
	Roads				360	277			
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Routes								
Recreation	CA Coastal Trail				0	35	67		
	Parks	sq f			554,607	1,077,546	62,319		
Parcels	Parcels	ct			3	8	4		
ewer	Lif Stations	ct							
	Laterals				0	89	0		
	Force Mains								
	Gravity Mains					534			
Stormwater	Drainage Pipes				26	82	24		
	Drainage Channels				6	788	313		
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains					[illegible]	27		
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)				298	572	[illegible]		
	Breakwater (Rip-Rap)				5,401	61	298		
	Launch Ramps				452		6		
	Rock Groins					316	7		
	Rock Groins (Rip-Rap)				658	61	227		
	Waterfront Street Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	Production Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-26. Santa Barbara Exposed Public Works Asse s

Subarea H

			Year 2060, LIG						
Category	**Asse s**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tanspor a tion	Railroads								
	Roads				432	243	450	267	
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables					314			2
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacuation Routes					5			
Recreation	CA Coastal Trail				798	859	563	29	
	Parks	sq f		202,648	1,418,209	737,604	248,337	47,451	[illegible]
Parcels	Parcels	ct		5	8	8	3	5	9
Sewer	Li S a ions	c							
	Laterals				253	237	646	27	8
	Force Mains								
	Gravity Mains				931	2,929	3,260	571	7
Stormwater	Drainage Pipes			58	538	[illegible]	651	411	29
	Drainage Channels			273	879	66		20	27
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains					25			
	Recycled Mains				900	2,587	536	65	72
	Recycled Laterals					3	47		
Harbor Infrastructu	Breakwater (Concrete)				3,753	551	732		
	Breakwater (Rip-Rap)				6,067	23	89		
	Launch Ramps				458				
	Rock Groins				480	396	482		
	Rock Groins (Rip-Rap)				[illegible]	66	53		
	Waterfront Street Parking					29	737		22
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-27. Santa Barbara Exposed Public Works Asses

Subarea H

Category	Asses	Units	Year 2100, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
Tanspora tion	Railroads								
	Roads				922		1,784		
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct			3				
	Fiber Optic Cables				3,948		3		
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacuation Routes				27				
Recreation	CA Coastal Trail			739	4,554				
	Parks	sq f		376,02	3,019,731	10,454	216,454	43	2,860
Parcels	Parcels	ct		5	59	5	48	6	6
Sewer	Li S a ions	c							
	Laterals			5	3,258		562		
	Force Mains								
	Gravity Mains			30	11,898	50	1,845		
Stormwater	Drainage Pipes			204	3,450		678	4	
	Drainage Channels			406	1,312		365	39	
	Water Control Structures	ct		1	1				
Water Supply	Raw Water Mains								
	Water Mains				25				
	Recycled Mains			750	4,823		161		
	Recycled Laterals			31	354		135		
Harbor Infrastructu	Breakwater (Concrete)				9,518	3			
	Breakwater (Rip-Rap)				6,338				
	Launch Ramps				458				
	Rock Groins				1,361				
	Rock Groins (Rip-Rap)				1,297				
	Waterfront Street Parking				4,753		939		4
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-28. Santa Barbara Exposed Public Works Asses

Subarea I

Category	Asses	Units	Existig Condi tions						
			Bluf Erosion*	Shore Erosion*	Tidal Inundation	Storm Waves	Storm Flooding	Low-Lying*	Flood Prone*
Cacs2or a ioc	Railroads						6		
	Roads						,		
	348liPu3arbic	sku							
9omm4ciPa iocs	ni8gruq2 iPu9a8icg s	P							
	ni8gruq2 iPu9a8lgs						6		
9ritiPalunaPili igs	nirguFtatiocs	P							
	3oliPguFtatiocs	P							
	e aP4atiocuRo4 gs								
RgPrgatioc	9pu9oas aluCrail				0	SE , v			
	3arbs	sku			vE, AS	A TETA	ESTO		
3arPgls	3arPgls	P					6		
Fgwgr	5i uFtatiocs	P							
	5a grals								
	norPguL aics								
	Mra i GuL aics				Tv6	1ESAT	6v		
Ftormwatgr	Draica gu3i2gs					6v			
	Draica gu9haccgls						E, , ,		
	Watgru9oc roluF r4Pt4rgs	Pt							
WatgruF422lG	RawuWatgruL aics								
	WatgruL aics								
	RgPGPlgduL aics				0	SEvTy			
	RgPGPlgdu5a grals								
Har8oruIcfrastr4P 4	Brgabwatgru(9ocPrgtg)								
	Brgabwatgru(Ri2-Ra2)								
	5a4cPhuRam2s								
	RoPbuMroics								
	RoPbuMroicsu(Ri2-Ra2)								
	Watgrfroc uFtrggtu3arbic								
Wglls	Mro4cdwa gruWglls	P							
	L oci oric uWglls	P							
	3rod4P iocuWglls	P							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-29. Santa Barbara Exposed Public Works Asses

Subarea I

Category	Asses	Units	Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
			Year 2060, LIG						
Tanspora tion	Railroads				6		43		,480
	Roads				3	610	49	3,305	3,271
	Public Parking	sq f							
Communications	Fiber Optic Cabin s	ct							2
	Fiber Optic Cables				67	2,696	3	217	,993
Critical Facilities	Fire Stations	ct							
	Polic S a ions	c							
	Evacuation Routes								2
Recreation	CA Coastal Trail				24	3,543			
	Parks	sq f		708,259	56,087	734,044	,977	112,068	27,21 4
Parcels	Parcels	ct		4		4	5	50	237
Sewer	Li S a ions	c							
	Laterals					4		,645	,959
	Forc Mains								
	Gravity Mains			,335	473	,215	2	2,051	293
Stormwater	Drainage Pipes			90	8	564	93	3,883	2,698
	Drainage Channels				,265		2,151	,431	635
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains			,430	416	,612	35	4	,524
	Recycled Laterals			5	6			27	60
Harbor Infrastructu	Breakwater (Concre)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Str t Parking					,186		60	,926
Wells	Groundwa r W lls	c							
	Moni oring W lls	c	0	0	0	2	0	2	3
	Produc ion W lls	c							

Table F-30. Santa Barbara Exposed Public Works Asses

Subarea I

			Year 2100, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tanspora tion	Railroads				454		9,060		48
	Roads				19,138	504	8,878		19,661
	Public Parking	sq f							
Communications	Fiber Optic Cabin s	ct			5		6		
	Fiber Optic Cables			1,262	5,293	7	5,154		,536
Critical Facilities	Fire Stations	ct					1		
	Polic S a ions	c							
	Evacuation Routes				800		1,059		
Recreation	CA Coastal Trail			,819	1,394	124			
	Parks	sq f		1,353,68	934,68	44,852	261,054	,859	72,286
Parcels	Parcels	ct		4	8		737		4
Sewer	Li S a ions	c							
	Laterals				6,639		601	7	13,224
	Force Mains						41		
	Gravity Mains			,669	15,060	163	40,986	48	18,431
Stormwater	Drainage Pipes			67	14,943	5	6,820	86	16,628
	Drainage Channels				5,823				985
	Water Control Structures	ct							
Water Supply	Raw Water Mains						1,571		424
	Water Mains								
	Recycled Mains			,123	,395	48	,301		1,171
	Recycled Laterals			9	49		1,084		117
Harbor Infrastructu	Breakwater (Concre)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Str t Parking			471	10,166	51	7,834	9	6
Wells	Groundwa r W lls	c							
	Moni oring W lls	c	0	2	5	0	6	0	3
	Produc ion W lls	c							

Table F-31. Santa Barbara Exposed Public Works Asse$_s$

Subarea J

Category	Asse$_s$	Units	Existi$_g$ Condi tions						
			Bluf Erosion*	Shore Erosion*	Tidal Inundation	Storm Waves	Storm Flooding	Low-Lying*	Flood Prone*
anspor a tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Routes								
Recreation	CA Coastal Trail					472			
	Parks	sq f			53,139	844,027			
Parcels	Parcels	ct							
Sewer	Lift Stations	ct							
	Laterals								
	Force Mains								
	Gravity Mains								
Stormwater	Drainage Pipes					98			
	Drainage Channels				87	390			
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking					533			
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	Production Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-32. Santa Barbara Exposed Public Works Asses

Subarea J

Category	Asses	Units	Year 2060, LIG						
			Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
va s9or a io	Railroads								
	Roads					6, 3			
	48Pliub4arci k	snb							
Fomm8 iua io s	giPqrb2 9 iubFaPi q s	u							
	giPqrb2 9 iubFaPlqs					e e			
Fritiualbgauilitiqs	girqbp a io s	u							
	4oliuqbp a io s	u							
	CSau8atio bRo8 qs								
Rqurqatio	FE bFoas albvrail					AA,			e
	4arcs	snb		eT	67̸5A3	617		1337̸51T	67̸T35
4aruqls	4aruqls	u		e	T	A		e	5
pqwqr	Liftbp a io s	u							
	La qrals								
	goruqbMai s								
	GraSitybMai s					6e			
ptormwatqr	Drai akqb4i9qs					Aee		Te	61e
	Drai akqbFha qls			T5A	eT	T5		6A	, ,
	WatqrbFo rolbp r8u 8rqs	u							
Watqrbp899ly	RawbWatqrbMai s								
	WatqrbMai s								
	RquyulqdbMai s								
	RquyulqdbLa qrals								
HarPorb frastr8u 8	Brqacwatqrb(Fo urq q)								
	Brqacwatqrb(Ri9-Ra9)								
	La8 uhbRam9s								
	RoucbGroi s								
	RoucbGroi sb(Ri9-Ra9)								
	Watqrfro bptrqq b4arci k								
Wqlls	Gro8 dwatqrbWqlls	u							
	Mo i ori kbWqlls	u							
	4rod8u io bWqlls	u							

Table F-33. Santa Barbara Exposed Public Works Asses

Subarea J

			Year 2100, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tanspora tion	Railroads						4,423		
	Roads				2,654	1,099	14,566		
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct				1			
	Fiber Optic Cables					30	537		
Critical Facilities	Fire Stations	ct							
	Police S a ions	c							
	Evacua ion Rou es								
Recreation	CA Coastal Trail				3,771	31	264		
	Parks	sq f		590,41	1,938,957	230,44	399,135	134,959	
Parcels	Parcels	ct		3	30		802	10	16
Sewer	Li S a ions	c							
	Laterals				323	279	3,595	8	
	Force Mains								
	Gravity Mains				1,890	98	10,280	154	
Stormwater	Drainage Pipes				3,349	314	3,718	4	
	Drainage Channels			383	2,372		3,812	444	396
	Water Control Structures	ct			1				
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains				34		4,300	28	
	Recycled Laterals				45		296		
Harbor Infrastructu	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Street Parking				1,111		2,430		
Wells	Groundwa er Wells	c							
	Moni oring Wells	c							
	Produc ion Wells	c							

Table F-34. Santa Barbara Exposed Public Works Asses

Subarea K

			Existig Condi tions						
Category	**Asses**	**Units**	**Bluf Erosion***	**Shore Erosion***	**Tidal Inundation**	**Storm Waves**	**Storm Flooding**	**Low-Lying***	**Flood Prone***
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	Police Stations	ct							
	Evacuation Ro es								
Recreation	CA Coastal Trail								
	Parks	sq f			20,932	45,542	8,515		
Parcels	Parcels	ct			2	1	2		
Sewer	Lift Stations	ct							
	Laterals								
	Force Mains								
	Gravity Mains								
Stormwater	Drainage Pipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Groundwater Wells	ct							
	Monitoring Wells	ct							
	rodu ction Wells	ct							

** Bluff Erosi Sh re Erosi Low-Lying Areas, and Flood Prone Area were n ot considered for Exist g C diti*

Table F-35. Santa Barbara Exposed Public Works Asses

Subarea K

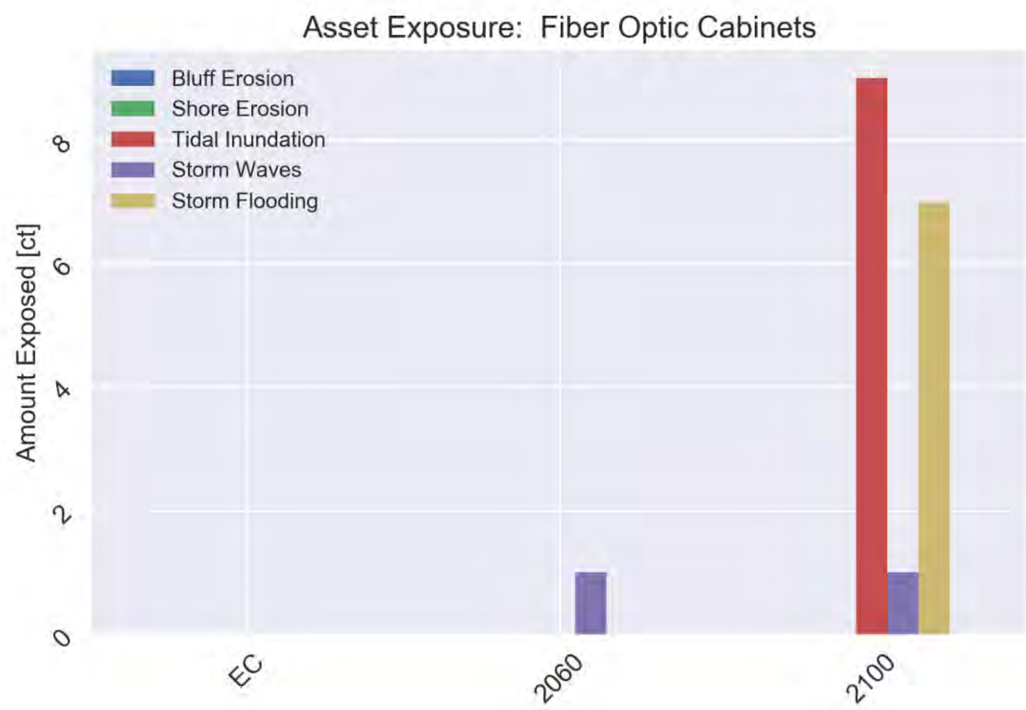
			Year 2060, LIG						
Category	**Asses**	**Units**	**Bluf Erosion**	**Shore Erosion**	**Tidal Inundation**	**orm Waves**	**Storm Flooding**	**Low-Lying**	**Flood Prone**
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	olice S a ions	c							
	Evac a ion Ro es								
Recreation	CA Coas al Trail								
	Parks	sq f	42,703	33,867		0,182			
Parcels	arcels	c		1	0	1	0	0	0
Sewer	Li S a ions	c							
	La erals								
	Force Mains								
	Gravi y Mains								
Stormwater	Drainage ipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Gro ndwa er Wells	c							
	Moni oring Wells	c							
	rod c ion Wells	c							

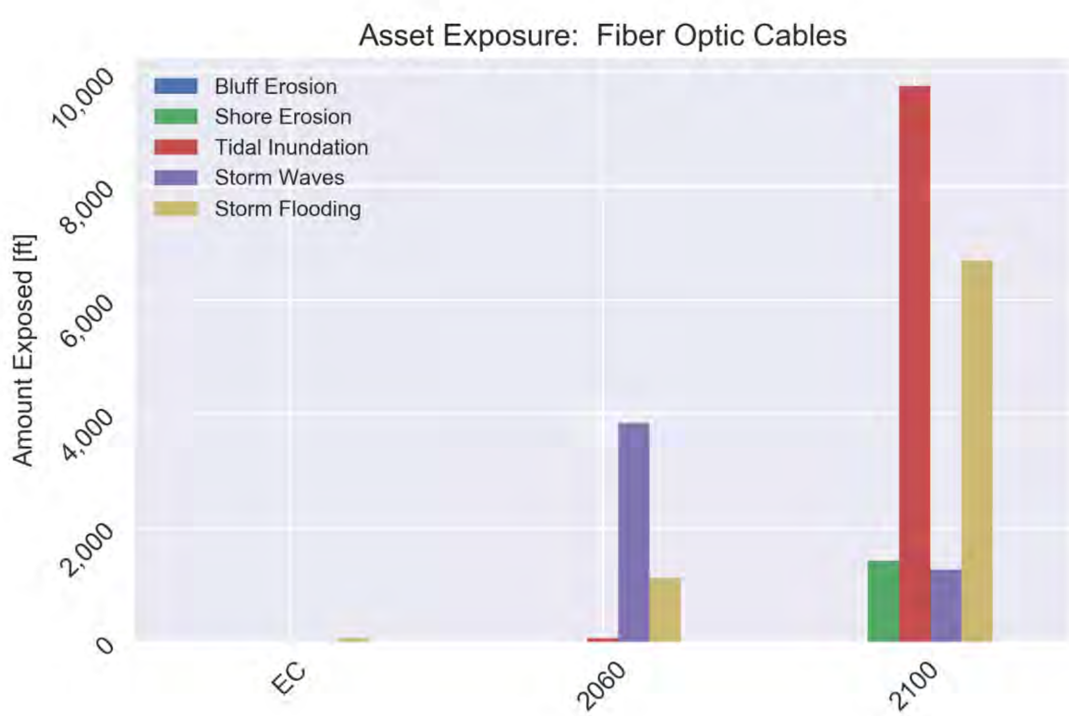
Table F-36. Santa Barbara Exposed Public Works Asses

Subarea K

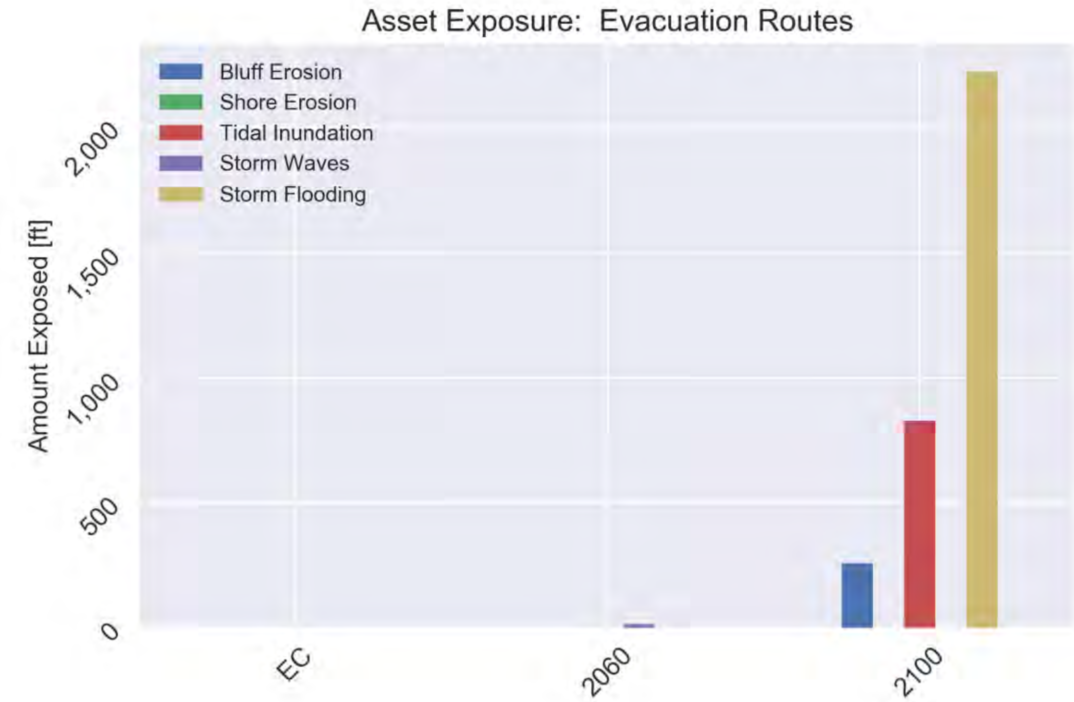
Category	Asses	Units	Year 2100, LIG Bluf Erosion	Shore Erosion	Tidal Inundation	orm Waves	Storm Flooding	Low-Lying	Flood Prone
Tanspora tion	Railroads								
	Roads								
	Public Parking	sq f							
Communications	Fiber Optic Cabinets	ct							
	Fiber Optic Cables								
Critical Facilities	Fire Stations	ct							
	olice S a ions	c							
	Evac a ion Ro es								
Recreation	CA Coas al Trail								
	Parks	sq f	51,124	51,886				157	
Parcels	arcels	c	2						
Sewer	Li S a ions	c							
	La erals								
	Force Mains								
	Gravi y Mains								
Stormwater	Drainage ipes								
	Drainage Channels								
	Water Control Structures	ct							
Water Supply	Raw Water Mains								
	Water Mains								
	Recycled Mains								
	Recycled Laterals								
Harbor Infrastruct	Breakwater (Concrete)								
	Breakwater (Rip-Rap)								
	Launch Ramps								
	Rock Groins								
	Rock Groins (Rip-Rap)								
	Waterfront Stree Parking								
Wells	Gro ndwa er Wells	c							
	Moni oring Wells	c							
	rod c ion Wells	c							

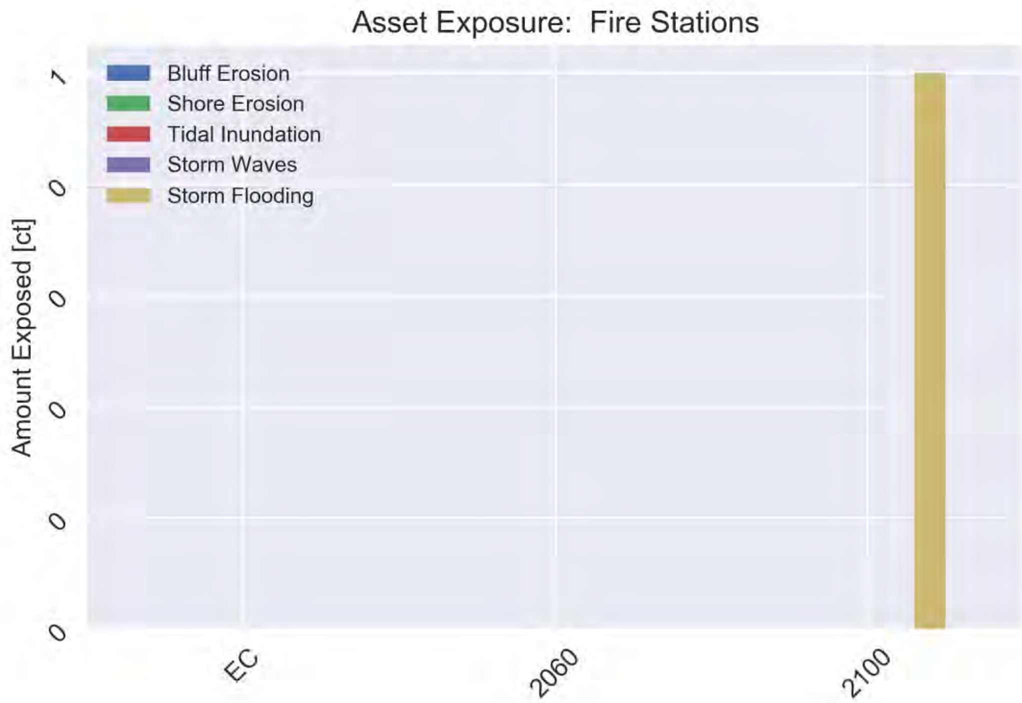
Communications

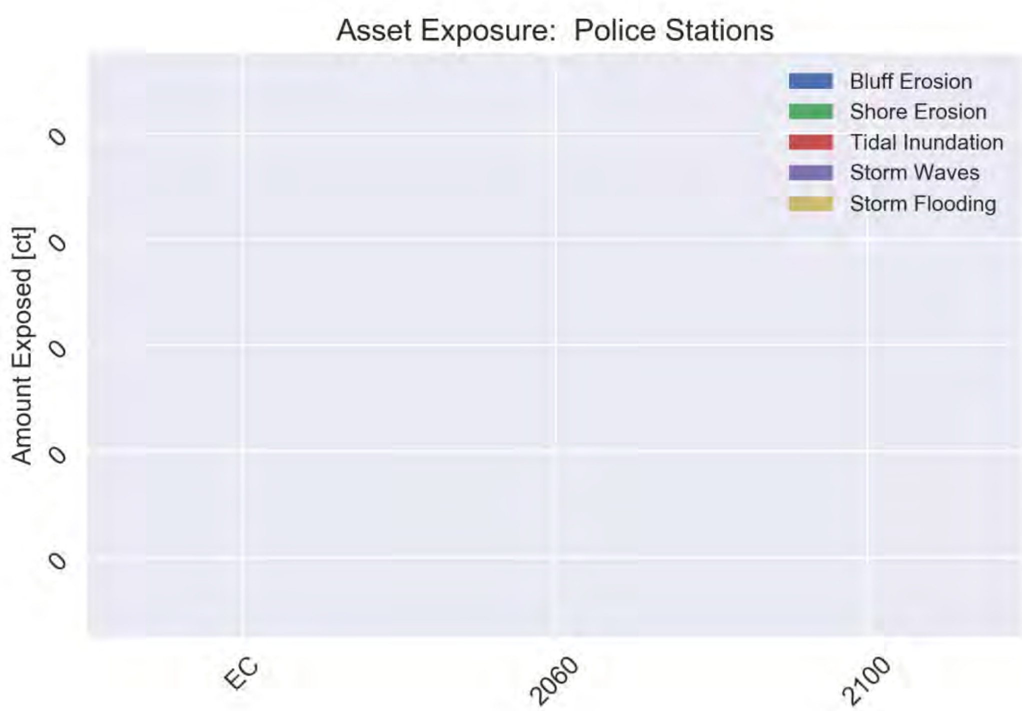




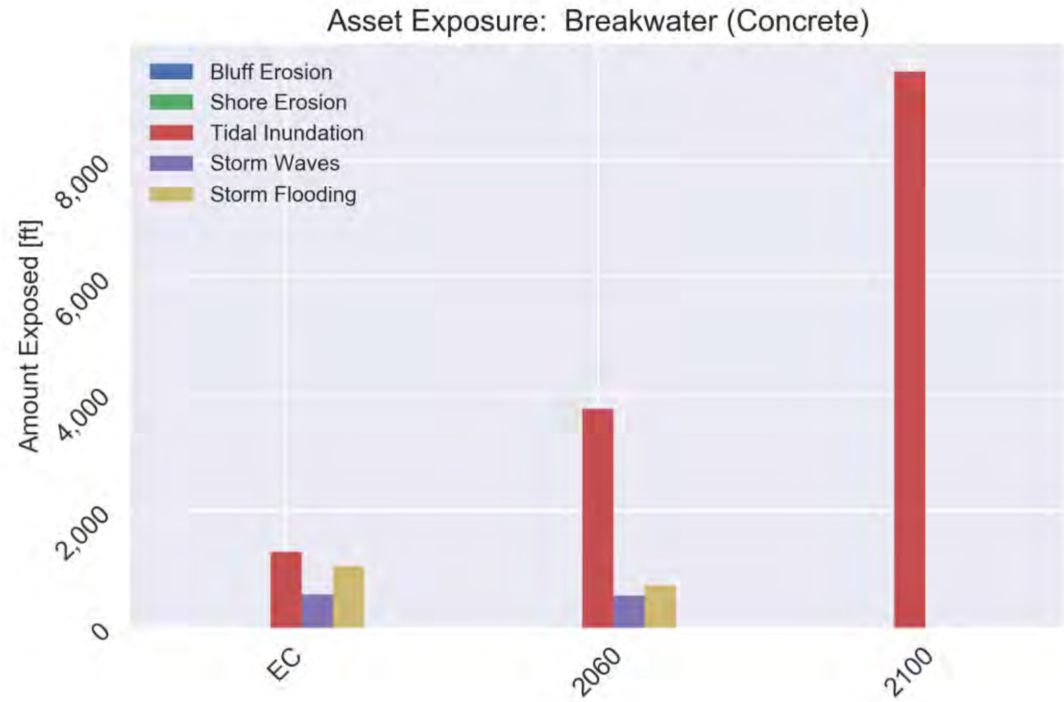
Critical Facilities

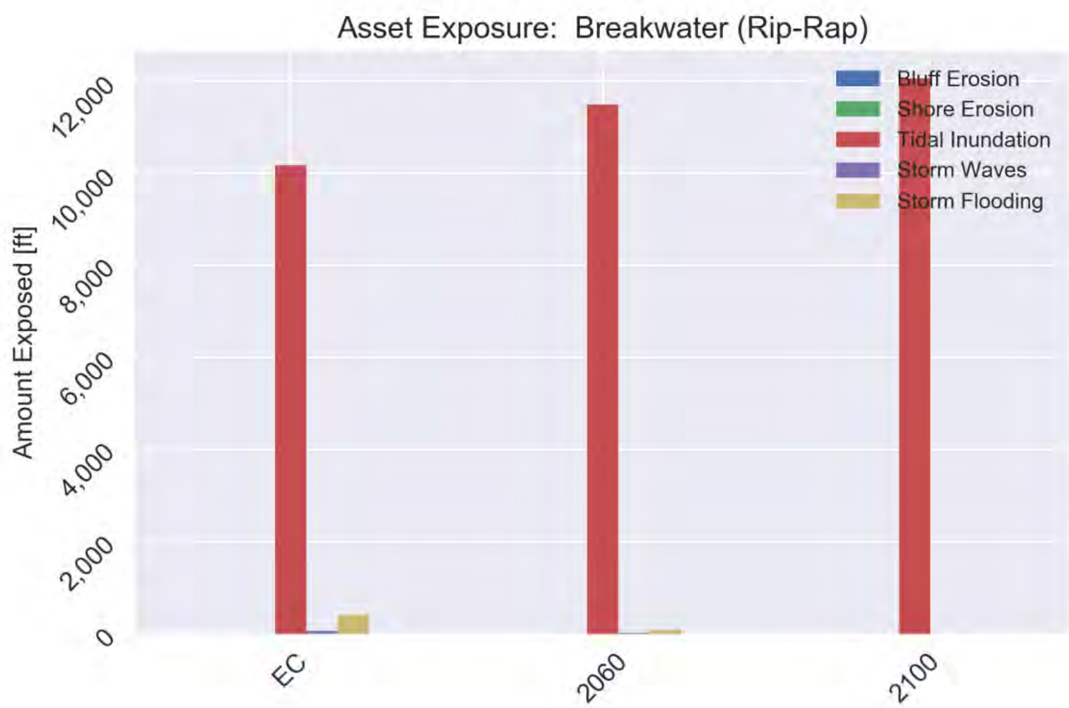


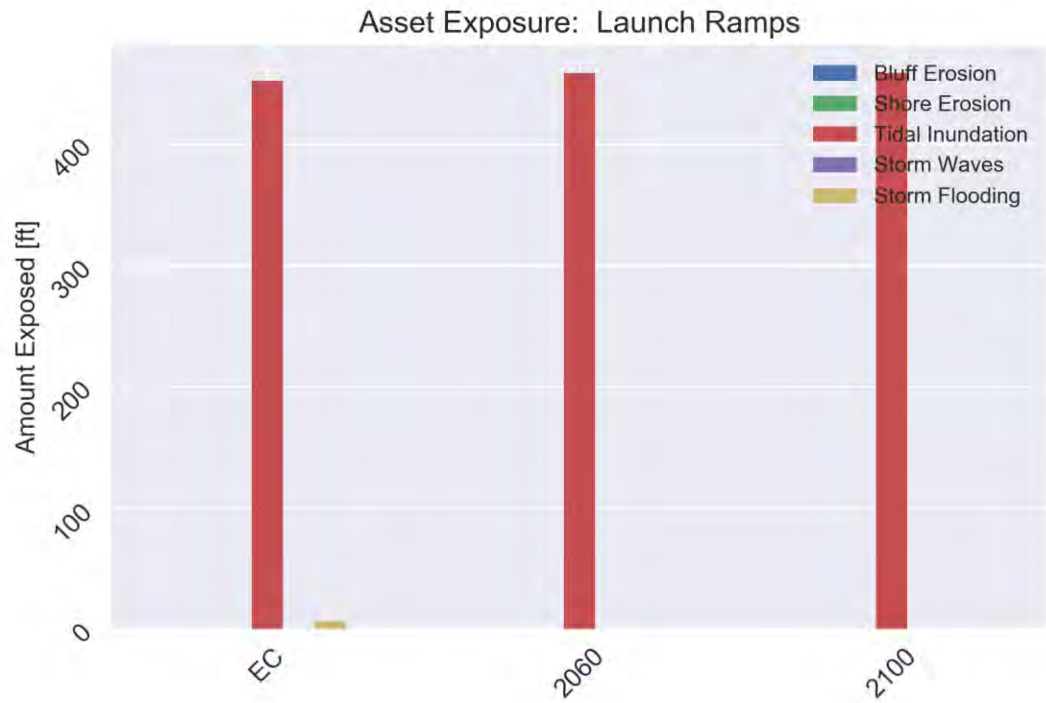

Asset Exposure: Fire Stations
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ct]
1
0
0
0
0
0
EC
2060
2100


Asset Exposure: Police Stations
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ct]
0
0
0
0
0
EC
2060
2100

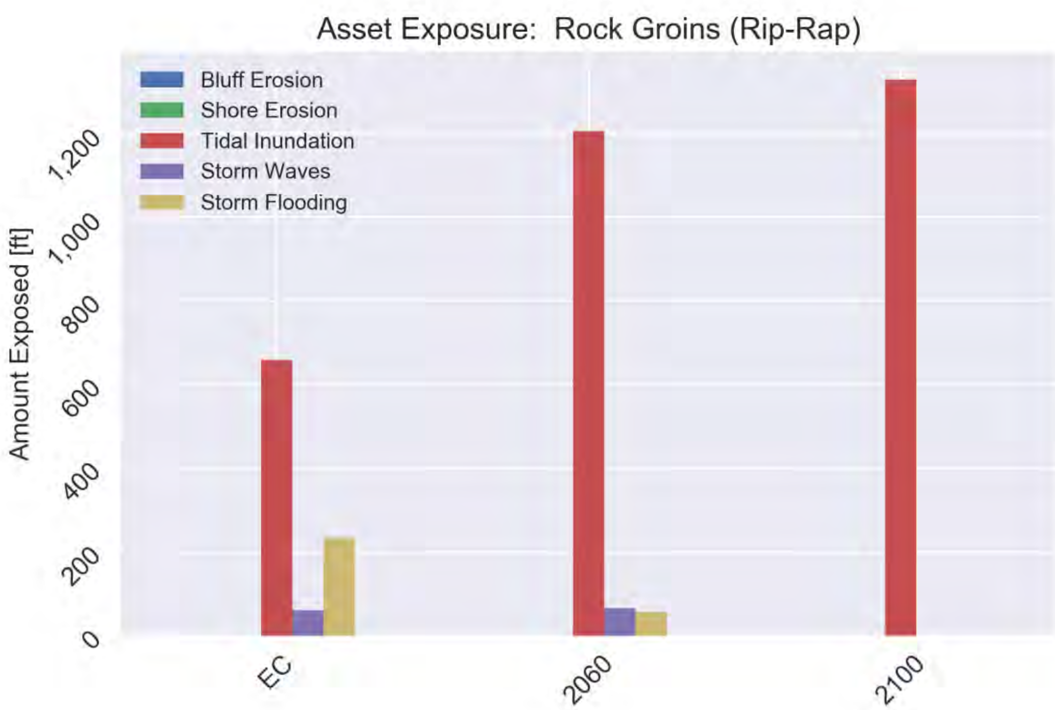
Harbor Infrastructure



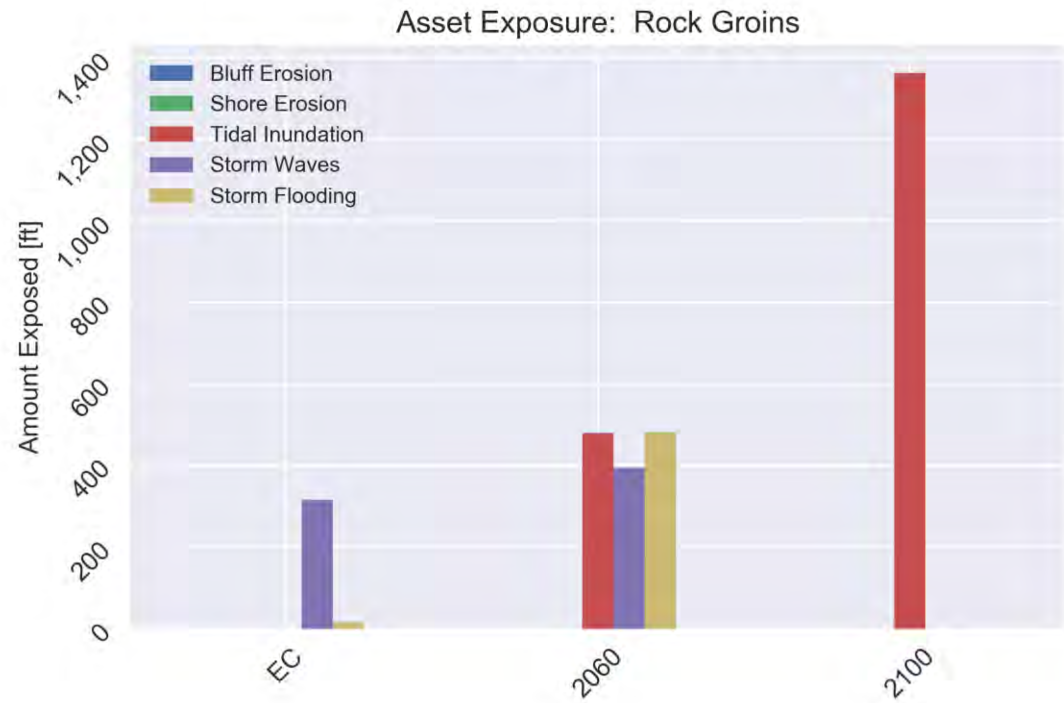




Asset Exposure: Launch Ramps
Amount Exposed [ft]
0
100
200
300
400
EC
2060
2100
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding

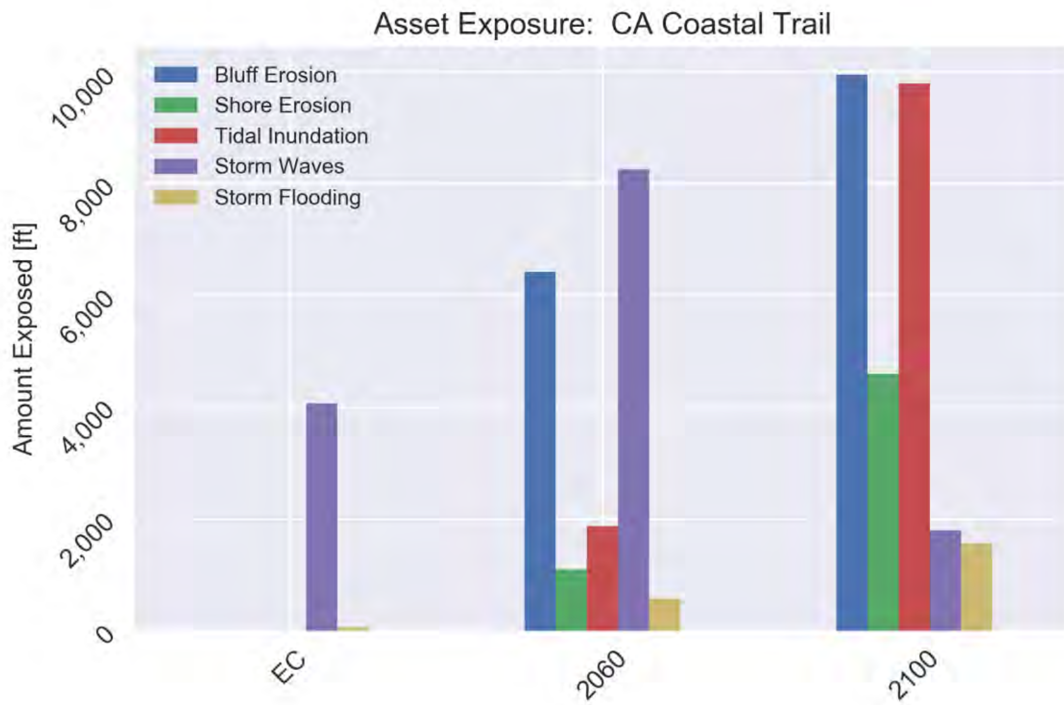


Asset Exposure: Rock Groins (Rip-Rap)
Amount Exposed [ft]
0
200
400
600
800
1,000
1,200
EC
2060
2100
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding

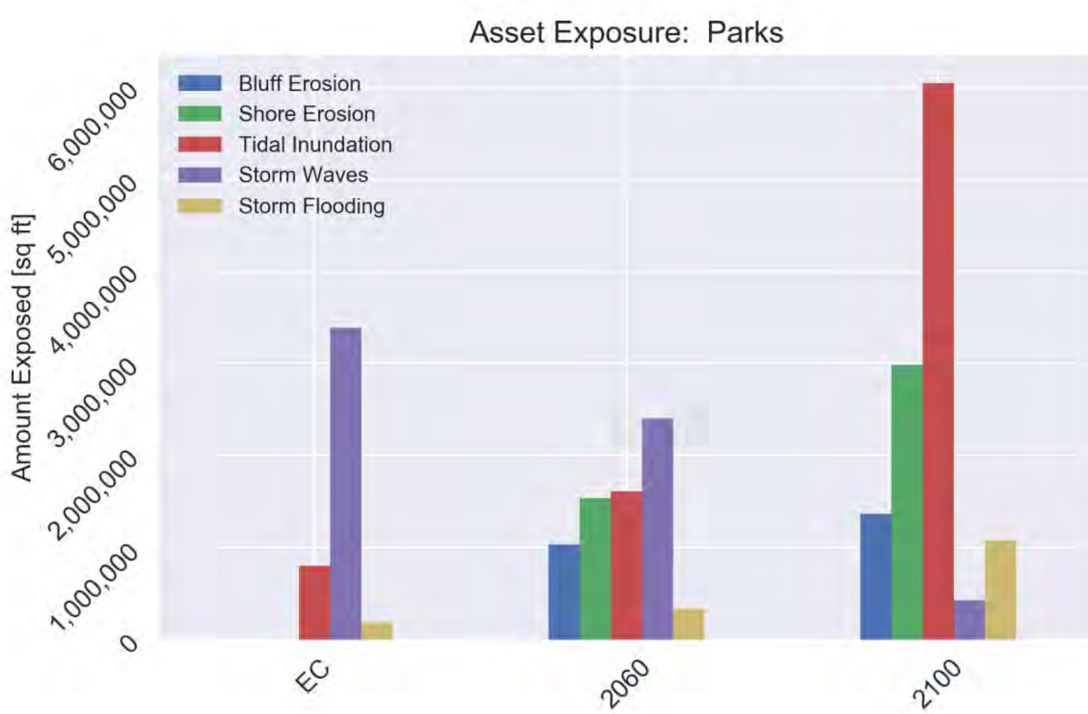

Asset Exposure: Rock Groins
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
200
400
600
800
1,000
1,200
1,400
EC
2060
2100


Asset Exposure: Waterfront Street Parking
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
EC
2060
2100

Recreation

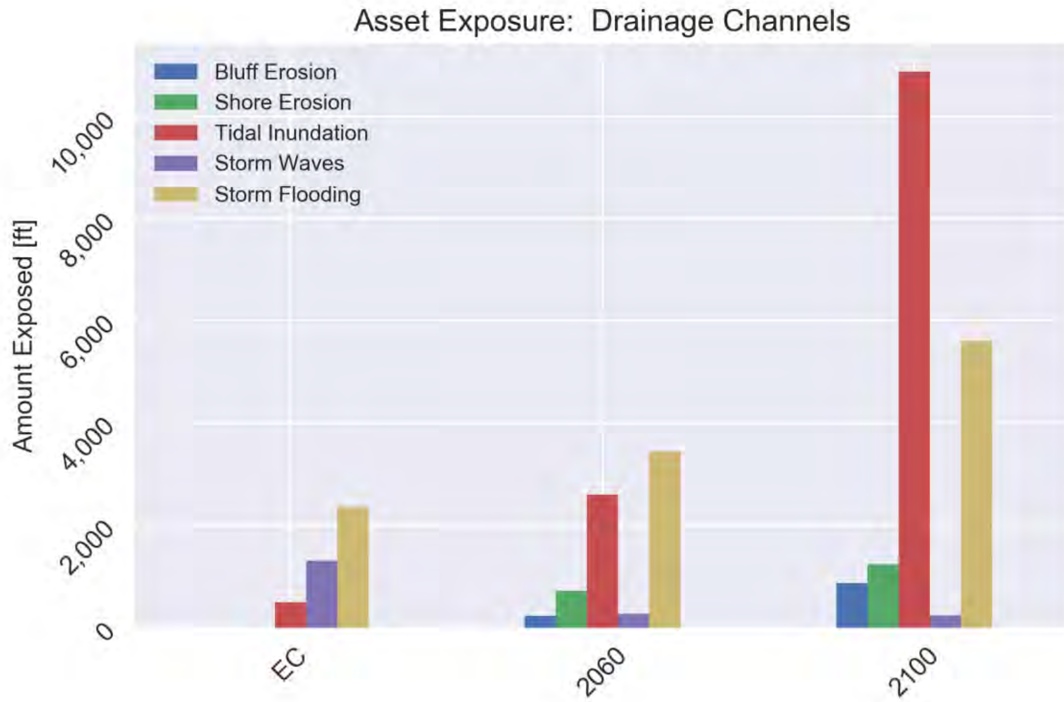


Asset Exposure: CA Coastal Trail
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
2,000
4,000
6,000
8,000
10,000
EC
2060
2100

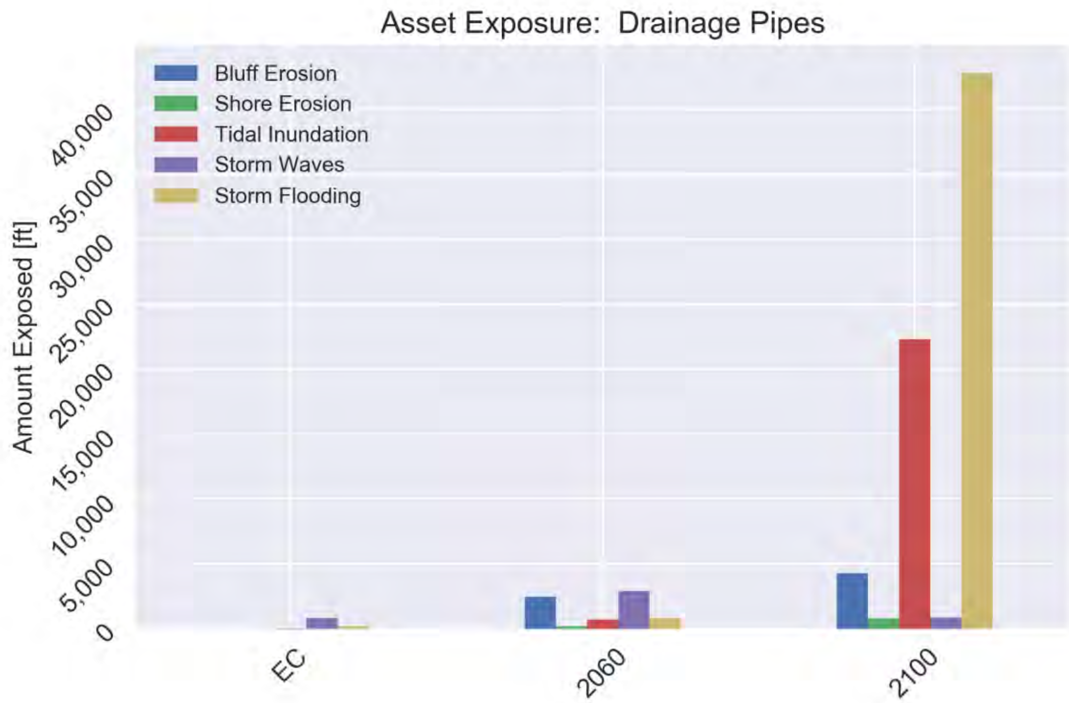


Asset Exposure: Parks
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [sq ft]
0
1,000,000
2,000,000
3,000,000
4,000,000
5,000,000
6,000,000
EC
2060
2100

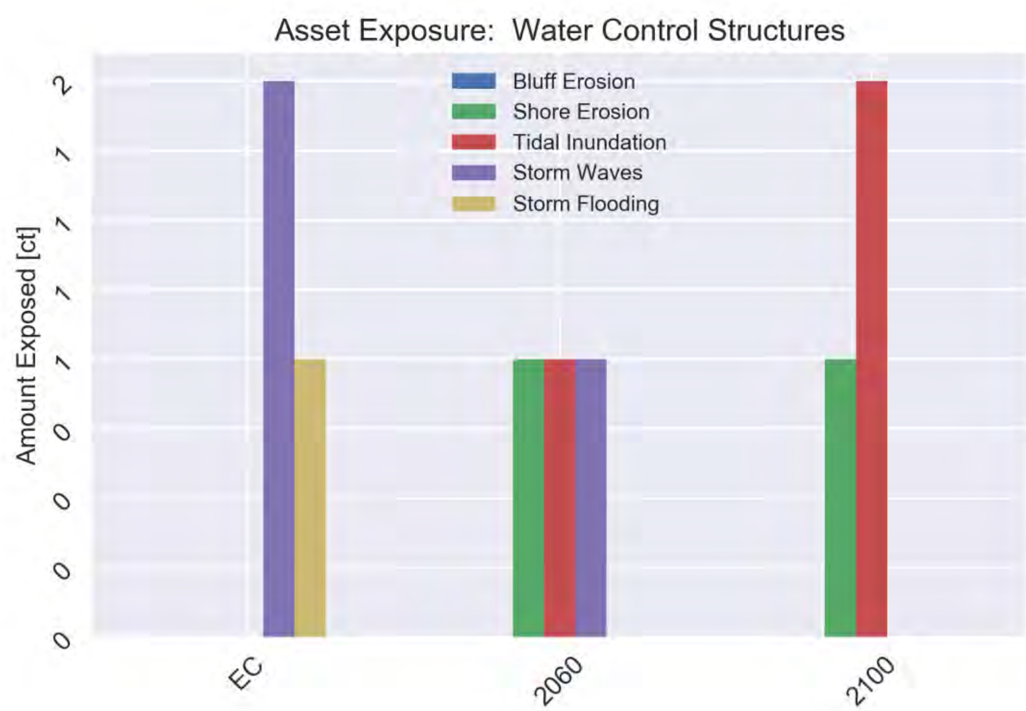
Stormwater



Asset Exposure: Drainage Channels
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
2,000
4,000
6,000
8,000
10,000
EC
2060
2100

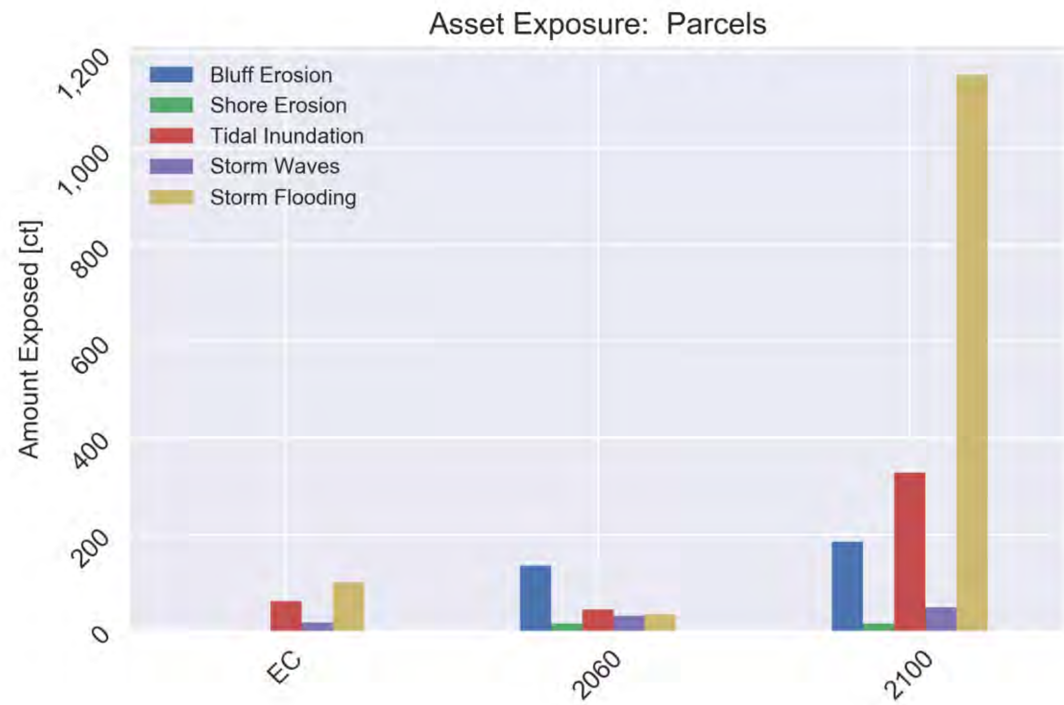


Asset Exposure: Drainage Pipes
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
EC
2060
2100

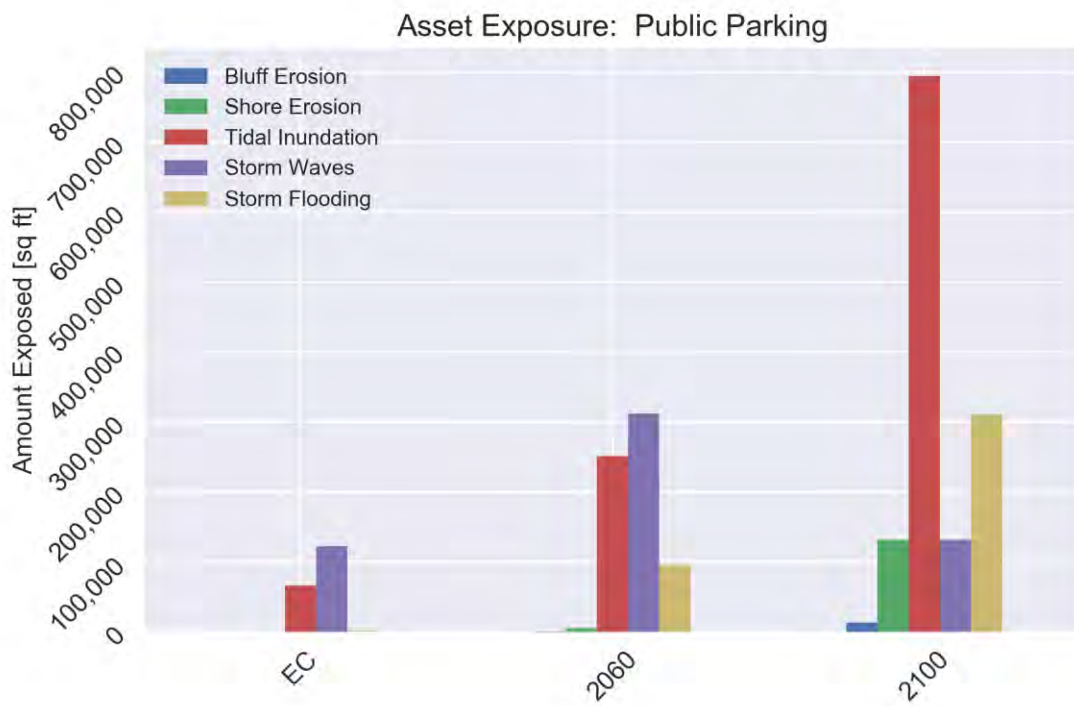


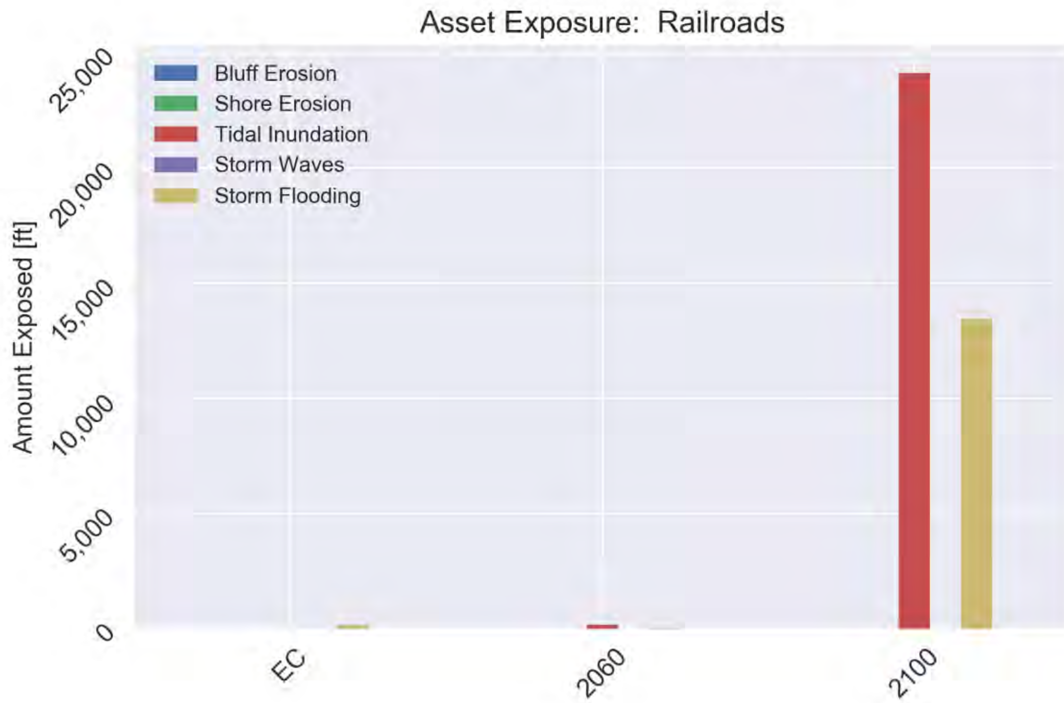
Asset Exposure: Water Control Structures
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ct]
0
0
0
0
1
1
1
1
2
EC
2060
2100

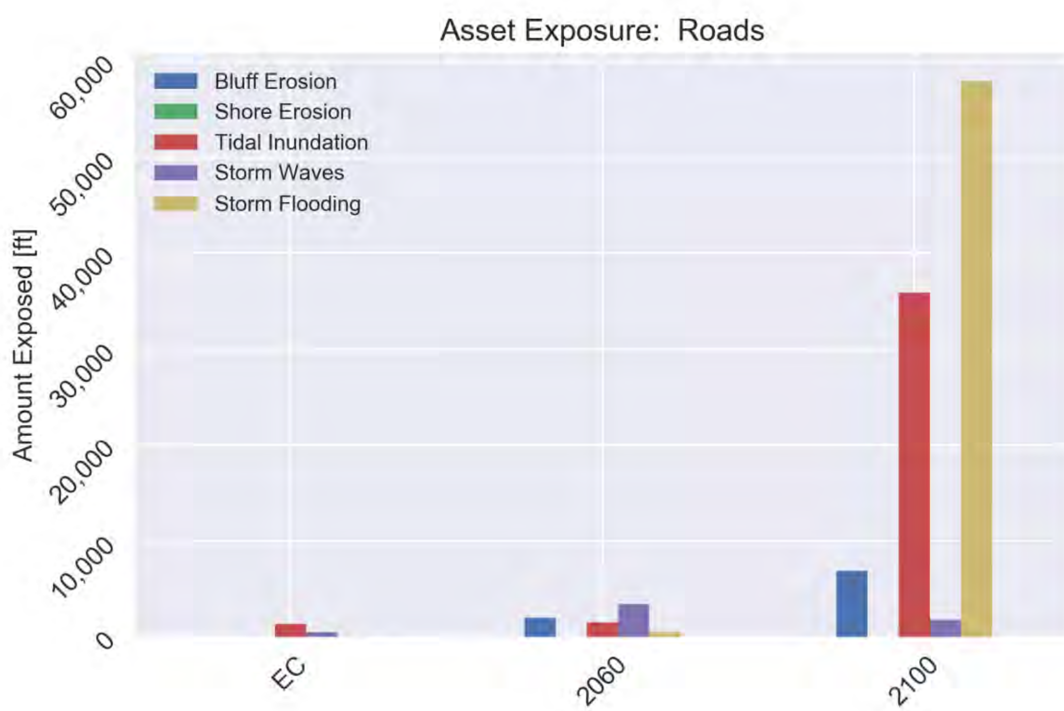
Public and Private Properties (Parcels)



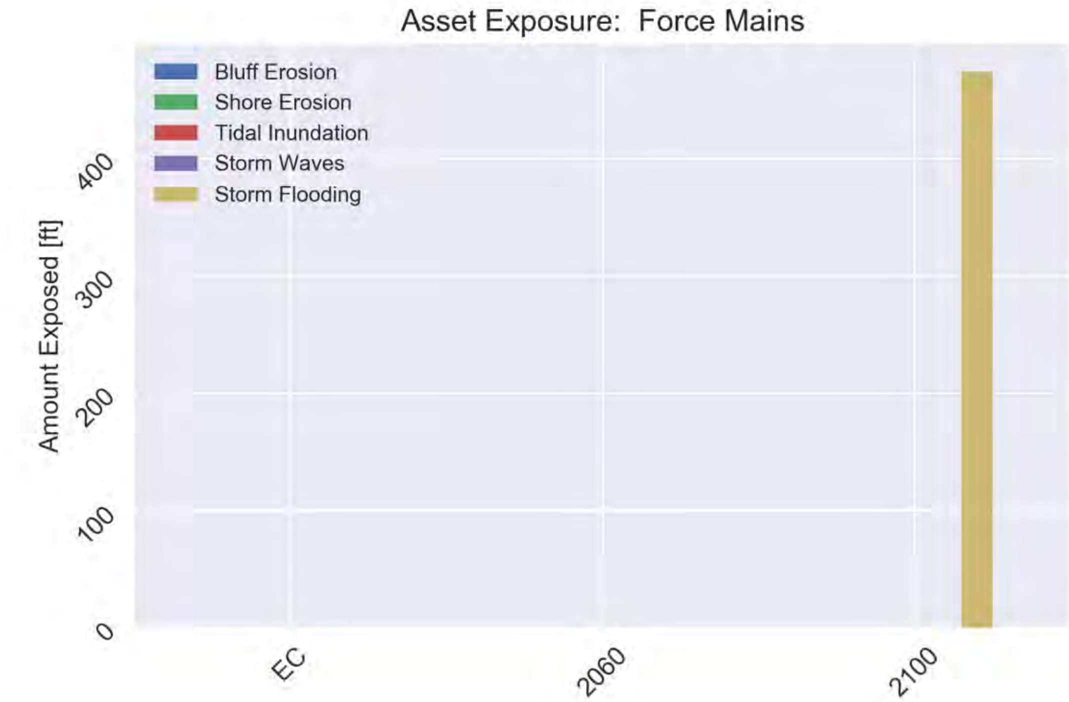
Transportation



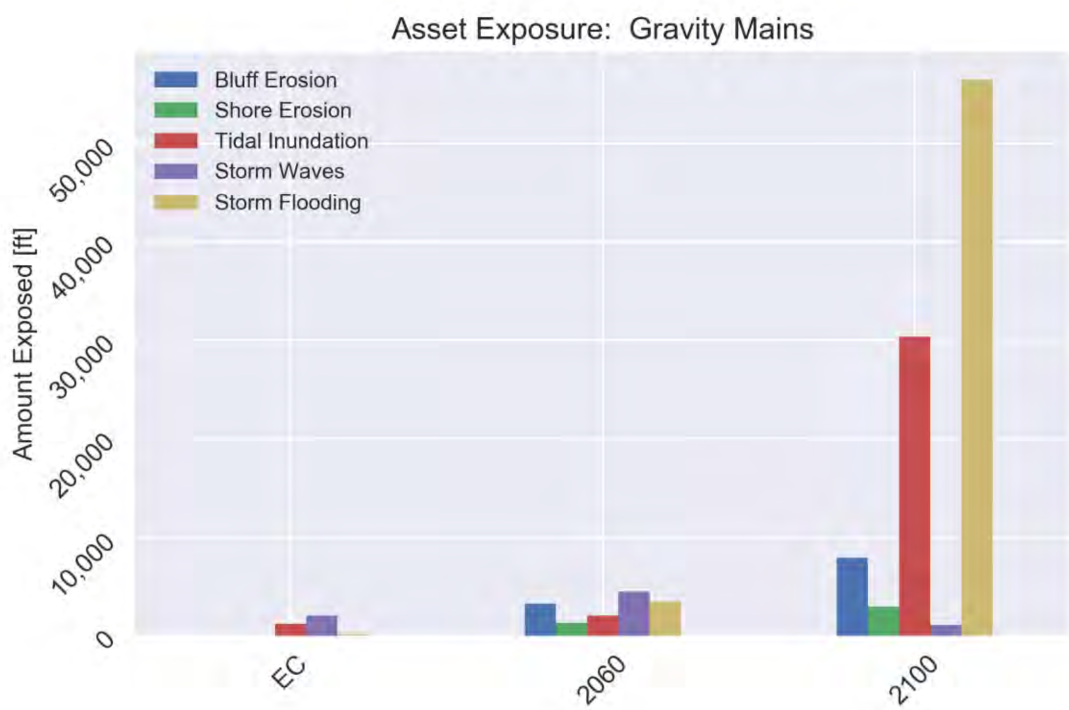

Asset Exposure: Railroads
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
25,000
20,000
15,000
10,000
5,000
0
EC
2060
2100


Asset Exposure: Roads
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
60,000
50,000
40,000
30,000
20,000
10,000
0
EC
2060
2100

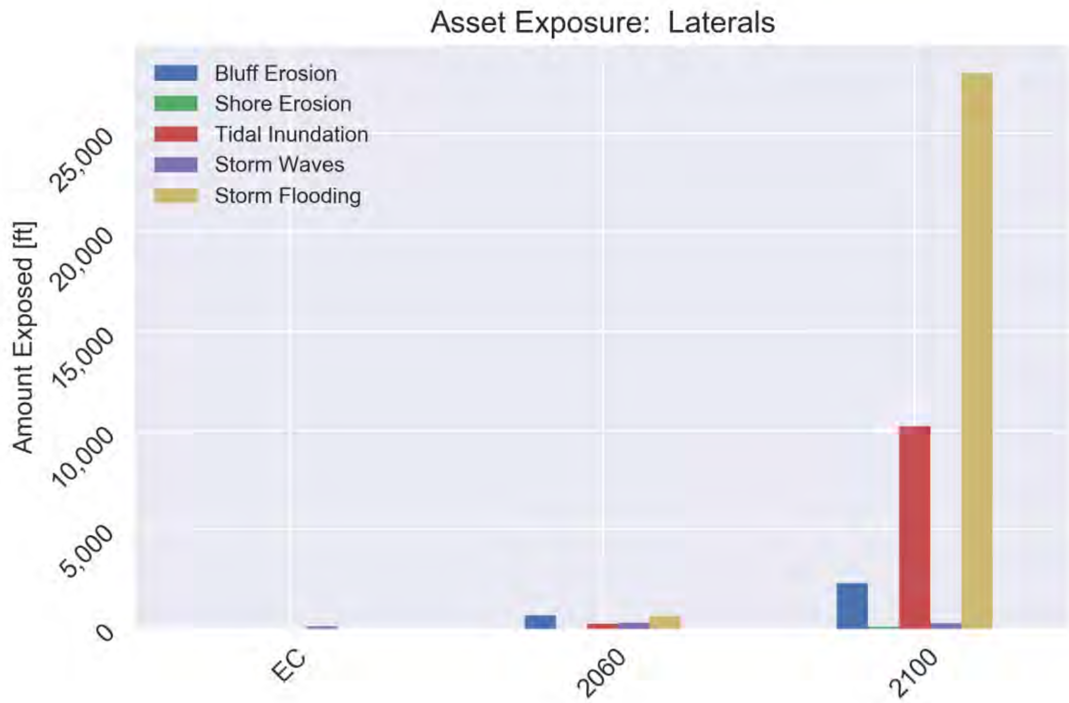
Wastewater

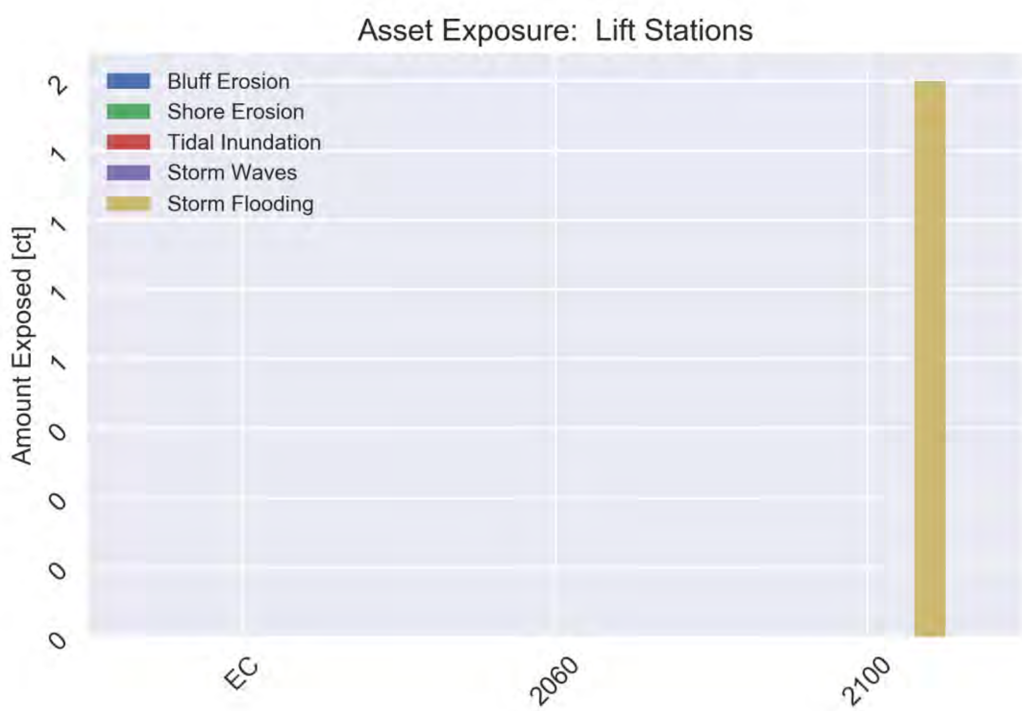


Asset Exposure: Force Mains
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
100
200
300
400
EC
2060
2100

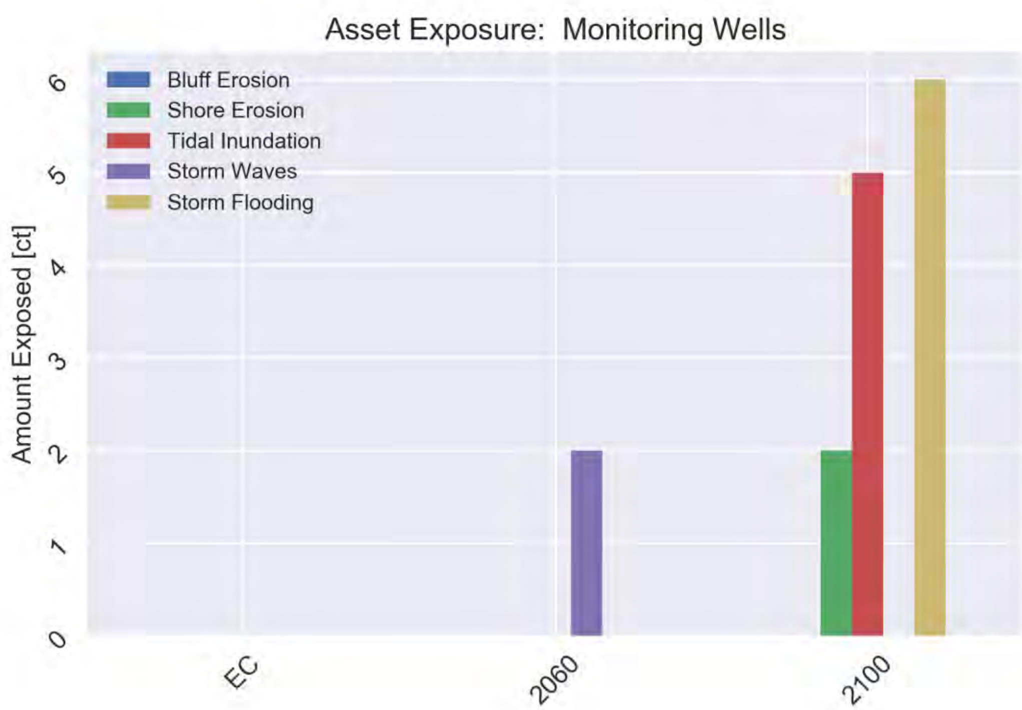


Asset Exposure: Gravity Mains
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
10,000
20,000
30,000
40,000
50,000
EC
2060
2100

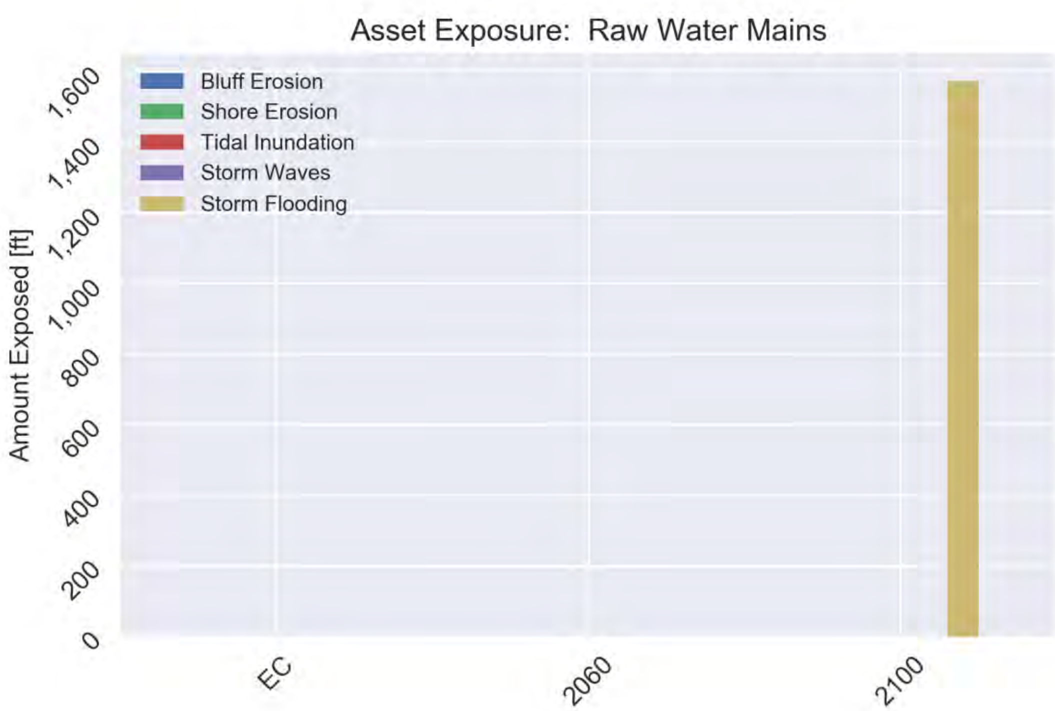

Asset Exposure: Laterals
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
25,000
20,000
15,000
10,000
5,000
0
EC
2060
2100


Asset Exposure: Lift Stations
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ct]
2
1
1
1
1
0
0
0
0
EC
2060
2100

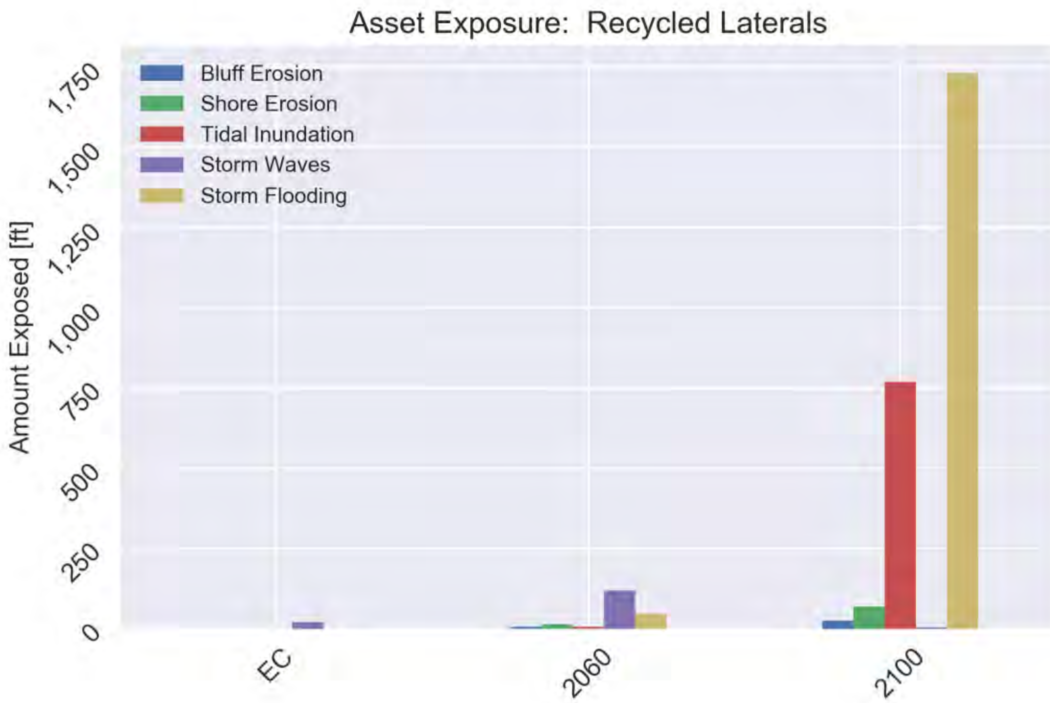
Water Supply

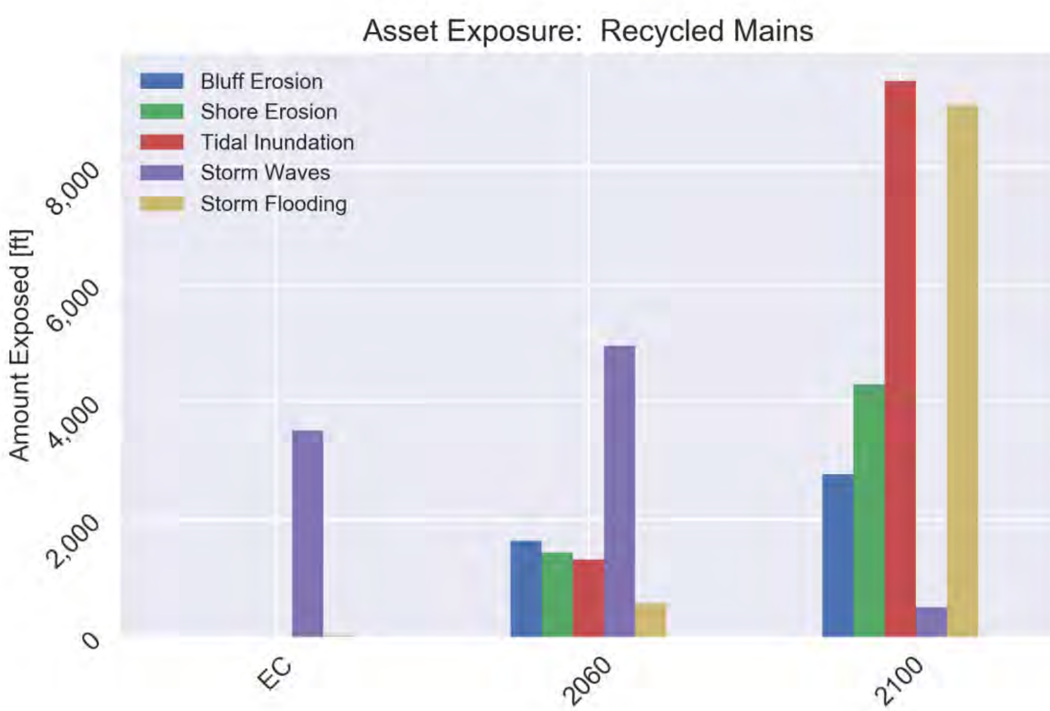


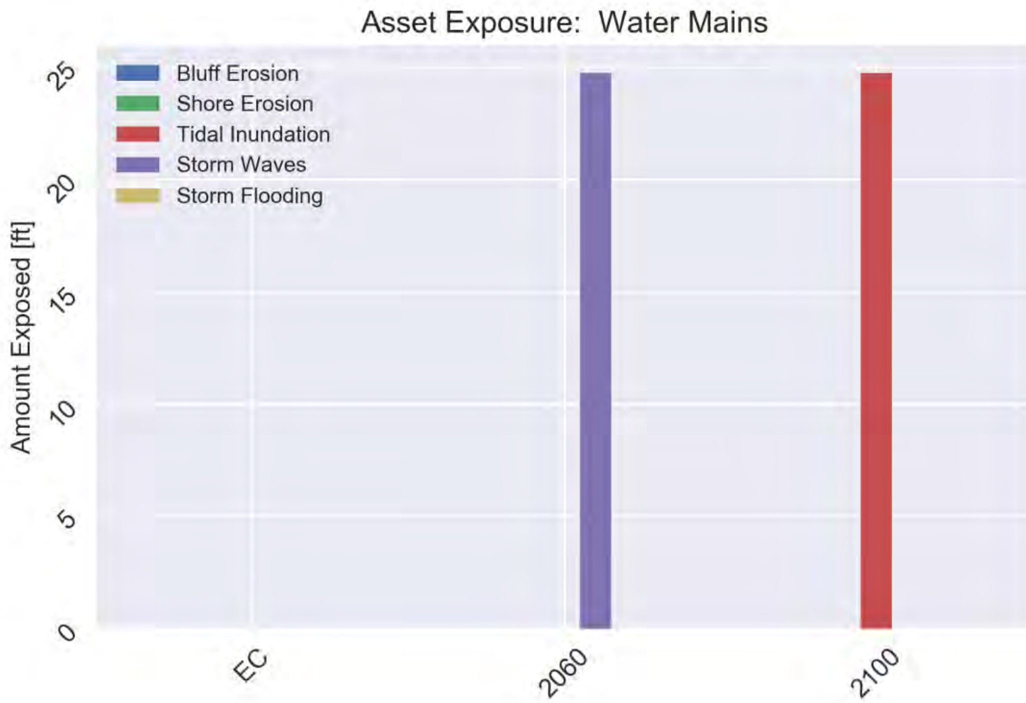
Asset Exposure: Production Wells
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ct]
1
0
0
0
0
0
EC
2060
2100



Asset Exposure: Raw Water Mains
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
1,600
1,400
1,200
1,000
800
600
400
200
0
EC
2060
2100


Asset Exposure: Recycled Laterals
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
250
500
750
1,000
1,250
1,500
1,750
EC
2060
2100


Asset Exposure: Recycled Mains
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
2,000
4,000
6,000
8,000
EC
2060
2100


Asset Exposure: Water Mains
Bluff Erosion
Shore Erosion
Tidal Inundation
Storm Waves
Storm Flooding
Amount Exposed [ft]
0
5
10
15
20
25
EC
2060
2100

Appendix G
Shoreline Response Model

ESA Shoreline Evolution Model

In order to project beach widths through time, ESA applied its shoreline evolution model that separately tracks shoreline and backshore erosion with beach width. The shoreline evolution model relies on historic shoreline and backshore erosion rates, shore geometry and SLR amount to calculate future erosion distances and beach width for each City sub-area. Historic erosion rates were determined from CoSMoS bluff erosion transects and Coastal Resilience Santa Barbara (CRSB) shoreline erosion rates. For bluff-backed beaches, the historic shoreline and bluff erosion rates was assumed to equal the CoSMoS bluff erosion rate and future bluff erosion distances were set to equal CoSMoS outputs for the 2m SLR @ 2100 scenario. For low backshores (Ledbetter Beach, West and East Beaches) the CRSB shoreline erosion rates were applied and the backshore was assumed to be held in place (at the development line). Existing beach widths were determined for each sub-area using the digital elevation model used for CoSMoS hazard modeling and mapping. Shore geometry (foreshore slope and shoreface slope) was determined from CRSB study data.

Beach Width

The beach width is the distance between the shoreline[1] and the backshore. A starting beach width was estimated for each reach using the representative distance between the mean high water line[2] and the backshore location as observed in the 2013 NOAA Coastal California TopoBathy Merge Project DEM. Subsequent beach widths are calculated based on the relative movement of the shoreline and backshore. If the shoreline erodes more quickly than the backshore, then the beach narrows, and vice versa.

Shoreline Movement

Three components contribute to shoreline movement in this quantified conceptual model: landward movement due to sea level rise (SLR), shoreline erosion caused by other coastal processes (e.g., waves, wind, changes in sediment supply), and seaward movement of the shore due to sand placement activities:

$$Shoreline\ Movement = SLR\ transgression + Ongoing\ erosion + Beach\ nourishment$$

Sea Level Rise Transgression

The impact of sea level rise on shoreline movement is incorporated by assuming that the shoreline will move inland based on the shape of the beach profile and the amount of sea level rise:

$$Sea\ Level\ Rise\ Transgression = \frac{increase\ in\ sea\ level}{shoreface\ slope}$$

The shoreface slope used in this equation depends on whether or not the backshore is eroding. A1 shows how the sea level rise erosion changes with beach width. When the backshore is not allowed to erode, or the beach is so wide that backshore erosion is not occurring (like when the beach is widened after beach nourishment), the

[1] Assumed to be located at Mean High Water (MHW=4.55 ft NAVD88, from NOAA Santa Barbara tide gage).
[2] The MHW line was extracted from the 2013 NOAA Coastal CA TopoBathy Merge Project

shoreline erodes according to a standard Bruun[3] slope, which is the slope between the depth of closure and the backshore toe location (shoreface height/active profile length).

However, if the backshore is allowed to erode, it will release sand into the system that will slow future erosion. In this case, a modified Bruun slope is used, which accounts for the eroding dune height. This slope is calculated as: (shoreface height + dune height)/(active profile length). Therefore, if the dune is very high, the slope increases and the sea level rise transgression is reduced. The taller the dune, the more the sea level rise transgression is reduced. In the beach nourishment scenarios, the shoreface slope is changed over time to reflect decreasing availability of beach-sized sediments. See the discussions about beach nourishment below for more detail.

The model assumes a linear transition between when a regular Bruun slope is used and when the modified Bruun slope is used (Figure A1Figure). When the beach is more than 2x wider than the stable beach slope, the Bruun slope is used. When the beach is narrower than the stable beach slope and the backshore is allowed to erode, the modified Bruun slope is used. In between these two beach widths, the erosion is linearly interpolated between the two methods.

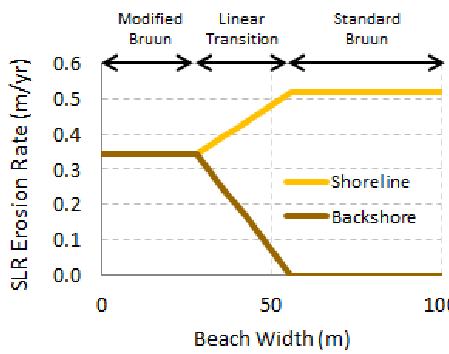


Figure A1: Example of empirical relationships between sea level rise-induced erosion rate and beach width. In this example the existing beach width is 28 meters. The sea level rise erosion rate for the standard Bruun slope is 0.52 m/yr, while the modified Bruun slope, which takes into account sediments released by the eroding dune, is 0.34 m/yr. In between the two conditions, a linear transition is assumed.

As the rate of sea level rise increases towards the end of the century, the contribution of sea level rise to shoreline movement will likely be greater than ongoing erosion in areas with a beach, while narrow beaches fronting bluffs or armoring structures may be lost entirely.

Background Erosion

All four reaches have a historic shoreline trend – either erosion or accretion. If no action is taken, and the beach and dunes are allowed to erode, this component of erosion will remain constant. However, if actions are taken that modify the beach's behavior (like beach nourishment or building a seawall), this component of erosion can increase or decrease. In this model, shoreline erosion is specified as a function of beach width. When the beach is nourished, the beach widens and the shoreline moves seaward. In this unusually wide beach configuration, the shoreline erosion rate is expected to increase (Dean 2002). If the beach narrows (either due to sea level rise or background erosion combined with holding the line), shoreline erosion decreases. An exponential empirical

[3] Bruun, P., 1962. Sea-level rise as a cause of shoreline erosion. Proceedings of the American Society of Engineers. Journal of the Waterways and Harbors Division 88, 117-130.

relationship was established between shoreline erosion rate and beach width for each reach that reflects this conceptual model.

$$E_{shoreline}(t) = \min(E_{shoreline,historic} * e^{a\left(\frac{BW(t)}{BW_{stable}} - 1\right)}, E_{shoreline,max})$$

Where:

$E_{shoreline}$ (t)	= Shoreline erosion at time t
$E_{shoreline,\ historic}$	= Historic shoreline erosion rate
$E_{shoreline,max}$	= Maximum shoreline erosion rate
BW (t)	= Beach width at time t
$BW_{ambient}$	= "Ambient" beach width
a	= calibration parameter for erosion rate responsive to beach width

Similar exponential relationships have been proposed for existing sand placement projects (Dean 2002). One assumption is that sand placements are self-similar. Previous studies have shown that an exponential relationship may overestimate the erosion rates (Dette et al. 1994). Because very little data exist related to response of shoreline erosion to sand placement, the decay parameter was selected based on wave exposure. Then, the value of (a) was increased in areas with higher wave exposure, like Manor, and decreased in reaches with lower wave exposure, like Pacifica State Beach. When a groin is implemented, the decay parameter is reduced by 50%, to account for the reduced potential sediment transport. In the beach nourishment scenarios, the decay parameter can be increased over time to reflect decreasing availability of beach-sized sediments (finer sediments are removed from the system more quickly). See the discussions about beach nourishment below for more detail.

An example of this relationship is plotted in Figure A2Figure. When the beach width is equal to the ambient beach width, the erosion rate is equal to the long-term historic erosion rate. The equation is capped with a maximum erosion rate to acknowledge that there is a limit to how quickly sand can be removed from the beach. A high value of the calibration parameter (a) leads to erosion rates being more responsive to beach width. A value of 0 would result in a constant erosion rate equal to the historic erosion rate, regardless of beach width.

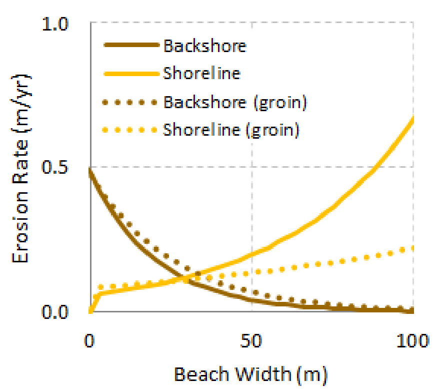


Figure A2: Example of empirical relationships between erosion rate and beach width. In this example, the existing beach width is 29 meters. The historic shoreline and backshore erosion rates are both 0.12 m/year. When a groin is added, the ambient beach width is assumed to widen by 25% to 36 meters; the shoreline erosion rates for beaches wider than the ambient beach with are reduced compared to no-groin conditions.

Beach Nourishment

This component of the equation applies during beach nourishment scenarios. Each time beach nourishment is implemented, it widens the beach by shifting the shoreline seaward. The amount the shoreline is shifted seaward depends on the volume of sand placed on the beach, the profile characteristics, and sand quality.

Backshore Erosion

The backshore location is tracked using a similar empirical relationship as the shoreline. The basic equation is similar except that the beach nourishment adjustment (which only changes the shoreline) is replaced with a placement loss distance (which only affects the backshore when armor is constructed).

$$Backshore\ Movement = SLR\ transgression + Ongoing\ erosion - Placement\ Loss$$

Sea Level Rise Transgression

As with the shoreline, the impact of sea level rise on backshore movement is incorporated by assuming that the backshore toe will move inland based on the shape of the beach profile and the amount of sea level rise:

$$Sea\ Level\ Rise\ Transgression = \frac{increase\ in\ sea\ level}{shoreface\ slope}\ or\ 0$$

The sea level rise component of backshore erosion is plotted on Figure A1 along with the shoreline erosion. If the backshore is allowed to erode and the beach is narrower than the stable beach width, a modified Bruun slope is used in this equation. This slope is calculated as:

$$Modified\ Bruun\ Slope = \frac{shoreface\ height + dune\ height}{active\ profile\ length}$$

If the scenario is to hold the line or the beach is wider than twice the stable beach width, the backshore does not erode. The backshore erosion is linear between 0 and the modified Bruun transgression when the beach is between the stable beach width and 2x the stable beach width.

Background Erosion

Bluff erosion is expected to have the opposite response to beach width: when the beach is wide, the backshore is expected to erode more slowly than if the beach is narrow, due to the additional protection from waves provided by the wide beach. When the beach becomes narrow, the backshore is expected to erode more quickly due to more frequent wave contact at the backshore toe. Once again, the erosion rate is capped by the maximum backshore erosion rate to acknowledge that the backshore (bluff/cliffs in particular) should have a maximum erosion rate which is a function of geology. This relationship is plotted, along with the similar relationship for shoreline erosion, in Figure A2.

$$E_{backshore}(t) = \min(E_{backshore,historic} * e^{-b\left(\frac{BW(t)}{BW_{stable}}-1\right)}, E_{backshore,max})$$

Where:

$E_{backshore}$ (t) = Backshore erosion at time t

$E_{backshore, historic}$ = Historic backshore erosion rate

$E_{backshore,max}$	= Maximum backshore erosion rate
BW (t)	= Beach width at time t
$BW_{ambient}$	= "Ambient" beach width
b	= calibration parameter for erosion rate responsive to beach width

In this case we calculate the decay parameter (b) using the ratio:

$$b = \frac{shoreface\ height + dune\ height}{shoreface\ height}$$

which is derived from a modified Bruun profile. This value could be modified in more detailed studies with additional information about how the backshore responds to narrower or wider beaches. Most reaches were relatively insensitive to this parameter.

It is important to note that this model does not address backshore erosion due to terrestrial processes (e.g., ground water levels, seismic forces, geology, land use, etc.) that are independent of coastal processes and outside the scope of this study.

Placement Loss

Placement loss refers to the space taken up by construction of a coastal protection structure like a revetment or seawall. These structures are usually placed at the back of the beach and cover part of the existing beach width, effectively shifting the backshore line seaward. For the current study, a placement loss of 7.6 meters (25 feet) is assumed for new armoring structures.

Appendix H
Vulnerability Studies Completed for Santa Barbara

VULNERABILITY STUDIES COMPLETED FOR SANTA BARBARA

Multiple coastal hazard assessments have already been completed at both a local and regional level that provide vulnerability data for the Santa Barbara study area (updated from ESA, 2015). As a Vulnerability Assessment Update, the current study leans heavily on previous studies and aims to refine and augment them based on newer data available from the City and studies they have commissioned. These studies served as the baseline from which the Vulnerability Assessment Update was prepared.

- FEMA flood hazard maps, which are used for the National Flood Insurance Program, present coastal (from the ocean) and fluvial (from rivers and creeks) flood hazards. New coastal flood studies were recently completed and updated maps are available and included in this report (see Appendix D and Section 2.3). These maps assess existing hazards and do not consider erosion or projected sea-level rise. See Section 3.10 for further discussion of the differences between the FEMA flood hazard maps and Coastal Hazard Mapping.

- In 2012, the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center created the Digital Coast Sea-level Rise and Coastal Flooding Impact Viewer ("NOAA SLR Viewer," available at http://coast.noaa.gov/slr/) for the entire U.S. coastline. The viewer allows users to see how existing high-tide inundation areas will change with 1-ft increments of sea-level rise.

- Tsunami inundation maps, developed by CalEMA, the University of Southern California, and the California Geological Survey, are also available for the entire state of California.

- In 2009, Philip William and Associates, Ltd. (PWA, now ESA) was funded by the Ocean Protection Council to provide the technical hazards analysis in support of the Pacific Institute report on the "Impacts of Sea-level Rise on the California Coast" ("The Pacific Institute study," PWA 2009). In the course of this work, PWA projected future coastal flooding hazards for the entire state based on a review of existing FEMA hazard maps. In addition, PWA projected future coastal erosion hazard zones for the northern and central California coastline. These hazard zones were used in the Pacific Institute study, which evaluated potential socioeconomic impacts of sea-level rise. The maps completed as part of the Pacific Institute study used statewide datasets and were not to be used for local planning purposes, but the modeling methods (Revell et al 2011) were developed to be readily re-applied as improved regional and local data became available. These "Pacific Institute study" maps were used in the City of Santa Barbara General Plan Update Environmental Impact Report (EIR) prepared by AMEC in 2010. The "Pacific Institute study" maps did not extend beyond the Santa Barbara Harbor, and while additional maps were developed for the General Plan EIR, they only used elevation to show inundation from sea-level rise, without considering where water is actually expected to flow.

- Griggs and Russell (2012) completed a preliminary assessment of the City of Santa Barbara's vulnerability to sea-level rise. This project used the exposure maps in the General Plan Update EIR (AMEC, 2010) described previously, as well as best practices and available data for sea-level rise vulnerability being used that that time. The study provided an assessment highlighting the risks that wave damage, flooding and inundation, and erosion pose to shoreline development and infrastructure in Santa Barbara into the future. It also addressed opportunities for the adaptive capacity for these hazards, but acknowledged that a more detailed understanding of the hazards and of the sensitivity of assets would improve future analyses.

- The UCSB Bren School 2015 master's project, titled City of Santa Barbara Sea-level Rise Vulnerability Assessment (Denka et al. 2015), identified vulnerabilities within human populations, critical infrastructure, recreation and public access, and ecological resources, as well as identified adaptation strategies that the City could consider for their Local Coastal Program update. It builds on the work of Griggs and Russell (2012) and pre-dates coastal resilience modeling by others that refined the flood and erosion hazards associated with various amounts of sea-level rise.

- The Goleta Slough Areas Sea-level Rise and Management Plan, was prepared by ESA for the Goleta Slough Management Committee in 2015. This study focused on the ecological resources at Goleta Slough near the Santa Barbara Airport and the implications of sea-level rise for them. The study concluded with a set of goals for the area and policies and planning steps that could be used to reach those goals.

- Coastal Resilience modeling of coastal hazards was completed by ESA under contract to the County of Santa Barbara with funding from the State of California in 2016. The report is called Coastal Resilience Santa Barbara and is available on the Coastal Resilience website operated by The Nature Conservancy[1]. The study included two phases: south County from Jalama Beach County Park to Rincon Point which is approximately 70 miles of coast (ESA, 2015), and north County from Jalama Beach to the San Luis Obispo County line (ESA,2016). The study is similar to those completed for the counties of Santa Cruz, Monterey (Monterey Bay), Ventura, and Los Angeles. The methodology and approach were more refined than the approach used in the Pacific Institute Study and were intended to inform local coastal planning. The hazard information provided in the Coastal Resilience Santa Barbara report was used to inform a vulnerability assessment prepared by the County of Santa Barbara. The County-wide work was also informed by a separate focused study prepared for the City of Santa Barbara (ESA, 2016b), which inventoried existing structures along the coast, developed and applied methods to account for coastal structures, and updated hazard maps "with armoring" for the City. The inventory method used in the focused City of Santa Barbara study was subsequently applied to the countywide study (ESA, 2016b).

- Coastal Storm Modeling System (CoSMoS) version 3.0 was applied by the United States Geological Survey (USGS) to the southern California Bight[2], which includes the City of Santa Barbara (Erickson et al, 2017). This version of CoSMoS addresses coastal erosion and flooding hazards included in the

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1 http://maps.coastalresilience.org/california/#

2 The southern California Bight is the curved coastline of Southern California from Point Conception to San Diego.

prior Coastal Resilience Project (County of Santa Barbara), but applies different methods and assumptions. Technical reports, maps and data are available on-line at the CoSMoS 3.0 weblink. [3]

3 https://www.sciencebase.gov/catalog/item/589ccbf1e4b0efcedb772583

Appendix I
Upland Hazards

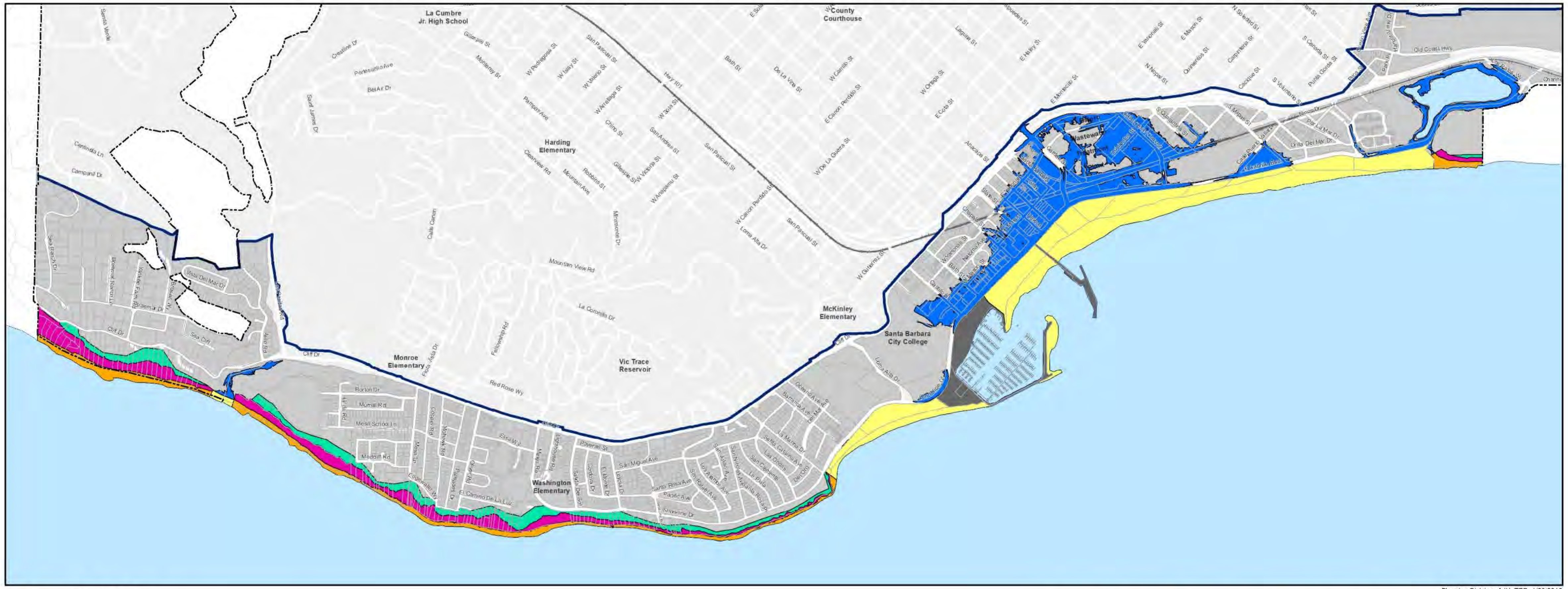
Upland Hazards

This appendix describes the source of the upland hazards mapping used in this Vulnerability Assessment (VA). Upland hazards in the vicinity of coastal bluffs were added to this VA at the request of the City of Santa Barbara. The upland hazards were added to represent the instability of the upper bluffs and adjacent inland areas for the purposes of land use planning and policy. The upland hazards are associated with geologic and geotechnical stability of coastal cliffs, including consideration of landslides and other terrestrial erosion processes. The Upland Hazards are mapped in addition to the Coastal Storm Modeling System (CoSMoS) which, as explained in the main body of the VA, addresses the exposure to coastal flooding and erosion under existing conditions and with higher sea levels projected for the future.

The City's Draft Local Coastal Program Land Use Plan has an Interim Shoreline Hazards Screening Area that includes coastal erosion and flooding, as well as areas of upland hazards associated with landslide and erosion of bluff tops (Figure I-1 copied from Figure 5.1-1, City of Santa Barbara, 2018). The upland hazards in this VA consist of the Bluff Face and Bluff Top zones in Figure I-1. These zones are based on focused study by URS (2009) on behalf of the City of Santa Barbara. Figure I-2 shows landslide and other slope failure hazard zonation 1 through 4: Several historical landslides are mapped and most of the bluff tops in Santa Barbara have the most severe risk rating of 4 (Source: Map 6, URS (2009)). A bluff top hazard zone was established 75 feet inland of landslide scarps and bluff edges, as shown in Figure I-3 (Source: Map 10, URS (2009)). Mapped landslides include the ancient Sea Ledge Lane vicinity, El Camino de la Luz (occurred 1978) and Shoreline Park (occurred 2008) which incurred a bluff top loss of approximately 38 feet (City of Santa Barbara, 2018; Campbell Geo, 2018 Appendix C).

The upland hazards and coastal hazards mapped in this VA are not completely independent, but rather, are based on different analyses that are complementary. The coastal hazards address erosion by waves and wave runup at the base (or "toe") of the bluffs, which results in bluff recession (landward erosion) that may extend to the top of the bluff or only to an intermediate location on the face. Over time, the erosion at the base of a bluff can be expected to result in failure at the top of the bluff. However, the bluff top recession can lag the erosion at the bluff base, and bluff top recession is also affected by terrestrial erosion processes (e.g. driven by rain and wind). Terrestrial bluff erosion can take the form of landslides or other erosion events, for example when an over-steepened bluff is saturated from rainfall and drainage causing the weight of the bluff to exceed its strength. The slope failure risk depends on other factors, such as the bluff layering and faulting, and groundwater flows which are not modeled explicitly in the coastal hazard modeling. While the historic erosion rates derived from historical maps and aerial photographs include terrestrial erosion processes, the use of long-term average bluff erosion rates does not necessarily convey the potential for a mass failure in any given year. For this reason, the Coastal Resilience Santa Barbara (CRSB) mapping includes a "safety buffer" of upland erosion hazards based on an approximate estimate of the dimensions of historical bluff failures plus the calculated uncertainty in long-term bluff erosion rates for a given time frame. An example is shown in Figure I-4 (ESA, 2015). For existing conditions, a block-failure width of 5 to 120 meters was used depending on the location and geology. For future conditions, an additional buffer distance was computed as the elapsed number of years multiplied by the standard deviation of the historic erosion rates. Note that the CRSB bluff-top safety buffer is not analyzed in the VA, but may be considered to approximately indicate higher risks and uncertainty with future conditions.

FIGURE 5.1-1 INTERIM SHORELINE HAZARDS SCREENING AREAS



Planning Division, AJN, TRB, 1/29/2018

NAD 1983 State Plane
California V FIPS 0405 (Feet)

1:24,000

BOUNDARIES

- Coastal Zone
- City Limits

SHORELINE HAZARDS SCREENING AREAS

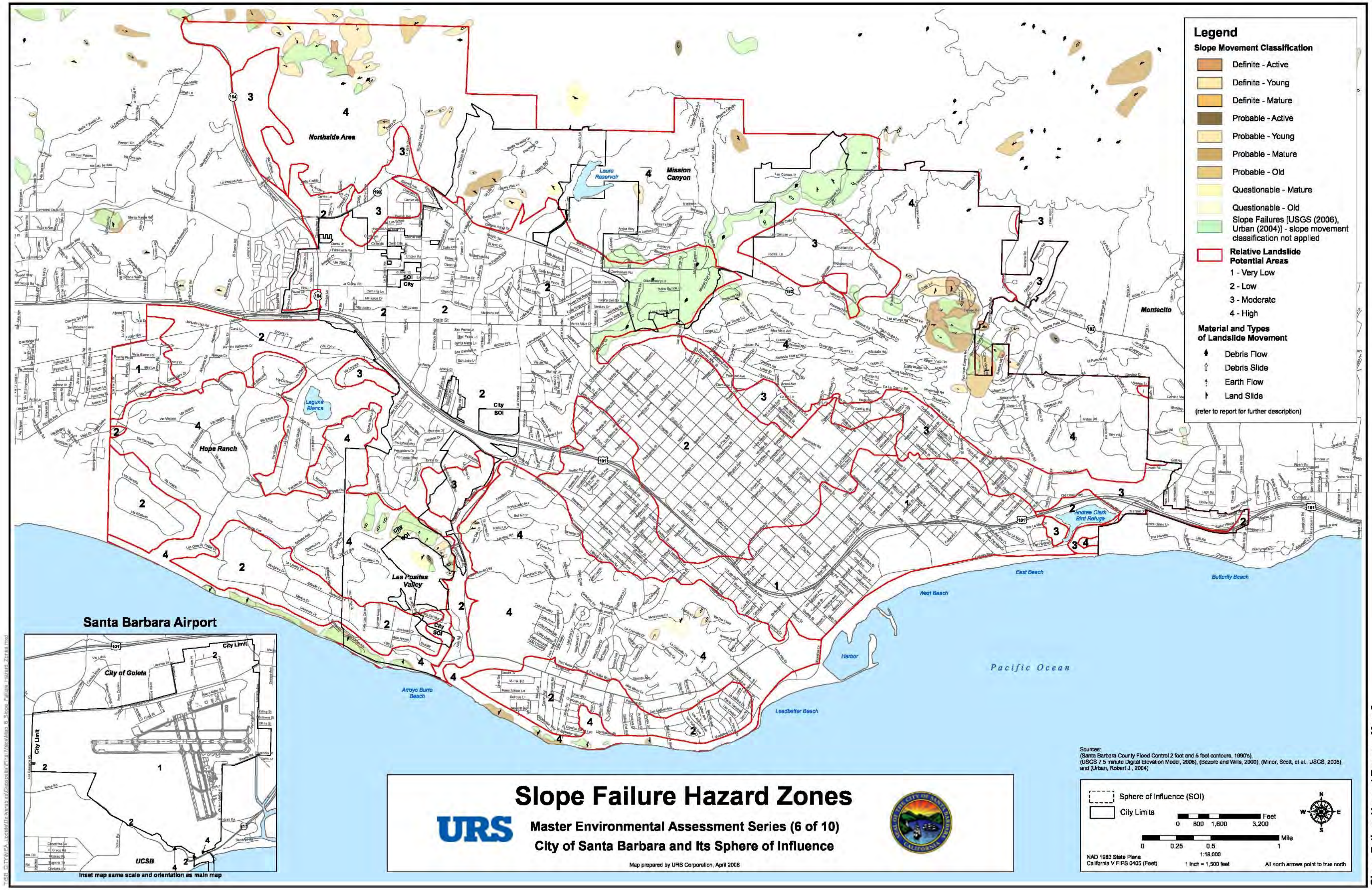
- Area 1 - City-Owned Low-Lying Beach and Backshore Areas
- Area 2 - Bluff-Backed Beaches
- Area 3 - Coastal Bluff Faces
- Area 4 - Coastal Bluff-Tops
- Area 5 - Stearns Wharf and Harbor
- Area 6 - Inland Coastal Flooding Area

Note: This map was created using the middle confidence bound of the USGS CoSMoS 3.0 model outputs for the 150cm SLR scenario with a 100 year storm event, no beach nurishment, and no consideration of existing coastal protective structures. This is an illustrative tool used to depict hazard screening areas potentially subject to shoreline hazards including: beach erosion; coastal bluff erosion; coastal bluff slope failure or instability; coastal flooding; and wave impacts, now and in the future and factoring in the anticipated effects of sea level rise. This map is based on model outputs and does not account for all of the complex and dynamic geologic conditions and coastal processes that could occur at any given site, future construction, shoreline protection upgrades, or other changes to the City or region that may occur in response to sea level rise. This map provides a screening-level tool for when site specific technical evaluations may be required and when development standards pertaining to shoreline hazard areas may be applied. Any areas subject to beach erosion, coastal bluff erosion, coastal bluff slope failure, coastal flooding, and/or wave impacts that are not depicted on the Map, shall also be subject to the policies of this Coastal LUP. This map shall be used in the interim period between Coastal Commission certification of this Coastal LUP and when new shoreline hazard screening procedures and maps are certified as part of a future Sea Level Rise Adaptation Plan process. Further information on the Shoreline Hazards Screening Areas can be found in Policy 5.1-28 Interim Shoreline Hazards Screening Areas Map.

Sources: California Coastal Commission GIS/Mapping Unit (2017), USGS CoSMoS 3.0 (2017), City of Santa Barbara (2017), URS (2009)

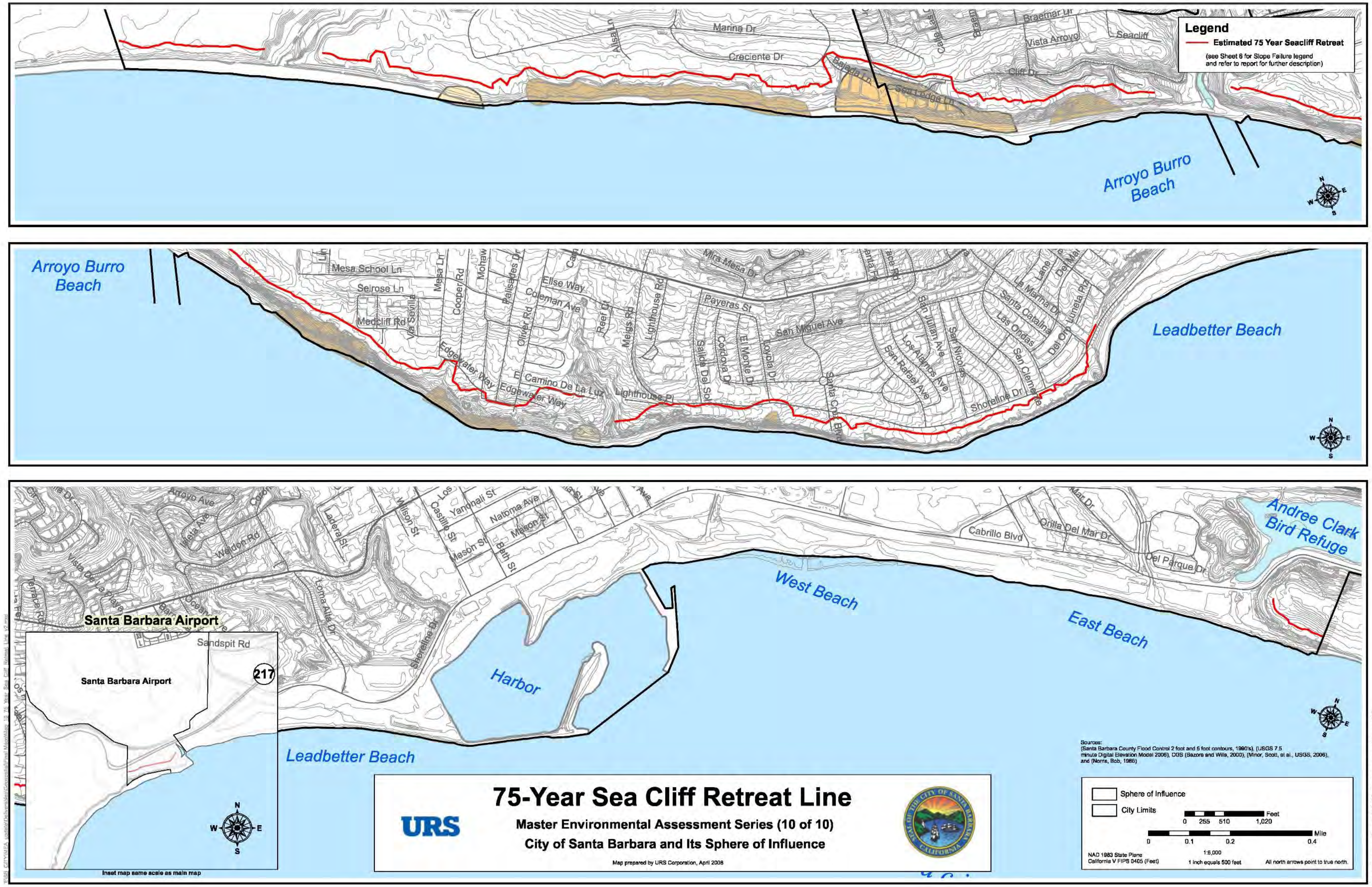
SOURCE: Santa Barbara Draft Land Use Plan, 2018

Figure I-1
Interim Shoreline Hazards Screening Areas



SOURCE: URS, 2009

Figure I-2
URS Slope Failure Hazard Zones



SOURCE: URS, 2009.

Figure I-1
URS 75-Year Sea Cliff Retreat Line

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City of Santa Barbara Sea-level Rise Adaptation Plan for the LCP Update / D171018.00

SOURCE: TNC, et al. 2015; ESA, 2015

Figure I-4
Bluff-top Safety Buffer for Existing Conditions

References

City of Santa Barabara draft land use plan, draft for City Council, April 2018

ESA 2015, Santa Barbara County Coastal Hazzard Modeling and Vulnerability Assessment, Technical Methods Report. November, 2015

URS (2009) Geology and Geohazards Master Environmental Assessment, Technical Report and Evaluation Guidelines. Prepared by URS Corporation. 2009.