Santa Cruz County
Coastal Climate Change Vulnerability Report

JUNE 2017

CENTRAL COAST WETLANDS GROUP

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Prepared for

The County of Santa Cruz

Funding Provided by:

The California Ocean Protection Council

Grant number C0300700

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Summary of Findings

This report is intended to provide greater detail on the risks to resources and assets within unincorporated Santa Cruz County from coastal climate change during three future time horizons (2030, 2060 and 2100). Risks to properties were identified using the ESA PWA Monterey Bay Sea Level Rise Vulnerability Study[1] layers developed in 2014 using funding from the California Coastal Conservancy. Key findings of this evaluation include:

- The ESA coastal hazard model results for the 2010 planning year identified numerous residential properties within Santa Cruz County at risk of coastal storm flooding and erosion (472 in Santa Cruz County).
- Significantly more residential (797 in Santa Cruz County) and commercial buildings (122 in Santa Cruz County) are identified by FEMA as being at risk of flooding (although many of these are protected by levees and other structures).
- There are more than 10 miles (54,300 feet) of coastal protective structures (seawalls and rip-rap) in Santa Cruz County.
- Coastal flooding hazards for 2030 are predicted to impact areas below 3 meters elevation.
- Coastal access, parking and 80 commercial and residential buildings are vulnerable to wave damage and coastal flooding by 2030 within the low-lying sections of Rio del Mar. More than 130 buildings within the Pajaro Dunes Colony (many comprised of multiple residences) are also vulnerable to flooding during winter storms.
- By 2060 more than 800 additional buildings are at risk of impact from a predicted 2.4 ft. rise in sea levels as coastal protective structures begin to fail. If current structures are replaced, it is estimated that 500 of the vulnerable buildings would be protected, 400 of which are private residence.
- If all of the 54,300 feet of coastal armoring are replaced (at current dimensions) but no additional structures are constructed, more than 900 buildings will remain vulnerable to predicted 2060 coastal climate hazards.

[1] ESA-PWA. 2014. *Monterey Bay Sea Level Rise Vulnerability Study: Technical Methods Report Monterey Bay Sea Level Rise Vulnerability Study*. Prepared for The Monterey Bay Sanctuary Foundation, ESA PWA project number D211906.00, June 16, 2014.

- If all current coastal armoring is replaced and additional structures are constructed to protect the additional 500 buildings and 35,000 feet of roadway, more than 12 miles of the Santa Cruz County coastline would be armored by 2060.
- By 2100, more than 1,800 residential properties within the unincorporated county are vulnerable to coastal climate change hazards.
- The total value of residential properties at risk increases to $1.75 billion (84% of coastal resources) by 2100.
- Almost 3.5 miles of new coastal armoring will be necessary to protect the current north county highway alignment through 2100.
- By 2100 most of Seacliff, Aptos and Manresa beaches will be flooded during high tides if coastal bluffs are not allowed to erode inland.

1. Introduction

1.1. Background

This report was funded by The Ocean Protection Council through the Local Coastal Program Sea Level Rise Adaptation Grant Program. This grant program is focused on updating Local Coastal Programs (LCPs), and other plans authorized under the Coastal Act such as Port Master Plans, Long Range Development Plans and Public Works Plans (other Coastal Act authorized plans) to address sea-level rise and climate change impacts, recognizing them as fundamental planning documents for the California coast.

This project is intended to achieve key objectives to further regional planning for the inevitable impacts associated with sea-level rise (SLR). This project will:

1. Identify what critical coastal infrastructure will be compromised due to SLR and estimate when those risks may occur; and
2. Define appropriate response strategies for these risks and discuss with regional partners the programmatic and policy options that can be adopted for LCP updates.

This project has incorporated the most complete inventory of coastline revetment and seawalls for the Monterey Bay[2] with coastal hazard GIS layers developed by Phil Williams and Associates and ESA Consulting to account for current protections from current and future coastal hazards. For the Capitola and Moss Landing communities, the project further evaluated the combined impacts of sea level rise and changes in fluvial processes on municipal infrastructure, private properties and natural resources. The project also evaluated relevant state policies and adaptation response alternatives ranging from "grey to green" for integration into municipal planning documents. The project has also fostered regional discussions regarding inclusion of appropriate adaptation strategies into Local Coastal Program and other planning documents.

1.2. Coastal Commission Guidance

The Coastal Act requires that the 61 cities and 15 counties in coastal California prepare Local Coastal Programs (LCPs) to govern land use and development in the coastal zone inland of the mean high tide. LCPs are prepared by local governments to guide decisions for short- and long-term conservation and use of coastal resources. LCPs become effective only after the Commission certifies their conformity with the policies of Chapter 3 of the Coastal Act. After an LCP has been approved, the Commission's coastal permitting authority is transferred to the local government, which applies the policies of the LCP

[2] The California Coastal Commission maintains a GIS database of coastal structures within Santa Cruz County and has worked with CCWG and others to improve the base layer for Monterey County as well.

when reviewing proposed new development. The Commission retains permanent coastal permit jurisdiction over development proposed on public trust lands, submerged lands and tidelands, and reviews and approves amendments to previously certified Local Coastal Programs.

The California Coastal Commission Sea Level Rise Policy Guidance, adopted by the Commission in August 2015[3], provides a framework for addressing SLR in LCPs and Coastal Development Permits. The Commission recommends the following six steps to address sea level rise as part of the development of an LCP, LCP Amendment, or other plan. Steps 1-3 are often referred to as a "sea level rise vulnerability assessment" in other sea level rise planning contexts and therefore are similar to other sea level rise-related resources. The intent of this OPC funding is to provide Santa Cruz and Monterey counties and the City of Capitola with a sufficiently detailed "sea level rise vulnerability assessment" to address steps 1-3 of the guidance and support integration of these findings into future LCP updates for these areas.

1.3. Geographic Scope of Study

The geographic scope of this report lies within the coastal zone of unincorporated Santa Cruz County, and extends from Año Nuevo in the north to the Pajaro River in the south (Figure 1). However, this report also provides less detailed results for the incorporated areas of the City of Santa Cruz, City of Capitola, and the City of Watsonville. A separate report provides more detailed evaluation of potential impacts and adaptation strategies for the City of Capitola[4].

For the purpose of this report, results for unincorporated Santa Cruz County will be divided into 4 geographic areas: Section 1) North County: Año Nuevo to western Santa Cruz City Limits, Section 2) East Cliff: 7th Ave to western City of Capitola city limits, Section 3) Seacliff: Seacliff to Manresa, and Section 4) Pajaro Valley: Manresa to Pajaro River/Monterey County Border (Figure 1).

[3] California Coastal Commission. 2016. California Coastal Commission Sea Level Rise Policy Guidance: Interpretative Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits. Adopted August 12, 2015.
[4] Central Coast Wetlands Group. 2017. City of Capitola Coastal Climate Change Vulnerability Report, Draft Report. Prepared for the City of Capitola with funding from by the Ocean Protection Council, Grant Number C0300700.

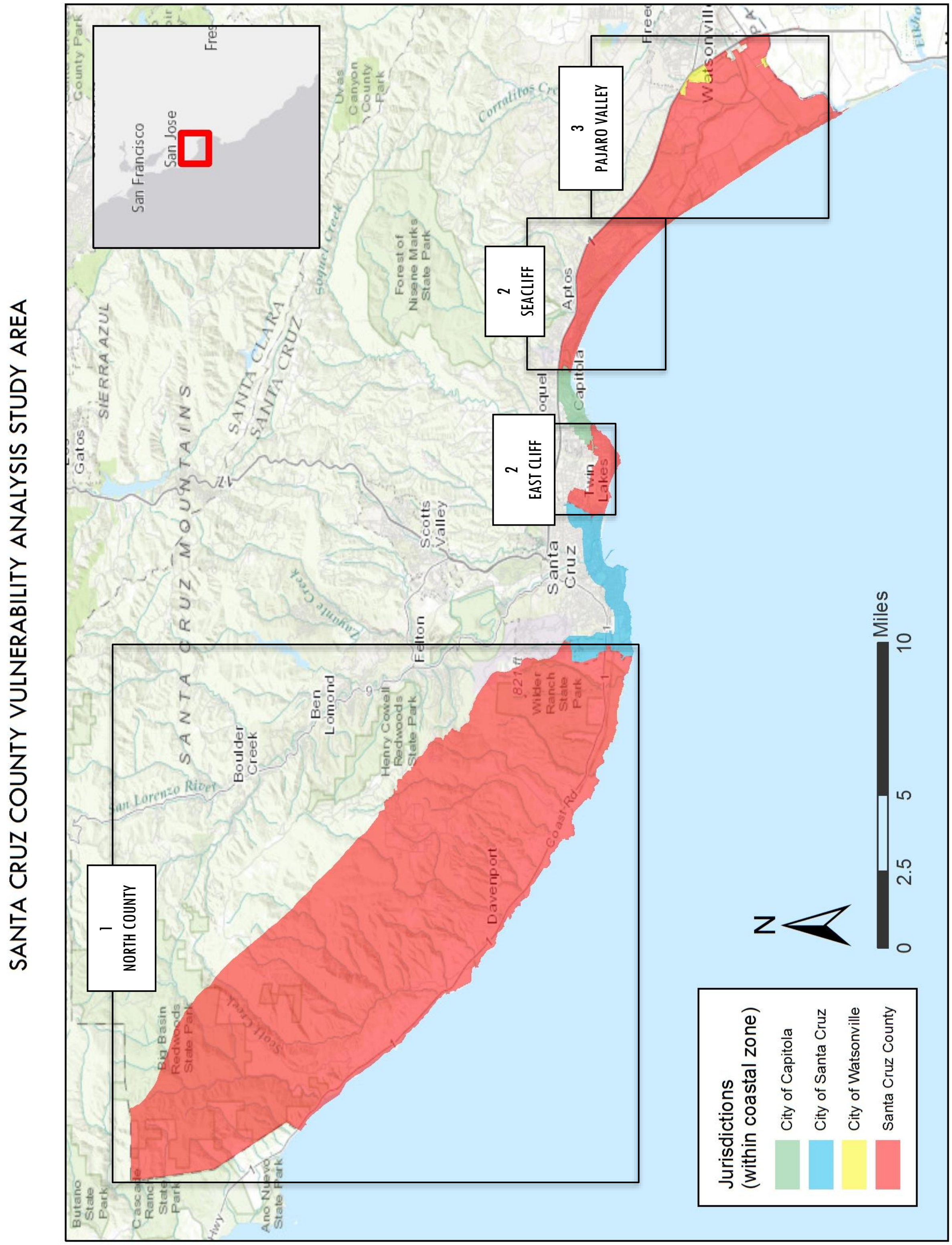

Figure 1. Geographic Scope of Coastal Climate Change Vulnerability Analysis

2. Community Profile

2.1. Setting and Climate[5]

Santa Cruz County is a 445.17 square mile county in the northern Monterey Bay along the Central Coast of California, bordered by San Mateo County to the north, Santa Clara County to the east, and Monterey County to the south. Santa Cruz County has four incorporated cities: Santa Cruz, Capitola, Scotts Valley, and Watsonville. The unincorporated area, including 26 census-designated places, accounts for 417 square miles of the county.

Santa Cruz County's physical environment is incredibly diverse, from the shady redwood forests of the Santa Cruz Mountains to the sunny beaches of the coastal terraces and the alluvial soils in the southern Pajaro Valley. The coastal location and topographic features contribute to the mild Mediterranean climate, with average monthly high temperatures ranging from 62°F in December to 76°F in August and September, and average monthly lows ranging from 41°F in December and January to 54°F in July and August. The county has an average annual precipitation of 31 inches, with most coming during the winter months.

The California Coastal Act of 1976 required Santa Cruz County to prepare and adopt a Local Coastal Program Land Use Plan for the coastal zone of the County. The Local Coastal Program Land Use Plan was published as a separate companion volume to the 1980 Santa Cruz County General Plan, but it is now incorporated into the 1994 General Plan. The coastal zone of the County encompasses parts of the North Coast, Bonny Doon, City of Santa Cruz, Live Oak, Aptos, La Selva, and San Andreas areas, as well as most of the City of Capitola.

2.2. Culture and Industry

Santa Cruz County is a popular destination for tourists and a loved home by locals, with many beaches, the Santa Cruz Beach Boardwalk, world-class surf breaks, Capitola Village, Santa Cruz and Capitola Wharfs, University of California, Santa Cruz, Cabrillo College, several State Parks, Long Marine Lab and Seymour Marine Discovery Center, coastal redwood forests, rugged cliffs, and many outdoor activities including hiking, kayaking, sailing, surfing, beach volleyball, biking, running, golfing, stand up paddle boarding, fishing, and more.

Santa Cruz County also hosts cultural events and festivals including Santa Cruz Shakespeare, Santa Cruz County Symphony, Cabrillo Festival of Contemporary Music, Open Studios Art Tour, First Fridays Art

[5] Much of the community profile is excerpted from the Santa Cruz County General Plan.

Tours, O'Neil Cold Water Classic Surf Contest, Wharf to Wharf 10K Race, Mushroom Festival, Clam Chowder Festival, Friday Night Beach Concerts (Summer), and Woodies on the Wharf.[6]

The diverse landscape contributes to the varied economic base, which includes agriculture and food processing in the South County, and tourism and service in the North County. Other dominant industries include government, technology, quarrying, forestry, wood products, fishing, and other manufacturing (LCP 1994).

2.3. Historical Context

Santa Cruz County was one of the 27 original counties when California became a state in 1850. Spanish explorers had arrived as early as 1769, and a mission was established in 1791 in what is now the City of Santa Cruz. Villa de Branciforte (now East Santa Cruz) was one of the first three pueblos, or Spanish settlements, in California. After Santa Cruz was recognized as a county, logging, lime processing, fishing, and agriculture became prominent industries, and the county became a popular resort community.[7]

2.4. Demographics

According to the US Census Bureau estimate for 2015, the total population of Santa Cruz County is 274,146 people. 50.4% identify as female. 87.4% of the population identifies as white, while 1.4% identify as black, 1.8% as American Indian and Alaska Native, 5% as Asian, 0.2% as Native Hawaiian and Other Pacific Islander, and 4.1% as two or more races. 33.3% of the population identifies as Hispanic or Latino (of any race). The median household income in 2014 dollars is $66,923, and 16.1% of the population is under the poverty line. 85.5% of the population (over 25) has a high school diploma, and 37.5 have a bachelor's degree or higher.[8]

2.5. Community Resources and Assets

Coastal Cities and Communities

The County of Santa Cruz is the second smallest county in California by land area and third smallest by total area. Approximately half of the county's population resides within 4 incorporated cities (Santa Cruz, Watsonville, Scott's Valley and Capitola) with the rest of the population is small communities or census designated places, including many which fall into the coastal zone (Rio del Mar, Pleasure Point, Twin Lakes, Seacliff, La Selva Beach, Davenport, Bonny Doon, Pajaro Dunes).

[6] Santa Cruz Neighborhoods. SantaCruzChamber.org. Santa Cruz Chamber of Commerce.
[7] History. CityofSantaCruz.com. City of Santa Cruz.
[8] United States Census Bureau website. www.census.gov/quickfacts/table/PST045215/00. Accessed August 15, 2016.

Land Use

Emergency Services: There are 2 hospitals equipped with emergency rooms, 1 maternity and surgery center, 1 inpatient psychiatric facility, and numerous primary and urgent care facilities in Santa Cruz County. Law enforcement facilities include city police stations (Watsonville, Capitola, Santa Cruz, Scott's Valley), county sheriff's offices and substations, a University of California at Santa Cruz police department, multiple state highway patrol offices and the rangers and game wardens of the state and federal parks and wildlife refuges. Fire stations comprise a mix of state, county, contract city, district or volunteer-staffed equipment. Santa Cruz County fire department personnel are dispatched by CAL FIRE San Mateo Santa Cruz Unit Emergency Command Center and are part of the "Integrated Fire Protection System" under contract with the State of California. Seventeen county facilities include service centers and training centers from Saratoga Summit Fire Station 21 in Los Gatos in the north county to Pajaro Dunes Fire Station 42 in the south county.

Schools: Santa Cruz County houses 10 public school districts (Bonnie Doon Union Elementary, Happy Valley Union Elementary, Live Oak, Mountain Elementary, Pacific Elementary, Pajaro Valley Unified, Santa Cruz City, San Lorenzo Unified, Scotts Valley Unified, and Soquel Union Elementary) which oversee 78 district and charter schools for grades K-12. In addition, there are 19 alternative schools managed by the County Office of Education and 34 private schools for PreK-12 grades.

Accommodations, Food, Shopping and Amenities: Santa Cruz County has 29 miles of coastline dotted with state parks and beaches. From the coast to the mountains are many quaint towns offering accommodations ranging from spots to pitch a tent, to AirBnB room rentals, to rustic and luxury hotels and beach house rentals. There are a plethora of galleries featuring handcrafted home goods, apparel and jewelry, and local vineyards, breweries, bakeries and restaurants offer sustenance at many price points, from downright cheap taco food trucks to high end seafood eateries with an ocean view. Cultural amenities include the Santa Cruz County Symphony, the Cabrillo Music Festival, Shakespeare Santa Cruz, the University of California Performing Arts Center and the Henry J. Mello Performing Arts Center. The Santa Cruz Beach Boardwalk is a popular tourist destination and one of the top five employers in the County. Recreational activities include sailing, fishing, surfing, kayaking, golf, hiking, and more.

Agriculture: Agriculture is one of the largest industries in Santa Cruz County, contributing $1.46 billion to the local economy annually and providing approximately 11,000 jobs to the county economy. Strawberries and raspberries are the number one and two crops in the county, respectively. Other high value crops include Brussels sprouts and other vegetables, blueberries, and nursery crops such as cut flowers, cut greens, and nursery stock. Organic crops account for approximately $115 million of the total value. Products are exported throughout the United States and the world.[9,10]

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[9] Agricultural Impact Associates LLC. 2013. Economic Contributions of Santa Cruz County Agriculture, part of the "Crop Report Plus" series. Prepared for the Santa Cruz County Agricultural Commissioner's Office. 12 pp.

[10] Office of the Agricultural Commissioner. 2015. Santa Cruz County 2015 Crop Report. Watsonville, CA. 14 pp.

Recreation and Public Access

Beaches, Parks, and Reserves: Santa Cruz County has several state parks, state beaches, and state and national reserves within its borders. State parks include Big Basin Redwoods State Park, Coast Dairies State Park, Wilder Ranch State Park, Henry Cowell Redwoods State Park, and the Forest of Nisene Marks State Park. In addition to many small pocket beaches surrounded by rugged cliffs, county beaches also include Natural Bridges State Beach, Seabright State Beach, Twin Lakes State Beach, New Brighton State Beach, Seacliff State Beach, Rio Del Mar State Beach, Manresa State Beach, Sunset State Beach, Pajaro River mouth and many popular tourist beaches including Main Beach and Capitola Beach. The county also includes Ellicott Slough Wildlife National Wildlife Refuge and Natural Bridges State Marine Reserve. The entire coastline of the county falls into the Monterey Bay National Marine Sanctuary, designated in 1992. Nineteen county parks have facilities for recreational activities including baseball, basketball, hiking, soccer, swimming, volleyball and public art viewing.

Coastal Access and Public Visitor Parking: Along the northern coast of Santa Cruz County, many of the beaches are accessible via Highway 1, and some of the larger beaches have roadside dirt parking lots with trails to the beaches. In the City of Santa Cruz, West Cliff Drive travels along the coast of the west side, with beach access points at various locations, and East Cliff and Opal Cliff Drives provide access on the east side. Highway 1 is further inland south of City of Capitola, but there are access roads along the coast, with parking lots for beach access.

Transportation

Roads: Highway 1, a scenic highway, runs all along the coastal edge of Santa Cruz County. In the Northern part of the county, it is a two-lane highway along the coastal bluffs; it then passes through the City of Santa Cruz on Mission Street, and then becomes two (or occasionally three) lanes each way as it passes more inland in the southern part of the county. Highways 9 and 17 leave the City of Santa Cruz and travel north through the redwoods, to the Ben Lomond/Boulder Creek area and to the Los Gatos/San Jose area, respectively. Highways 129 and 152 connect Watsonville to Santa Clara County. The General Plan specifically states that a goal of the County is to reduce automobile trips and congestion by improving alternative transportation modes and improving efficiency rather than increasing the size of the existing road system.

Rail: Railroad tracks span from north of Davenport to Watsonville and link to additional rail infrastructure leading into Monterey County and inland into Santa Clara County. There's also a popular line that runs passenger trains through a portion of south county all year long, and a special tourist and holiday trains along various sections of the tracks including Santa Cruz City to Felton's Roaring Camp. The County recently purchased the rail line and has long-term plans to provide local passenger service in the future.

Public Transportation: The Santa Cruz Metro runs public busses throughout Santa Cruz County, including the Amtrak Highway 17 Express, and local busses, which include routes in the City of Santa Cruz including UCSC's campus, Scotts Valley and SLV, the North Coast, Mid-County, Live Oak, Cabrillo/South County, and local Watsonville. There is also a Greyhound bus stop in Santa Cruz City.

Air: The Watsonville Municipal Airport is a regional airport serving the City of Watsonville, Santa Cruz County, and the Monterey Bay area. Serving approximately 40% of all general aviation activities in the Monterey Bay area, the airport is owned by the City of Watsonville and supports private flying, flight training, ground school, aircraft rental, maintenance, air ambulance, law enforcement aviation, air charter and other aviation-related activities and businesses.

Conservation and Open Space

Sensitive Habitat: Santa Cruz County is home to areas of sensitive habitat designation, which are defined according to certain criteria, including;

- Areas of special biological significance as identified by the State Water Resources Board;
- Areas which provide habitats for locally unique biotic species/communities;
- Areas adjacent to essential habitats of rare, endangered or threatened species;
- Marine habitats including nearshore reefs, rocky intertidal areas, sea caves, islets, offshore rocks, kelp beds, marine mammal hauling grounds, sandy beaches, shorebird roosting, resting and nesting areas, cliff nesting areas and marine, wildlife or educational/research reserves, dune plant habitats, wetlands, estuaries, and lagoons;
- Freshwater habitats such as lakes, wetlands, estuaries, lagoons, streams and rivers, riparian corridors;

Environmentally sensitive habitat areas (ESHA) are those sensitive habitats defined by the California Coastal Act as “any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments” (Section 30107.5).” Policies in the Santa Cruz County General Plan provide for the protection of ESHA, in particular aquatic and marine habitats, Monterey Bay and coastal water quality, as well as freshwater resources, and hydrological, geological and paleontological resources, visual resources, open space, timber resources, agriculture, mineral resources, air quality, and archaeological and historic resources.

Wetlands/Riparian corridors: Wetlands provide resiliency to SLR, helping to mitigate erosion and flooding, filtering pollutants from the water, and sequestering carbon from the air. Many of the county’s creeks and rivers are bordered by riparian and wetland habitat. Many of these coastal confluences support anadromous fish populations and many threatened and endangered species. The Watsonville Slough system of wetlands, marsh and grasslands creates a diverse ecosystem that provides foraging and breeding habitats for a variety of wildlife, including five federally-listed species and 16 state-listed species of special concern.

Dunes: Dune habitat is not widespread along Santa Cruz’s rocky coastline, but dunes are found at multiple state beaches distributed along the coastline with large dune systems located in south county near the Pajaro River. Healthy beach dunes act as a reservoir of sand for beach erosion and protect valuable farmlands from flooding.

Beaches: Multiple beaches make up the coastal zone in Santa Cruz County. While all these beaches are not associated with dune habitat, the beaches themselves act as a buffer from coastal flooding. Twenty-nine miles of beaches extend from Año Nuevo State Park in Pescadero to Sunset State Beach in Watsonville, with many state, municipal and city beaches in between.

Water and Utility Infrastructure

Water Supply*:* Unlike much of California, Santa Cruz County is served almost exclusively by local water sources that generate supplies for residential, commercial and agricultural uses. The General Plan designates certain areas as primary groundwater recharge areas. Within the County, water is primarily supplied by four agencies: the City of Santa Cruz Water District, the Soquel Creek Water District, the Central Water District, and the Watsonville Water Department. Independent groundwater pumping usually provides agricultural water. The primary source of residential and agricultural water supply in the southern two-thirds of the county is groundwater aquifers, while the northern third of the county relies primarily on surface water supplies.

Groundwater Use: All groundwater aquifers in the county are in some degree of overdraft. Over-pumping of groundwater can increase saltwater intrusion by dropping the level of the fresh groundwater, thereby reducing its water pressure and allowing saltwater to flow further inland. Saltwater intrusion can be worsened by extreme events like storm surges. Recycling of waste water for agricultural irrigation is one of the main means for decreasing groundwater pumping, as well as instituting conservation measures and finding additional supply of freshwater. Under the County General Plan, any new developments must provide evidence of water availability in order to proceed.

Wastewater Treatment: In urban areas wastewater is treated at facilities which provide sanitary sewer services. All sanitation districts have the ability to meet current usage and projected increases. In rural areas of the county, wastewater is treated in individual septic systems or community package treatment plants. There are two major waste water treatment plants located within low lying coastal areas within the City of Santa Cruz and the Pajaro Valley adjacent to Watsonville.

Electric and Gas Utilities: Santa Cruz County is served by Pacific Gas & Electric. There are approximately 22 energy substations in the county, most concentrated in the areas of highest population, the cities of Santa Cruz and Watsonville. The General Plan recommends that all new power line distribution systems and all services to new development are to be placed underground. PG&E did not provide geographic information on the location of their infrastructure for this report.

Solid Waste Disposal: There are two recycling and solid waste disposal sites within Santa Cruz County. One, the Buna Vista Landfill, is approximately 1.5 miles from the coast in the southern part of the county. The other, the Ben Lomond Transfer Station, is approximately 8 miles from the coast northeast of Davenport in the northern part of the county.

Coastal Protection

Shoreline protective structures are used to protect development and infrastructure from wave action, to avoid erosion and to retain soil adjacent to development. Impacts of constructing and maintaining coastal protection structures include visual degradation of coastal vistas, loss of beach area, restrictions to public access, loss of sand supply from eroding beaches and cliffs, and passive and active down shore erosion. The most common forms of coastal armoring are seawalls, revetments, breakwaters, and groins.

Seawall: A seawall is a vertical wall parallel to the shoreline that protects land behind it from wave erosion and flooding.

Revetment: A revetment is a protective structure designed to maintain a slope and is constructed parallel to a shoreline of a sturdy material such as stone.

Breakwater*:* A breakwater is a hardened structure parallel to the shoreline that is designed to protect the coast from the force of waves. Unlike a seawall or revetment, a breakwater is offshore and often submerged. Waves are forced to break before they meet the shoreline, decreasing the energy with which the water reaches the coast.

Groin: A groin or jetty is a rigid linear structure that extends out into the nearshore zone perpendicular to the shoreline and interrupts water flow and limits the down shore movement of sediment. Groins may be constructed in a series, known as a groin field, to trap sand in between-groin sections along a coast. Unlike seawalls, revetments, and breakwaters, which are constructed to prevent erosion in order to protect buildings and infrastructure, groins are constructed to expand beaches but often reduce beach width down coast of the structures.

Local, state, and federal governments as well as private landowners have installed hard structures to protect development threatened by coastal erosion. Between 1983 and 1993, 47 shoreline armoring projects were permitted in the Santa Cruz County LCP jurisdiction, with another 13 in the City of Santa Cruz and four in Capitola's jurisdictions.[11] These projects were granted through both regular and emergency permits by the Coastal Commission. The most common types of coastal armoring structures in central California are seawalls and riprap,[12] and both are readily apparent in the study area throughout Santa Cruz County's coastal zone (e.g. Opal Cliffs, Lighthouse Point, Cowell's Beach, Westcliff Drive, Pleasure Point).

Coastal erosion and storm damage along the coast of Santa Cruz County are maximized when several factors occur simultaneously, all of which are associated with El Nino-Southern Oscillation events. Those

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[11] California Coastal Commission Monterey/Santa Cruz ReCAP. 1995. https://www.coastal.ca.gov/recap/rcmontsum.html. Accessed October 31, 2016.

[12] Stamski R. 2005. The impacts of coastal protection structures in California's Monterey Bay National Marine Sanctuary. Marine Sanctuaries Conservation Series MSD-05-3. US Department of Commerce, National Oceanic and Atmospheric Administration, Marine Sanctuaries Division, Silver Spring, MD. 18 pp.

factors include high tides, higher than normal sea level, and more frequent and larger storm waves. Natural processes such as cliff retreat, storm inundation, and beach erosion occur sporadically and have not been fully recognized, appreciated or understood by coastal builders, developers, realtors and home buyers. Much of California's oceanfront development took place between the mid-1940s and the mid-1970s, a period of below-average rainfall and storm frequency that characterizes La Nina periods. Ignorance coupled with La Nina conditions created a developed coast that is very vulnerable to the more severe and frequent El Nino events of the Pacific decadal oscillation.[13]

Since the late 1920s, there have been at least 11 storms that have caused significant and documented damage to coastal assets in this reach.[14] Storm-driven waves have destroyed seawalls, roads, buildings, parking lots, sewer lines, and recreational facilities such as camping sites.[15]

Coastal storm damage from the 1983 El Nino caused an estimated $200 million in damage to houses, businesses, parks, harbors, and public infrastructure in California, including an estimated $10M ($24M - 179 in today's dollars) in damage in the City of Santa Cruz.[16,17]

Table 1. Major Floods in Santa Cruz County, 1861 to Present[18]

DATE	DESCRIPTION OF DAMAGE
1799-1852	No verifiable sources have been found dating and estimating damage for floods prior to 1861, although noticeable floods likely occurred within the City of Santa Cruz.
Winter 1861-1862	*Bridges and mills upstream of City of Santa Cruz destroyed, buildings built on the banks of the San Lorenzo River within the city were washed out to sea, and water eroded 30 feet of soil away from the base of Mission Hill. Upper River St. area flooded. Water levels of approximately 16 feet. After the flood, it was claimed that the river was "several hundred feet nearer to the town" than it had been before. A bulkhead was built to stabilize the riverbank near the plaza (site of Bulkhead St. today). Townspeople began to change the river channel so it would run past Mission Hill rather than straight at it and property owners on what is now Pacific St. began to raise the grade in their lots. No bridges yet spanned the San Lorenzo River, so there were no structures to trap debris and raise the water level behind them. 1862 became the legendary flood for late 19th and early 20th century Santa Cruz oldtimers,

[13] Griggs GB. 2005. The impacts of coastal armoring. Shore and beach 73 (1), 13-22.
[14] Griggs GB, Johnson RE. 1983. Impact of 1983 storms on the coastline of Northern Monterey Bay. Santa Cruz County: California Geology 36 (8), 163-174.
[15] The United States Army Corps of Engineers, Monterey Bay National Marine Sanctuary, Noble Consultants, Inc. 2014. Coastal Regional Sediment Management Plan for the Santa Cruz Littoral Cell, Pillar Point to Moss Landing. Prepared for the Coastal Sediment Management Workgroup.
[16] Griggs GB, Johnson RE. 1983. Impact of 1983 storms on the coastline of Northern Monterey Bay. Santa Cruz County: California Geology 36 (8), 163-174.
[17] The United States Army Corps of Engineers, Monterey Bay National Marine Sanctuary, Noble Consultants, Inc. 2014. Coastal Regional Sediment Management Plan for the Santa Cruz Littoral Cell, Pillar Point to Moss Landing. Prepared for the Coastal Sediment Management Workgroup.
[18] County of Santa Cruz Planning Department. 2013 Chapter 5 of the Climate Action Strategy. Adopted by the Board of Supervisors 2/26/2013.

DATE	DESCRIPTION OF DAMAGE
Winter 1871	* First mention of bridge damage from flooding on the San Lorenzo River. Water levels were comparable to 1862 but the damage was estimated at half as much. Bulkhead area covered by about a foot of water. Flooding of 1-3 ft of water on east bank area of Broadway/Barson Tract/Riverside/May St. Basements of buildings on Pacific Ave. flooded. Water level at 16.03 ft at Water St. bridge.
January 1878	* Damage caused throughout much of the state by heavy winds and rain. The San Lorenzo River rose 5 ft. Island in the San Lorenzo River had houses on it which were evacuated by boat (approximately the location of present day of San Lorenzo Park Plaza Shopping Center.
1880	Flooding occurred along the San Lorenzo River. Bulkhead area covered by about a foot of water. Island in the San Lorenzo River had houses on it which were evacuated by boat (approximately the location of present day of San Lorenzo Park Plaza Shopping Center. Water level of 15.11 ft.
1881	* San Lorenzo River caused debris flow and storm water floods. Bridges across the river damaged by flooding. Water level of 15.41 ft.
December 1889-February 1890	* Severe flooding, the “highest yet known.” The rail bridge pilings at the mouth of the San Lorenzo River are believed to have created a debris dam which made the flood much worse. The rail bridge’s failure allowed flood waters to drop. The practice of using pilings to span the river was stopped after this flood. The flood was well remembered for 50-60 years. Bulkhead area covered by about a foot of water. The Pajaro River Basin also overflowed near Watsonville. Water levels to 16.35 ft.
1894	* Flooding near Watsonville caused by overflow of the Pajaro River Basin.
1895	Estimated 16 ft. water level.
March 1911	More than 2,000 acres of farmland destroyed along Salinas River, electric light plant, pumping plant, oil tanks half submerged, buildings along river underwater, debris.
January 1914	* Bridge damage, some bridges carried away, torrential rains.
December 1937	* San Lorenzo River flooded due to heavy rainfall, Soquel Creek flooded main street of Soquel including houses on Porter Avenue.
February 1940	* Log jam at Soquel Bridge at Soquel Drive which was eventually flooded by Soquel Creek. Bridges damaged. Flooding of 1-3 ft of water on east bank area of Broadway/Barson Tract/Riverside/May St. Bridges damaged by floods. 17.41 ft flood level at Water St., 24,000 c.f.s. at Felton.
Dec 1940-Jan 1941	* Floods of 15.3 and 17.41 ft in the City of Santa Cruz by the San Lorenzo River. Flooding of 1-3 ft of water on east bank area of Broadway/Barson Tract/Riverside/May St. Bridges damaged by floods.
November 1950	* Soquel business district suffered damage because a log jam forced water from Soquel Creek into businesses and houses
December 1955	* Costliest, deadliest and most well-known flood in the history of Santa Cruz. Soquel Drive Bridge destroyed, 40 year flood levels, water reached maximum possible at Riverside Ave. bridge and began to back up (luckily not at high tide); 7 people killed; 390 people displaced in Santa Cruz County; approximately $1 million in damages in Santa Cruz County. Flooding of 1-3 ft of water on east bank area of Broadway/Barson Tract/Riverside/May St. Footings of unfinished Hwy 1 bridge and Riverside Ave. bridge damaged, older half of Soquel Ave. bridge undermined. Water level at Water Street bridge measured at 20.8 ft. Basements of buildings on Pacific Ave. flooded by a few feet. 30,400 c.f.s. at Felton, 39,000 c.f.s. below Branciforte Creek. 410 acres inundated. Pajaro River severely flooded.

DATE	DESCRIPTION OF DAMAGE
April 1958	* Boulder Creek Dam overtopped by flood waters; 250 people in northern Santa Cruz County evacuated; Damage in San Lorenzo River Basin estimated at $170,000 due to erosion of houses and sediments, bank sloughing. Greater than 14 ft flood stage at Water St. 17,200 c.f.s at Felton, 18,500 c.f.s. in Santa Cruz. Pajaro River severely flooded.
January 1978	A series of storms emanated from a more southerly direction than normally occurs. High water levels were accompanied by very large storm waves. Jetties and breakwater barriers were overtopped and in some cases undermined. Direct wave damage occurred to many beachfront homes. Accelerated erosion coupled with rain and saturated ground conditions weakened the foundations of beach-bluff top homes in Santa Cruz County. Seawalls and temporary barriers failed to protect beachfront properties.
January 1982	22 people killed, Soquel Avenue bridge cracked and partially fell into river, estimated > $56 million in damage to homes and private property, most eastside telephone lines destroyed. San Lorenzo River came close to topping the levees in Santa Cruz. Flooding along Branciforte Creek. Water level measured at Water St. bridge was 18 feet above sea level. 29,700 c.f.s. in Felton, 33,000 c.f.s. in Santa Cruz below Branciforte Creek. 30 year event. Some flooding occurred along the southeastern perimeter of Watsonville.
Winter 1982-1983	Several storms during this El Nino winter caused approximately $14 million in damage: beaches were eroded, Hwy 1 eroded at Waddell Bluffs, ocean front properties and public facilities were damaged by waves and erosion at Seacliff State Beach, Pajaro Dunes foredunes eroded inland up to 40 ft., waves broke through windows, sliding glass doors, and walls in Seascape, beaches scoured and large logs from San Lorenzo river deposited on the beach, which caused damage as waves drove the logs into timber seawalls and oceanfront properties. Several million dollars of emergency rock was brought in and piled against eroding dune faces to protect the Pajaro Dunes development.
Winter 1997-1998	Structures and homes damaged, roads and bike path damaged, approximately $6 million in damages; damage not as severe because of better infrastructure built after 1982-83 El Nino flooding.
February 1995	Severe flooding; Santa Cruz County declared a disaster area
February –March 1998	Severe flooding; Santa Cruz County declared a disaster area due to El Nino. Pajaro River severely flooded. Flooding caused 1 death and over $95 million dollars of total economic loss, including $67 million in damage to agricultural fields and $28 million in non-agricultural damage to the Town of Pajaro.
April 2006	Severe flooding; Santa Cruz County declared a disaster area
March 2011	Severe storm damage. County proclaimed in a state of emergency by Governor

3. Climate Science

3.1. Climate Change

Climate change refers to any significant change in measures of climate, such as average temperature, precipitation, or wind patterns over a period of time. Climate change may result from natural factors and/or from human activities that change the composition of the atmosphere and alter the surface features of the land. Such changes vary considerably by geographic location. Over time, the earth's climate has undergone periodic ice ages and warming periods, as observed in fossil isotopes, ice core samples, and through other measurement techniques. Recent climate change studies use the historical record to predict future climate variations and the level of fluctuation that might be considered statistically normal versus statistically significant given historical trends.

Significant changes in global climate patterns have recently been associated with global warming, an average increase in the temperature of the atmosphere near the Earth's surface. This gradual warming is the result of heat absorption by certain gases in the atmosphere and re-radiation downward of some of that heat, which in turn heats the surface of the Earth. These gases are called "greenhouse gases" (GHGs) because they effectively "trap" heat in the lower atmosphere, causing a greenhouse-like effect (Figure 2). Some GHGs occur naturally and are emitted into the atmosphere through natural processes; others are created and emitted solely through human activities. Additionally, the production rate of some naturally occurring GHGs can be increased by human activities.[19]

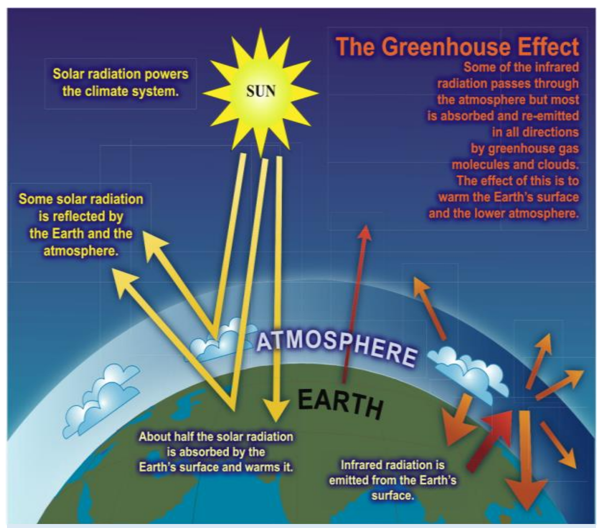

Figure 2. The Greenhouse Effect

The greenhouse effect helps to regulate the temperature of the planet. It is essential to life; without it, our planet would have an average temperature of about 14°F, as opposed to a comfortable 60°F. However, an accumulation of GHGs in the atmosphere is intensifying the greenhouse effect, threatening to raise average temperatures well beyond our "comfort zone." Nearly all climate scientists agree that human activities are to blame for the changing climate. The addition of carbon dioxide, the most

[19] California Natural Resources Agency. 2009. 2009 California. Climate Adaptation Strategy. A report to the Governor of the State of California in Response to Executive Order S-13-2008.

prevalent GHG, into the atmosphere as a result of burning oil, natural gas, and coal, in combination with the depletion of our dense forests and wetlands which act as natural carbon dioxide sinks, are leading to the highest concentrations of GHGs in history. High GHGs are in turn intensifying the natural greenhouse effect and leading to steadily increasing global temperatures.

Of the sixteen warmest years in recorded history, fifteen have occurred since 2001, with 2015 breaking the previous record by 0.29°F (0.16°C), the largest margin yet.[20] In addition, each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.[21] The temperature increase is widespread over the globe, and is greater at higher northern latitudes. Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. From 1971 to 2010, the ocean has absorbed over 90% of the heat added to the atmosphere.[22] In addition, the average temperature of the global ocean has increased to depths of at least 3000 meters.

The IPCC has linked this increase in global temperature to a wide array of changes to our natural world, including a widespread decrease in the amount of snow cover and thickness and range of glaciers across the globe. Since 1978, the Arctic ice cap has decreased in size by about 3 percent per year with an average summer decrease of 7.4 percent. A 10 percent decrease in global snow cover and earlier spring thaws of rivers and lakes in the northern hemisphere have also been observed. Over the past 50 years, heat waves and serious rain events have been more common, and in the past 30 years, there has been an increase in the number of northern Atlantic tropical storms (IPCC 2007a).[23] Ocean surface salinity has increased in areas where evaporation dominates, while it has declined in areas where precipitation dominates.[24] Ocean surface water acidity has increased 26 percent due to oceanic uptake of carbon dioxide.

IPCC scientists predict that the serious consequences of climate change will continue to grow and expand. The rapid and unprecedented increase in surface temperature is accelerating the planet's water cycle, which will make extreme storms and droughts more frequent and severe.[25] These events will likely disrupt and damage food and fresh water supplies. The extreme increases in temperature to come will continue to melt portions of the Greenland ice shelf and cause the oceans to thermally expand, both of which will raise the average level of all oceans. The continuing rise in sea level will have multiple effects, including coastline destruction, economic disruption, and the displacement of small coastal villages and major population centers, with varying levels of adaptive capacity.

[20] Galimberty, K. 2016. 2015 shatters record for warmest year globally by largest margin yet. Accuweather.com.
[21] IPCC 2014.
[22] Ibid.
[23] IPCC 2007.
[24] IPCC 2014.
[25] Karl, et al. 2008. Global Climate Change Impacts in the United States. Cambridge University Press.

3.2. Sea Level Rise Projections

Global Projections

The combination of ice melt and the thermal expansion of seawater (due to warmer water temperatures) has led to global sea level rise.[26] Research shows that since 1971, thermal expansion and glacial melt have caused 75% of observed sea level rise.[27] From 1870 to 2004, a reconstruction based on tide gauge data finds that during the 20th century, sea-level rise occurred at a rate of 0.07 inches per year (1.7 mm/year). During this time, sea-level rise also accelerated at a rate of 0.0005 inches per year^2 (0.013 mm/year^2).[28] More recent estimates show that from 1880 to the present, the average global sea level has risen by more about 8 inches (20 centimeters).[29] The IPCC's 2014 Fifth Assessment Report (IPCC 2014) projected sea level rise by the end of the century as a result of thermal expansion to range from 9 to 48 inches (0.23 to 0.98 meters). It predicts with "virtual certainty" that sea level rise will continue beyond 2100, and projects sea level rise beyond 2300 to be between 3.3 and 9.8 feet (1 and 3 meters).[30]

Regional Projections

Globally, sea level rise is driven by two primary factors—global ice melt and thermal expansion of seawater—but locally, other factors can alter the rate, extent, and duration of changes in sea level. These processes include "steric variations, wind-driven differences in ocean heights, gravitational and deformational effects, and vertical land motions along the coast"[31], and in California, are additionally affected by movement along the San Andreas Fault and climate patterns in the Pacific Ocean, including the El Niño Southern Oscillation and the Pacific Decadal Oscillation and Interdecadal Pacific Oscillation.[32] Large El Niño events can temporarily raise the sea level as much as three to 12 inches (10-30 cm) for several winter months.[33] Because of these variations, accurately predicting sea level over the coming centuries for specific locations is very challenging, but it is very likely that sea level will rise in more than 95% of the ocean by 2100.[34]

Mean sea level on the California Coast rose approximately 8 inches (17-20 cm) over the past century (1900–2005).[35] Since 1993, altimetry data suggests that the global mean sea level rise rate has increased from 2 to 3 mm/year, but during this time, data from altimetry and tide gauges show that the mean sea

[26] IPCC 2014.
[27] Ibid.
[28] Church, J.A., White N.J. 2006. A 20th century acceleration in global sea-level rise. Geophysical research letters 33.1.
[29] Church, J.A., White N.J. 2011. Sea Level Rise from the Late 19th to the Early 21st Century. Surv Geophys 32: 585. doi:10.1007/s10712-011-9119-1
[30] Committee on Sea Level in California, Oregon and Washington, Ocean Studies Board, and National Research Council. 2012. Sea-level rise for the coasts of California, Oregon, and Washington: past, present, and future. National Academies Press.
[31] Ibid.
[32] Ibid.
[33] Committee on Sea Level in California, Oregon, and Washington, Ocean Studies Board, and National Research Council. 2012. Sea-level rise for the coasts of California, Oregon, and Washington: past, present, and future. National Academies Press.
[34] IPCC 2014.
[35] Cayan, Daniel R., et al. 2008. Climate change projections of sea level extremes along the California coast. Climatic Change 87: 57-73.

level along the Pacific coast has been stable due to wind stress.[36] When the regional climate patterns that drive local sea level trends shift, however, the Central Coast will likely experience a rate of sea level rise that will correspond to or exceed the mean global rate of sea level rise.[37]

3.3. State guidance

Currently, the State of California Sea-Level Rise Guidance Document[38] is using regional projections of sea level rise based on the NRC 2012 predictions, for coastal adaptation planning purposes. These projections suggest possible sea level rise (compared to 2000 levels) of 0.39-2.0 feet (12-61 cm) by 2050 and up to approximately 5.48 feet (167 cm) by 2100. However, recent evidence suggests these values may prove to be underestimates of the possible rise in global sea level.

The Sea-Level Rise Guidance Document further outlines key considerations for vulnerability and adaptation planning efforts. Specifically, the document recommends: use "the best available science on sea level rise" and "scenario-based analysis in response to sea level rise projection ranges", identify the "physical impacts of sea level rise" and include analysis of "storms, extreme events, and abrupt change".

This Coastal Climate Change Vulnerability Report aims to meet these guidelines for Santa Cruz County.

3.4. Coastal Hazards from Sea Level Rise

Tidal Inundation

Tides in Santa Cruz County are mixed semidiurnal, with two high tides and two low tides per day, each differing in height. Regionally, sea level is influenced by the shape of the shoreline and local wind and weather patterns. As sea level rises, higher water levels allow waves to encroach further up on beaches and into low lying areas. Increases in tidal height may also cause localized flooding along river mouth estuaries and the agriculture and urban development placed within these river valleys, leading to periodic flooding.

Coastal Storm Flooding

Coastal storm flooding, or storm surge, is the abnormal rise of water elevations generated by a storm, over and above the predicted tides. The rise in water level can cause extreme flooding in coastal areas when large wave induced storm surge coincides with high tide. The maximum potential for storm surge depends on storm intensity, forward speed, size of the storm, angle of approach to the coast, shape of coastal bays and estuaries, and width and slope of the continental shelf. In general, storm surge makes it possible for waves to extend inland, thereby increasing the storm's impact on the upland. In addition to

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[36] Bromirski, Peter D., et al. 2011. Dynamical suppression of sea level rise along the Pacific coast of North America: Indications for imminent acceleration. Journal of Geophysical Research: Oceans 116.C7.
[37] Ibid.
[38] The Coastal and Ocean Working Group of the California Climate Action Team, The Ocean Protection Council's Science Advisory Team, and the California Ocean Science Trust. State of California Sea Level Rise Document. 2013.

the effect of increases in storm surge due to increases in sea level, climate change is linked to greater intensity and frequency of storms, which will increase the effect of storm surge on coastal lands.

Cliff Erosion

The Santa Cruz County coastline, with large portions comprised of sandstone cliffs, is highly susceptible to cliff erosion. Shorelines adjacent to cliffs often have beaches at the base which protect the cliffs from daily wave impacts. During winter storms when beaches are temporarily reduced in width, waves may break at the base of the cliff and undermine the cliff face, causing the cliff to erode. Depending on the composition of the cliff, wave exposure may cut into the cliff face by tens of feet during a single large storm. An increase in sea level will lead to waves breaking against cliffs more frequently.

Dune Erosion

Dunes provide a sediment reserve for beach processes, protect upland habitat from storm surges, and serve as substrate for ecologically sensitive and valuable coastal ecosystems.[39] When dunes are allowed to function naturally, they migrate as waves and currents push sand supply down coast. In Santa Cruz County, dunes protect agricultural fields and residential and commercial development from storm flooding and tidal inundation and support coastal strand and dune scrub plant communities.

3.5. Current Planning Landscape

Santa Cruz County General Plan and Local Coastal Program

Because Santa Cruz County experienced rapid growth in both population and development in the 1960s and 70s, the County and the voters implemented plans and policies that would provide high quality development and ensure adequate public services while also protecting the natural and agricultural resources that contribute to the character, scenic value, and economy of the County.

The County General Plan recognizes that the geography of the County (mountains inland, ocean to the west), the importance of agriculture along the northern and southern coasts, and the importance of preserving the natural landscape to attract tourists all result in limited land available for building and development. The plan states that “Considering the defining features of the Santa Cruz County landscape, the most appropriate location for more intense urban development and human activity are those areas without prime agriculture soils that are generally flat to gently sloping along the coastline and extending inland 1 to 4 miles.” Approximately one third of the urban land area appropriate for development is inside the Coastal Zone.

In 2012, a Flood Insurance Study (FIS) was conducted to update information on the existence and severity of flood hazards in Santa Cruz County. The Digital Flood Insurance Rate Map (DFIRM) and FIS Report for the countywide study were produced in digital format. Flood hazard information was converted to meet the Federal Emergency Management Agency’s (FEMA) DFIRM database specifications

[39] FitzGerald DM, MS Fenster, BA Argow, IV Buynevich. 2008. Coastal impacts due to sea-level rise. Annual Review of Earth and Planetary Science. 36:601-647.

and geographic information standards and is provided in a digital format so that it can be incorporated into a local Geographic Information System (GIS) and be accessed more easily by the community. In addition to reviewing the upland sources of flooding, a history of coastal flooding was assembled. According to the FIS, storms that cause significant coastal damage occur once every 3–4 years. Ocean flooding in Capitola and the City of Santa Cruz usually occurs when very high tides, large waves and storm swells occur simultaneously, often in the winter.

The Federal Emergency Management Agency (FEMA) in 2016 completed a detailed coastal engineering analyses and mapping of the Pacific coast of California. The analysis and mapping revised and updated the flood and wave data for the Santa Cruz County Flood Insurance Study report and Flood Insurance Rate Map panels along the open coast. The updated mapping indicates that some properties are more vulnerable to coastal flood hazards, and some properties are less vulnerable compared to previous mapping.

Residents and local governments have spent hundreds of millions of dollars on flood protection measures to prevent coastal flood damage. Installations have included seawalls, riprap, timber, and concrete bulkheads. A revegetation program was begun on the southern county sand dunes.

The Santa Cruz County General Plan requires that all development activities within coastal hazard areas be sited and designed to avoid or minimize hazards. This is achieved through adequate setbacks from the top edge of a coastal bluff or setback and elevation of structures on the beach. Shoreline protection measures are limited to structures that protect existing structures from a significant threat. Any application for a shoreline protection measure must include a thorough analysis of all reasonable alternatives and avoid, minimize, or mitigate impacts on coastal resources. Under existing standards future sea level rise is incorporated into project analysis. However, amended General Plan policies are being considered to provide an updated framework to incorporate sea level rise in the evaluation of projects on coastal bluffs and beaches.

Santa Cruz County Hazard Mitigation Plan

The purpose of hazard mitigation is to implement and sustain actions that reduce vulnerability and risk from hazards, or reduce the severity of the effects of hazards on people and property. Mitigation actions include both short-term and long-term activities which reduce the impacts of hazards, reduce exposure to hazards, or reduce effects of hazards through various means including preparedness, response and recovery measures. Effective mitigation actions also reduce the adverse impacts and cost of future disasters. The County of Santa Cruz LHMP represents the County’s commitment to reduce risks from natural and other hazards, and serves as a guide for decision-makers as they commit resources to reducing the effects of potential hazards.

Coastal Zone Management

The California Coastal Act of 1976 established a Coastal Zone along the state’s Pacific Coast. In Santa Cruz County, the coastal zone extends anywhere from 0.6 mi inland to about 5 miles inland, depending where on the coast you are located. In addition to required Coastal Zone permitting for development within the coastal zone, seven areas along the coast, because of their unique scenic, historical, or beachfront character, require special design standards. The County Planning Department reviews all permits, but some requests may be appealed to the California Coastal Commission.

California Coastal Commission Sea Level Rise Policy Guidance

The California Coastal Commission adopted a Sea Level Rise Policy Guidance document in 2015. The document provides an overview of the best available science for SLR in California and a recommended methodology for addressing SLR in Local Coastal Programs and in Coastal Development Permits. Adaptation strategies and planning recommendations are included, as well as best practice guidance for city and county planning and regulatory agencies. The Guidance describes and iterative process in which best available science is used to identify hazard areas, evaluate property risks, identify adaptation options, and draft policy to implement preferred strategies (Figure 3).

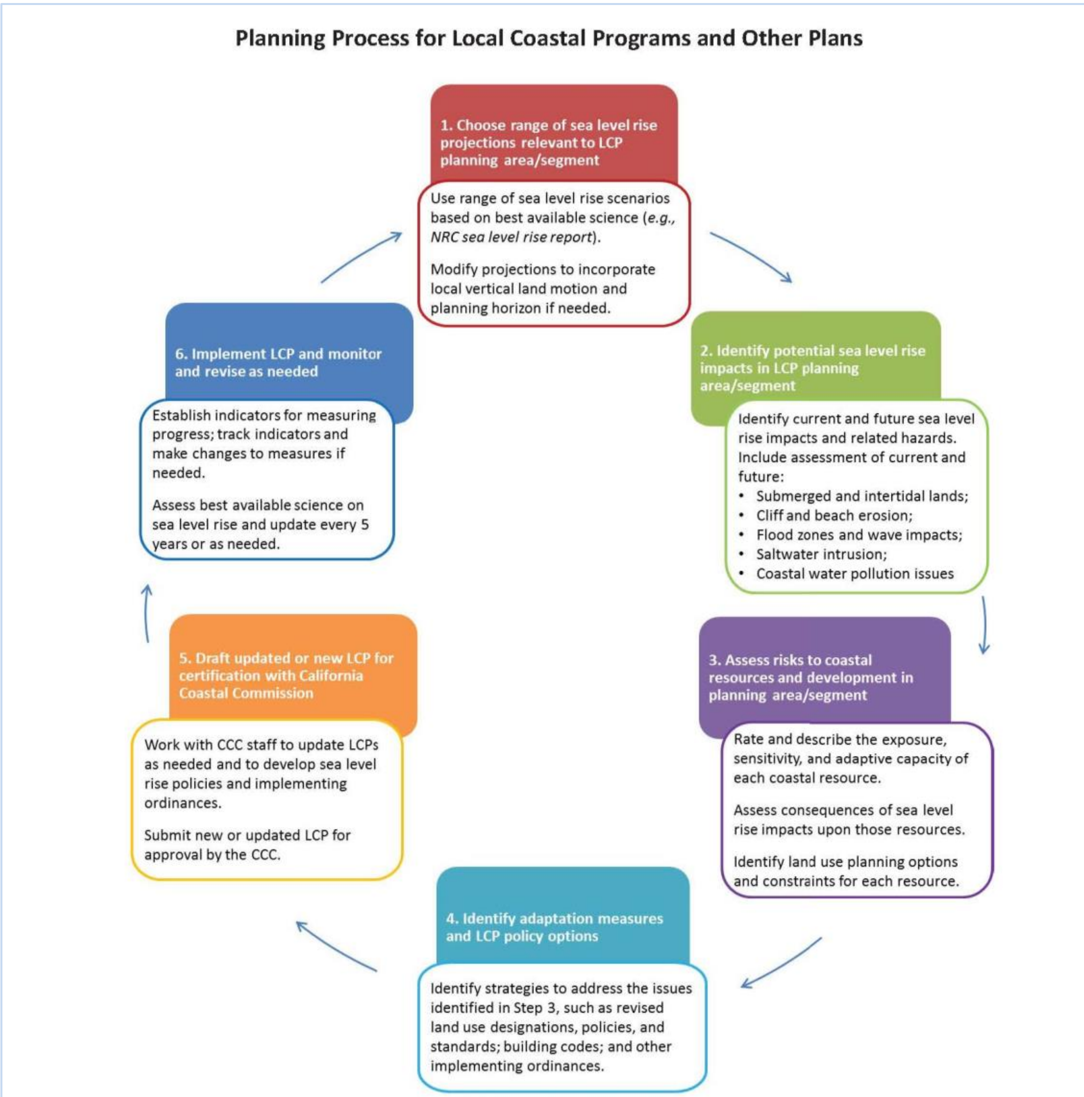

Figure 3. Flowchart for addressing sea level rise in Local Coastal Programs and other plans.
(Image source: Coastal Commission, 2015)

3.6. Previous Studies and Reports in the Region

PWA Coastal Regional Sediment Management Plan for Southern Monterey Bay (2008):

This plan, prepared by Philip Williams and Associates in 2008, aims to create a comprehensive regional strategy to approach issues of coastal erosion and protection in the Southern Monterey Bay, from Wharf 2 to the Monterey Submarine Canyon. The plan looks at local geomorphology, physical processes of erosion, sediment transport, sediment budget, critical habitat and species, existing vulnerable infrastructure, and various regulatory processes, and then proposes management strategies and analyzes their feasibility and projected effectiveness. These strategies include beach nourishment and restoration, sand reduction and removal, and continued natural erosion, while emphasizing the expansion of policies and governance structures to better manage coastal sediments.

PWA Technical Evaluation of Erosion Mitigation Alternatives (2012)

This study, conducted by Philip Williams and Associates, alongside the Southern Monterey Bay Coastal Erosion Working Group and the Monterey Bay National Marine Sanctuary, assesses various coastal erosion mitigation strategies through cost-benefit analyses to compare these strategies to more traditional coastal armoring in order to develop strategies to minimize erosion hazards in the Southern Monterey Bay Littoral Cell. This set of 22 proposed tools highlights rolling easements, cessation of sand mining, and managed retreat, with specific recommendations over four time frames for each sub-region.

Simulation of Climate Change in San Francisco Bay Basins, California: Case Studies in the Russian River Valley and Santa Cruz Mountains (2012)

Changes in climate, potential evapotranspiration, recharge, runoff, and climatic water deficit were modeled for the Bay Area. Detailed studies in the Russian River Valley and Santa Cruz Mountains, which are on the northern and southern extremes of the Bay Area, respectively, were carried out in collaboration with local water agencies. Results indicated large spatial variability in climate change and the hydrologic response across the region; although there is warming under all projections, potential change in precipitation by the end of the 21st century differed according to model. Hydrologic models predicted reduced early and late wet season runoff for the end of the century for both wetter and drier future climate projections, which could result in an extended dry season. In fact, summers are projected to be longer and drier in the future than in the past regardless of precipitation trends.

Climate Change Adaptation in Santa Cruz County Climate Action Strategy (2013):

The Climate Change vulnerability and adaptation sections of the County Climate Action Strategy describe the particular ways in which Santa Cruz County may be vulnerable to impacts of climate change, and suggests adaptation strategies for further consideration and implementation. Adaptation to climate change will be an ongoing process as the type and severity of potential impacts become clearer. The CAS assists in the positioning of County government and the community to plan for the changes that may occur, to make current decisions with consideration and understanding of how conditions may change as climate change proceeds, and to respond to impacts when they do occur.

ESA PWA Monterey Bay Sea Level Rise Vulnerability Study: Technical Methods (2014):

This vulnerability study and technical methods report, by Philip Williams and Associates, presents the methods and data used to develop maps of erosion and coastal flooding hazard zones for the Monterey Bay study area, from Año Nuevo to Monterey's Wharf 2. The hazard zones, including dune and cliff erosion, rising tides, and coastal storm flooding, take into account geology, tides, waves, historic erosion, existing armoring, and various sea level rise projections in order to most accurately represent the projected extents of erosion and flooding for 2030, 2060, and 2100. This report describes in depth the GIS layers and metadata for each hazard zone, and the processes used to create these layers.

The Nature Conservancy's Coastal Resiliency Mapping Tool (2015):

The Nature Conservancy has developed a publicly accessible interactive mapping tool to view projected sea level rise hazards for various geographies across the world, on both local and global scales. Users can explore the extent of flooding and erosion along selected coastlines—specifically in the Americas or on a global scale—for multiple time horizons or amounts of sea level rise, and can overlay ecological, social, or economic layers to view vulnerabilities.

Coastal Regional Sediment Management Plan for Santa Cruz Littoral Cell (2015):

In September 2015, Monterey Bay National Marine Sanctuary and the US Army Corps of Engineers (USACE) completed a consensus-driven guidance and policy document for the 75 mi stretch of coastline from Moss Landing to Pillar Point, which encompasses the entire Santa Cruz County coastline. The plan's purpose is to present ways to restore and maintain coastal beaches and other areas of sediment deficit, to reduce the proliferation of coastal armoring, to sustain recreation and tourism, to enhance public safety and access, and to restore coastal sandy habitats.

City of Monterey Final Sea Level Rise and Vulnerability Analyses, Existing Conditions and Issues Report (2016):

This report, by Revell Coastal, provides analyses of the existing conditions and future vulnerabilities from sea level rise of various sectors, including land use and structures, transportation, wastewater, hazardous materials, emergency services, ecological resources and more in the City of Monterey. The data is reported in detailed maps, charts, and recommendations for each sector. The report also details the physical setting of the City of Monterey, including the geology and geomorphology of the coastline and the coastline ecological habitats and human development, and looks at the current climate science and projections, including temperature, precipitation, wildfires, and sea level rise projections.

TNC Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay (2017):

This report, prepared by The Nature Conservancy, provides detailed economic analyses of various potential adaptation strategies for combating sea level rise and erosion in southern Monterey Bay, from Moss Landing to Del Monte. The report takes into account a range of sea level rise projections, and analyzes the social, environmental, and economic costs and benefits of many adaptation strategies in order to provide coastal planners with an understanding of the value of different strategies within each of the four focus areas. The report found that, contrary to conventional wisdom, in these four areas, hard shoreline armoring had significantly lower net present values than alternative adaptation strategies.

FEMA Pacific Coastal Flood Mapping (Expected Completion 2018):

FEMA is working to update the Pacific Coastal flood maps through the California Coastal Analysis and Mapping Project for Region IX. This project is incorporating the latest engineering and mapping data for areas impacted by coastal flooding for the California Coast in order to provide the most up-to-date coastal flood maps.

4. Vulnerability Assessment Methodology

4.1. Disclaimer: Hazard Mapping and Vulnerability Assessments

Funding Agencies

The hazard GIS layers were created with funding from The Coastal Conservancy and this report Vulnerability Analysis was prepared with funding from the Ocean Protection Council. The results and recommendations within these planning documents do not necessarily represent the views of the funding agencies, its 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 has 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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Data Usage

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4.2. Coastal Hazard Processes

The State Coastal Conservancy / Phil Williams and Associates vulnerability mapping effort led to set of common maps that integrate the multiple coastal hazards predicted for the Monterey Bay coastline (i.e. hazards of coastal climate change). These maps are available for viewing at http://maps.coastalresilience.org/california/.

One important limitation of the Monterey Bay hazard maps was addressed within separate focus area evaluations for Capitola and Moss Landing areas. ESA (previously Phil Williams Associates) was contracted for this project to predict the cumulative impacts of flooding from the combined effects of rising seas and increased winter river water elevations due to future changes in rainfall. The fluvial analysis for these two coastal communities adjacent to rivers helps to document the important interactions between river and ocean that increase the complexity of hazard analysis and development of coastal protection strategies. Further efforts to integrate fluvial hazards with coastal vulnerabilities would aid adaptation planning for several other Santa Cruz County confluences.

The Monterey Bay hazard maps also did not account for coastal armoring when predicting future cliff erosion rates. CCWG staff used the California Coastal Commission coastal armoring GIS layer (the layer has been greatly improved within Santa Cruz County) accounted for reductions in predicted cliff erosion provided by currently constructed coastal protection infrastructure. This refinement of coastal hazard mapping helped the project team to better estimate the future risks these coastal communities will face for each coastal hazard and each time horizon.

Each modeled coastal process threatens various coastal resources and structures differently (see Section 3.3). This report evaluates the risks to infrastructure from each coastal hazard process during each time horizon. This analysis is intended to link risks to appropriate adaptation alternatives. The following is a description of the hazard zone maps that were used for this analysis. For more information on the coastal processes and the methodology used to create the hazard zones please see the Monterey Bay SLR Vulnerability Assessment Technical Memo.[40]

FEMA

FEMA flood hazard maps are used for the National Flood Insurance Program and present coastal and fluvial flood hazards. These flood maps were used to identify current hazards as defined by FEMA. These maps, however, are assumed to underestimate coastal flood hazards for future time horizons.

Rising Tide Hazard Layers

These zones show the area and depth (in meters) of inundation caused simply by rising tide and ground water levels (not considering storms, erosion, or river discharge). The water level mapped in these inundation areas is the Extreme Monthly High Water (EMHW) level, which is the high water level reached approximately once a month. These zones do not, however, consider coastal erosion or wave overtopping, which may change the extent and depth of regular tidal flooding in the future. Predicted risks from rising tides lead to reoccurring flooding hazards during monthly high tide events.

Coastal Storm Flooding Hazard Layers

These hazard zones depict the predicted flooding caused by future coastal storms. The processes that drive these hazards include (1) storm surge (a rise in the ocean water level caused by waves and pressure changes during a storm), (2) wave overtopping (waves running up over the beach and flowing into low-lying areas, calculated using the maximum historical wave conditions), and (3) additional flooding caused when rising sea level exacerbate storm surge and wave overtopping. The original ESA hazard zones took into account areas that are projected to erode, sometimes leading to additional flooding through new hydraulic connections between the ocean and low-lying areas, but for this vulnerability analysis we removed erosion from the 2030 coastal flooding hazard layer so not to double count those impacts (See section 4.4). These hazard zones do NOT consider contributions from upland fluvial (river) flooding and local rain/run-off drainage, which likely play a large part in coastal flooding, especially around coastal confluences where a creek meets the ocean.

Cliff and Dune Erosion Hazard Layers

These layers represent future cliff and dune (sandy beach) erosion hazard zones, incorporating site-specific historic trends in erosion, additional erosion caused by accelerating sea level rise and (in the case of the storm erosion hazard zones) the potential erosion impact of a large storm wave event. The inland extent of the hazard zones represents projections of the future crest of the dunes for a given sea level rise scenario and planning horizon. Erosion can lead to a complete loss of habitat, infrastructure and/or use of properties.

[40] ESA-PWA. 2014. Monterey Bay Sea Level Rise Vulnerability Study: Technical Methods Report Monterey Bay Sea Level Rise Vulnerability Study. Prepared for The Monterey Bay Sanctuary Foundation, ESA PWA project number D211906.00, June 16, 2014.

Combined Hazard Layers

CCWG merged the coastal hazard layers to create a new combined hazard layer for each planning horizon (2010, 2030, 2060 and 2100). These merged layers represent the hazard zone for the combined impacts of "Coastal Climate Change" for each time horizon. Predictions of the combined hazards of Coastal Climate Change are intended to help estimate the cumulative effects on the community and help identify areas where revised building guidelines or other adaptation strategies may be appropriate. Combined hazards, however, do not provide municipal staff with the necessary information to select specific structural adaptation responses for specific processes. Therefore, this study also evaluates the risks associated with each individual coastal hazard.

4.3. Scenario Selection and Hazards

The California Coastal Commission guidance document[41] recommends all communities evaluate the impacts from sea level rise on various land uses. The guidance recommends using a method called "scenario-based analysis" (described in Chapter 3 of this Guidance). Since sea level rise projections are not exact, but rather presented in ranges, scenario-based planning includes examining the consequences of multiple rates of sea level rise, plus extreme water levels from storms and El Niño events. As recommended in the Coastal Commission guidance, this report uses sea level rise projections outlined in the 2012 NRC Report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*[42] (Figure 4). The goal of scenario-based analysis for sea level rise is to understand where and at what point sea level rise and the combination of sea level rise and storms, pose risks to coastal resources or threaten the health and safety of a developed area. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future sea level rise.

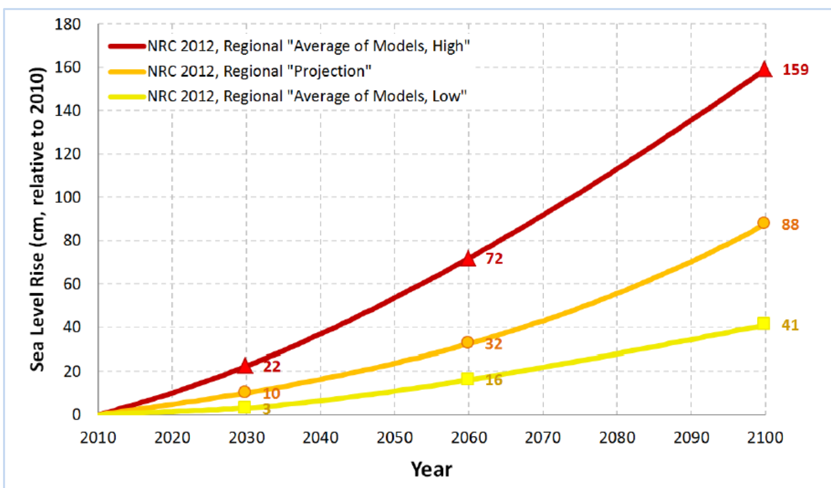

Figure 4. Sea Level Rise scenarios for each time horizon
(Figure source: ESA PWA 2014)

[41] California Coastal Commission. 2015. California Coastal Commission Sea Level Rise Policy Guidance: Interpretative Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits. Adopted August 12, 2015.

[42] National Research Council (NRC). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Report by the Committee on Sea Level Rise in California, Oregon, and Washington. National Academies Press, Washington, DC. 250 pp.

The Coastal Commission also recommends communities evaluate the impacts of the highest water level conditions that are projected to occur in the planning area. Local governments may also consider including higher scenarios (such as a 6.6 ft (2m) Scenario) where severe impacts to Coastal Act resources and development could occur from sea level rise. We use a similarly high scenario of 1.59m with an increase in projected storm intensity for this analysis (Table 2). In addition to evaluating the worst-case scenario, planners need to understand the minimum amount of sea level rise that will cause impacts for their community, and how these impacts will change over time, with different amounts of sea level rise.

The coastal climate change vulnerability maps used for this study identify hazard zones for each climate scenario for each of the three planning horizons (2030, 2060, and 2100). For clarity, this report focuses the hazard analysis on a subset of those scenarios (Table 2).

This project team solicited input regarding the appropriate sea level rise and future ocean condition scenarios to analyze for each time horizon from a wide range of experts. Input was provided by experts ranging from city and county planning and public works staff, coastal engineers, non-governmental organizations, and the California Coastal Commission. Climate scenarios chosen for this analysis (Table 2) assume a relative increase in sea level rise based on low, medium or high emissions models and an assumption in the intensity of future storm events (same intensity as present or an increase (doubling) in intensity).

Table 2. Sea level rise scenarios selected for analysis

TIME HORIZON	EMISSIONS SCENARIO	SLR	NOTES
2030	med	0.3 ft (10 cm)	Erosion projection: Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm)
2060	high	2.4 ft (72 cm)	Erosion projection: Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm) Future erosion scenario: Increased storminess (doubling of El Niño storm impacts in a decade)
2100	high	5.2 ft (159 cm)	Erosion projection: Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm) Future erosion scenario: Increased storminess (doubling of El Niño storm impacts in a decade)

4.4. Modifications to ESA Hazard Models

The ESA coastal hazard projections do not account for the protections provided by existing coastal armoring to reduce future bluff erosion. Because existing coastal armoring is not accounted for, the areas identified as vulnerable by the ESA GIS layers from ocean derived flooding and erosion overestimates future hazard zones (as recognized within the supporting documentation). CCWG modified the 2010 and 2030 ESA dune and cliff erosion hazard layers to account for the protective services of existing coastal structures by establishing inland GIS buffers, omitting erosion hazard projections inland of all sea walls and removing properties and structures predicted to be at risk within the 2030 vulnerability analysis.

Because the life span of coastal infrastructure is limited, this Santa Cruz County vulnerability analysis assumes that all existing coastal protection infrastructure will fail and will need to be removed, replaced or significantly redesigned at some point between 2030 and 2060. Therefore, the vulnerability assessments for planning horizons 2060 and 2100 assume that current coastal armoring will no longer function and that the predicted hazard zone layers provided by the ESA technical team properly reflect future hazards for these time horizons.

Cliff erosion and dune erosion were originally two separate coastal hazard processes provided by ESA-PWA. Cliff erosion was characterized as erosion of mudstone cliff sides generally along the Santa Cruz County coastline, whereas dune erosion was characterized as erosion of sandy slopes predominantly found along the Monterey Bay coastline. Since these two hazards were functionally different and spatially separate, it was decided to merge them into one ‘Erosion’ coastal hazard process using the ‘Merge’ tool within ArcGIS. Therefore, for each time horizon both cliff erosion and dune erosion impact zones were combined into a single erosion impact zone. The ‘erosion’ coastal hazard series was used throughout the analysis and included in the tables.

ESA-PWA included cliff areas predicted to have eroded during previous time horizons as being vulnerable to coastal storm flooding hazards because the land elevation within those areas was assumed to have been reduced due to that cliff erosion. For example, sections of cliff along Santa Cruz County that are projected to eroded by 2030 are also projected to experience coastal flooding and wave over-topping within those newly eroded coastal areas. This is an accurate interpretation of the projected coastal processes but does not reflect a progression of possible asset losses. Cliff top assets predicted to be vulnerable to erosion were, therefore, not also reported as vulnerable to coastal flooding because those structures would no longer be present in the future coastal flood hazard zones. To more accurately represent coastal flooding and wave over-topping vulnerabilities of low-lying assets behind coastal armoring, assets located below the 20-foot topographic contour line along the base of existing cliffs were reported to be vulnerable to Coastal flooding and wave over-topping vulnerabilities.

4.5. Data Compilation

CCWG staff spent considerable time and effort compiling geographic datasets for use within this hazard analysis. Land use and infrastructure GIS base layers provided by municipalities, special districts, state data repositories and field data collected by CCWG staff were overlaid with the sea level rise hazard maps to evaluate which and how many will be at risk under various future climate scenarios. Numbers of properties, buildings and infrastructure were tallied by jurisdiction or section of coast and portions of various land use designations (agriculture and natural resources) vulnerable to predicted impacts were reported in acres. Portions of linear infrastructure (pipes, roads, rail) at risk were reported in feet.

Coastal Commission Guidance recommends (page 80) accounting for potential impacts to vulnerable, low-income communities and considerer coastal development and resources, including but not limited to:

- Existing and planned development
- Coastal-dependent development and uses such as harbors, wharfs, ports, marinas, and commercial and recreational fishing areas and facilities
- Critical infrastructure-such as wastewater treatment plants, transportation infrastructure, and some power plants and energy transmission infrastructure
- Public access ways, beaches and other recreation areas, and the California Coastal Trail
- State Highway 1, 101, and other state and local roads that provide access to the coast
- Wetlands, environmentally sensitive habitat area (ESHA), and other coastal habitats and sensitive species
- Agricultural areas
- Cultural sites and archaeological or paleontological resource
- Visitor-serving development and uses

CCWG strived to provide a full analysis of these and other resources at risk from future coastal climate change. Datasets like roads, railways and public safety facilities were relatively easy to obtain as they are maintained and routinely updated by a state or county agency. Many datasets, however, were out of date or lacked appropriate documentation regarding when or how the data were collected (i.e. metadata). A few datasets were not used in this assessment because of privacy or homeland security concerns (electrical substations for example). In many other cases, the desired data did not exist or were inaccurate. Of the 59 datasets identified as necessary to understand impacts to resources, 45 were obtained and analyzed as a part of the Santa Cruz County vulnerability assessment. In most cases, existing data were used for this assessment. Creating, improving or updating geographic datasets generated by disparate entities was outside of the scope of this assessment.

4.6. GIS Mapped Assets Used for Analysis

For this study, community infrastructure and assets were divided into five categories that include: Land Use and Buildings; Water and Utility Infrastructure; Parks, Recreation and Public Access; Transportation; and Natural Resources. GIS layers were obtained from County and State data repositories, or created by the Central Coast Wetlands Group. In some cases, assets that were used in the analysis fell outside of the planning area and therefore are not included in this report. Further, several data layers that were intended to be used in this analysis were not available. Table 3 lists the asset used in the analysis.

Table 3. List of Assets Used in Analysis

ASSET CATEGORY	ASSET	STATUS OF ASSET IN ANALYSIS
Land Use	Building footprints	Analyzed
	Commercial, Residential, Public, Visitor Serving	Analyzed
	Emergency Services: Hospitals, Fire, Police	Analyzed
	Schools, Libraries, Community Centers, etc.	Analyzed
	Parcels	Not used in analysis[43]
	Farmland	Analyzed
	Military	None in Planning Area
	Historical and Cultural Buildings	Analyzed
	Landfills	Analyzed
	Cleanup sites	Analyzed
Water and Utilities Infrastructure	Sewer Structures & Conduits	Analyzed
	Water Main Lines	Analyzed
	Gas	Unable to obtain for analysis
	Storm Drain Structures & Conduits	Analyzed
	Tide gates and Culverts	Analyzed
	Wastewater Treatment Facility	Analyzed
Recreation and Public Access	Coastal Access Points	Analyzed
	Parks	Analyzed[44]
	Beaches	Analyzed
	Coastal Trail	Analyzed
	Coastal Access Parking	Analyzed
Transportation	Roads and Highways	Analyzed
	Rail	Analyzed
	Bridges	Analyzed
	Tunnels	None in Planning Area
Natural Resources	Wetlands	Analyzed
	Critical Habitat	Analyzed but not included[45]
	Dunes	Analyzed

[43] Building foot print layers were used instead of parcels maps to better project future structural vulnerabilities.
[44] The parks layer included acres of State Beaches as well as City Parks and was duplicative with the Beach impact analysis. City parks vulnerable to various hazards are listed within the text but not included in tabular form.
[45] Critical habitat data layers were not of high enough resolution to provide accurate estimates of impacts.

4.7. GIS Vulnerability Analysis Methods

To identify and summarize the assets within Santa Cruz County at risk to predicted coastal hazards, GIS staff manually and through Python scripts overlaid predicted areas at risk from various coastal climate change hazards (erosion, flooding, tidal flooding), and tallied the feature (i.e. building or road) located within the boundaries of those hazards. Features within those hazard zones were categorized as 'IMPACTED' within the GIS data file. This method was performed for 65 asset datasets and 25 hazard scenarios across the time horizons 2010, 2030, 2060, and 2100. The specific analysis procedure used to tally impacted resources depended on the GIS vector type (point, line, polygon) for those assets. Assets located behind coastal protective structures were characterized as "PROTECTED" to account for existing coastal armoring and tide gates. These details are outlined in the rest of this methods section.

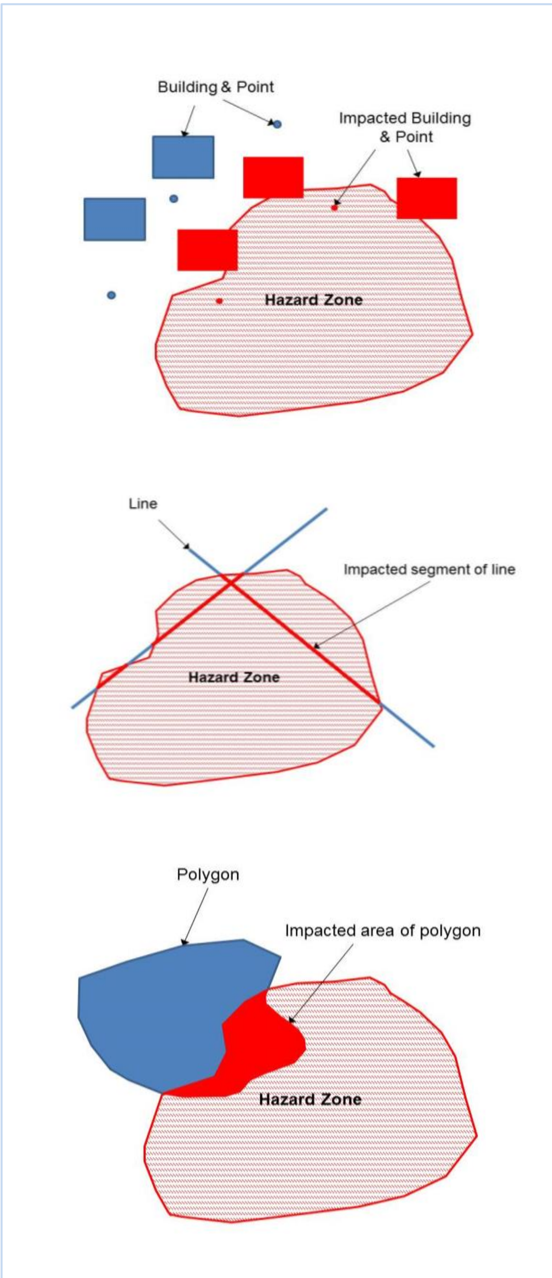

Figure 5. GIS Vulnerability Analysis Methodology for Point, Line, and Polygon features

Asset Vulnerability Analysis

Each GIS vector type was analyzed using a slightly different procedure to address the unique characteristics of the various data geometries (Figure 5). Each vector type was evaluated as follows:

Points and Building Footprints: A single point feature (i.e. sewer drain or coastal access location) was categorized as 'impacted' if it simply intersects the selected hazard zone. Similarly, buildings are considered 'impacted' if any part of the building is intersected by a hazard. For summarization, points and buildings are tallied and displayed in the result tables as the number of features impacted.

Lines: Line assets (i.e. roads or water pipelines) that are bisected by a predicted hazard area were split along the bisecting boundary of the hazard zone. The segments inside the hazard zone are then categorized as 'impacted.' The asset line lengths (in feet) within the hazard zone were calculated and reported within the result tables.

Polygons: A contiguous polygon asset (i.e. park, agriculture or wetland) that is bisected by a hazard was split along the bisecting boundary of the hazard zone. The area inside the hazard zone is then categorized as 'impacted.' For summarization, the asset polygon area (in acres) within the hazard zone was calculated for inclusion into the result tables.

Assumed Protections Provided by Coastal Structures

There are 54,300 feet of coastline behind coastal protection structures in Santa Cruz County that reduce risks of coastal erosion and storm flooding (Table 4). These protective structures were accounted for in this vulnerability analysis for the 2010 and 2030 planning horizons.

Table 4. Inventory of Existing Coastal Protection and Water Control Structures in Santa Cruz County

STRUCTURE LOCATION	TYPE OF STRUCTURE (APPROXIMATE LENGTH)
North County	Isolated rip-rap (1,016 feet)
City of Santa Cruz	Extensive rip-rap, isolated sea walls, hip wall and harbor jetty (11,758 feet)
7th Ave to Capitola	East Cliff sea wall, extensive rip-rap (13,073 feet)
City of Capitola	Rip-rap, coastal hip walls, & beach groins (4,088 feet)
Seacliff	Extensive rip-rap and wood piling structures (15,466 feet)
Pajaro Valley	Extensive rip-rap (9,008 feet)

Assets that were determined to be protected by existing coastal armoring (seawalls) were re-categorized from 'impacted' to 'protected.' The translation of assets from "impacted" to "protected" was completed for structures behind coastal armoring located within the 2030 erosion hazard layer. A similar analysis was completed for 2060 hazard zones to estimate the infrastructure that may be protected if existing coastal structures were rebuilt.

4.8. Considerations Regarding New and Rebuilt Sea Walls

Santa Cruz County coastal landforms include coastal cliffs or bluffs, backed by flat marine terraces and fronted by both large and small pocket beaches, and low elevation river mouth valleys fronted by sand dunes or barrier spits with back bays, lagoons or estuaries. Coastal erosion is a natural and ongoing process that has been significantly altered in communities where permanent structures have been constructed to reduce impacts to coastal infrastructure from shoreline flooding and erosion.

Responses to shoreline changes include taking no action, relocating structures, and construction of hard and soft armoring. Hard armoring includes revetments, seawalls, bulkheads, and other structures designed to reduce wave impact forces on cliffs, bluffs, or dunes. Such structures are often assumed by engineers to have a 20 to 30 year lifespan. Once in place, these structures must often be repaired, replaced or strengthened to maintain protection. These hard structures often limit or eliminate sand supply to adjacent beaches and cause passive erosion of the coastline in front of or adjacent to the seawall or revetment. Conversely, soft armoring is any form of reinforcement or coastal protection that mimics natural barriers, including sand dunes, beaches, and wetlands. Soft armoring is most applicable in areas where the shoreline is able to migrate inland in response to SLR, and does not prevent all shoreline erosion. Dr. Griggs from UCSC has estimated that approximately 30% of the Santa Cruz County coast has been hard armored in response to continued erosion or retreat of the shoreline.[46] This study corroborates these earlier findings through analysis of the Coastal Commissions GIS layer of coastal armoring for Santa Cruz County.

Section 30235 of the California Coastal Act states:

Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply.

4.9. Economic Analysis and Adaptation Alternatives

A simple cumulative property loss estimate was completed to tally the value of properties vulnerable to future climate risks for coastal areas of the unincorporated County. The estimated average property value of various assets (homes & commercial) and replacement costs of municipal buildings and infrastructure (fire stations & storm drains) was multiplied by the total number of each asset found within the various time horizons to generate a combined value of resources within future hazard zones. A number of assumptions and generalizations were made to complete the property loss estimates. Property valuations and replacement costs estimates used to calculate losses are cited (Table 5).

The analysis within this report is intended to contextualize future potential losses and help initiate discussions regarding adaptation and response alternatives. Recent reports by ESA[47] and The Nature Conservancy[48] provide estimates of property valuations and adaptation response costs that can be further utilized if a more comprehensive economic analysis is needed in the future. A more extensive cumulative economic impact analysis was proposed within the original project scope but was excluded due to limited state funding.

Municipal, Residential and Commercial Property Valuation

[46] Griggs GB. 1998. California needs a coastal hazards policy. California Coast & Ocean 14(3):30-33.

[47] ESA-PWA. 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group.

[48] Leo K, Battalio R, Heady WN, King P, McGregor A, Cohen B, Calil J, Vandebroek E, Jackson J, DePaolis F,Revell D, Vaughn R, Giliam J, Newkirk S. 2017. Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay. Monterey, CA. Technical Report prepared for the California State Coastal Conservancy by The Nature Conservancy. 2017/01. 227pp. ClimateReadyGrant#13-107.

For municipal buildings and urban infrastructure, data from several local economic analyses were used to estimate costs to replace or move critical infrastructure (Table 5).[49,50,51] Numerous techniques are used to estimate the average private property value for structures within various geographic areas. US Census data provide general valuation within neighborhoods, as do online resources such as Zillow. Using community property valuation estimates to estimate the cumulative cost of predicted impacts tends to underestimate the value of beach and ocean front properties that are more valuable and most vulnerable to the predicted hazards. Many studies use county assessor records to calculate property valuation. Because county assessor property and building valuation is determined based on the most recent purchase price, these data often undervalue coastal properties owned for more than 10 years.

Some studies (Santa Cruz County Draft Hazard Mitigation Plan and Coastal Regional Sediment

Table 5. Property valuation data sources for economic analysis

ASSET	VALUATION	SOURCE
Residential	$930,000	Capitola average sale price
	$2,100,000	Capitola beach front sale price
	$662,631	US Census
	$809,860	Santa Cruz Littoral Cell report
	$1,400,000	Pacific Institute Report 2009
	$987,727	SCC-DLHMP fire residential
	$958,043	***Average of studies***
Commercial	$145,005	SCC-DLHMP fire commercial
	$2,600,000	Average LoopNet Listings
Public	$4,000,000	Capitola Local Hazard Mitigation Plan
Emergency Services	$1,500,000	Capitola Local Hazard Mitigation Plan
Roads /ft	$280	TNC 2016
Rail /ft	$237	Fresno business plan
Storm Drain conduit /ft	$1,080	TNC 2016
Waste Water conduit /ft	$1,080	TNC 2016
Drinking Water conduit /ft	$189	TNC 2016

[49] RBF and Dewberry. 2015. Local Hazard Mitigation Plan. Prepared for the City of Capitola.
[50] Leo, et al. 2017. Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay.
[51] Heberger M, H Cooley, P Herrera, PH Gleick, E Moore. 2009. The Impacts of Sea-Level Rise on the California Coast. Prepared by the Pacific Institute for the California Climate Change Center.

Management Plan for the Santa Cruz Littoral Cell) have estimated future property loss separately for building values and land values. This technique is ideal for vulnerability studies, and enables the costs of predicted hazards to be calculated separately for structural impacts (due to coastal and river flooding) and property loss (due to coastal erosion and sea level rise). Unfortunately, because these refined property estimates remain linked to County assessor data, property valuation using these approaches continue to underrepresent the real economic risks.

Adaptation and Protection Cost Estimates

Regional cost estimates for coastal infrastructure upgrades are prone to error, and usually require site specific studies to account for project specific challenges that often increase costs. The project team has noted these limitations and has provided property valuations and replacement costs estimates as generalizations that may help further community discussions and prioritize more focused project evaluation efforts. Alternative average valuation methods can replace current values, if recommended by municipal staff or community members to better refine these initial estimates.

An expanded analysis that links the relative cost of projected impacts (property loss or relative damage) using the compiled data is recommended by the project team as next step.

5. Combined Impacts of Coastal Climate Change

5.1 Existing Vulnerabilities

FEMA Flood Hazard Maps

Federal Emergency Management Agency (FEMA) has produced flood hazard maps that identify numerous areas of Santa Cruz County as vulnerable to flooding during a 100-year flood event (based on historical rainfall data). Flooding within the FEMA hazard map area is expected to become more severe due to changing rainfall patterns associated with climate change (although not currently recognized by FEMA). Future threats from increased river flooding during less frequent but more intense rain events corresponding with extreme high tide events were investigated within the Capitola Focus Study and are reported separately.

ESA Existing Hazards (2010)

The combined risks of Coastal Climate Change were evaluated for unincorporated Santa Cruz County, the City of Santa Cruz and the City of Watsonville using the ESA 2010 hazards model layer. To note, the ESA coastal hazard layers do not account for hazards associated with river flooding except for Soquel Creek and the Old Salinas River (Monterey County). Existing coastal armoring was accounted for and properties behind these structures were excluded (through post processing) from the 2010 hazard analysis.

Predicted Hazards

The combined risks from current climatic conditions (2010 model years[52]) were evaluated for Santa Cruz County. Appendix A, Table A1-A3 documents the existing vulnerability to various assets and resources within Unincorporated Santa Cruz County, City of Santa Cruz and City of Watsonville separately. Within Santa Cruz County, the ESA coastal hazard model results for the 2010 planning year identified numerous residential properties at risk of coastal climate change (472 in Santa Cruz County and 143 in City of Santa Cruz). All buildings (33) identified as being currently vulnerable in Watsonville are identified as agriculture industry related. Numerous commercial properties are also at risk (84 in Santa Cruz County and 33 in City of Santa Cruz) as predicted by the 2010 ESA hazard maps. Significantly more residential (797 in Santa Cruz County and 828 in City of Santa Cruz) and commercial buildings (122 in Santa Cruz County and 199 in City of Santa Cruz) are identified by FEMA as being at risk of flooding (although many

[52] The fluvial analysis used 2015 existing condition year.

of these are protected by levees and other structures). Because FEMA identifies inland risks along all creeks and rivers within Santa Cruz County, whereas an analysis of fluvial flood risks was only done for Soquel Creek within the ESA hazard analysis, more assets are identified by FEMA as currently vulnerable to flooding. Significantly greater numbers of coastal resources (beaches, coastal trail, Highway 1) are identified as vulnerable within the ESA coastal hazard models compared with FEMA maps, most likely because coastal erosion processes are included in the ESA analysis. These modified 2010 ESA hazard maps do account for current coastal armoring.

Tables A1-A3 of Appendix A provide a comparison between the FEMA hazard zone and the modified ESA 2010 combined hazard zone. Many residents that fall within the FEMA hazard zone are located along county creeks and rivers outside of the zone threatened by storm induced ocean swells. Many of the properties within the FEMA flood zone are classified as protected by levees and other structures.

5.2 Future Hazards from Coastal Climate Change by Planning Horizon

Numerous properties and infrastructure throughout Santa Cruz County are predicted to be at risk from projected increases in sea level and storm intensity during future time horizons. The assets predicted to be at risk within this Monterey Bay SLR hazard evaluation (termed “coastal climate change”) are presented in Table A4–A7 of Appendix A for each time horizon for the unincorporated county and local jurisdictions separately. An extensive analysis of Capitola hazards is reported separately.

Unincorporated Santa Cruz County

There are more than 10 miles (54,300 feet) of coastal protective structures (seawalls and rip-rap) in Santa Cruz County. These structures resist wave induced erosive forces which lead to cliff failure, protecting many properties and buildings from damage or loss. For the 2030 vulnerability analysis we assumed that properties located behind these structures were protected from coastal erosion. Table 2a of Appendix A documents the combined effects of coastal climate change for unincorporated Santa Cruz County for each time horizon, accounting for protections currently provided by these structures and future reductions in protections as structures age. Appendix B (Maps B1, B5, B9, and B13) show the combined hazard zones for each of the four sections of unincorporated Santa Cruz County.

Santa Cruz County: 2030

Cumulative risks of Coastal Climate Change on unincorporated Santa Cruz County public and private infrastructure for 2030 is significant. Almost 850 buildings in the County are at risk (many from periodic coastal flooding) and more than half of those properties are private residence. Almost 105,000 linear feet of roadway and highway will be at risk of flood and erosion damage as well as 120,000 feet of storm and sewer pipe infrastructure. Two emergency services buildings (Soquel 3 Fire Station and CalFire Pajaro Dunes Fire Station 42) are identified to be at risk.

Thirteen hundred acres of parks land (including beaches), more than half of coastal access points and 15% of the currently constructed California Coastal Trail are at risk. Half of Santa Cruz County coastal wetlands and 2% of county dunes are vulnerable to the predicted 2030 coastal climate change hazards.

Santa Cruz County: 2060

By 2060 we assume that coastal armoring and water control structures will no longer function as designed. The 2060 combined hazard zone highlights the areas vulnerable to the combined effects of coastal climate change without protection from these structures (tide gates and coastal armoring).

By 2060 more than 800 additional buildings are at risk of impact as sea level rises by a predicted 2.4 ft. and as current coastal protective structures begin to fail. If current structures are replaced, it is estimated that 500 of the vulnerable buildings would be protected, 400 of which are private residence. If all of the 54,300 feet of coastal protective structures are replaced (at current dimensions) but no additional structures are constructed, more than 900 buildings will remain vulnerable to predicted 2060 coastal climate hazards.

An additional 35,000 feet of roadways will become vulnerable as well as 55,000 more feet of wastewater and storm drain pipes. Additional park lands will be at risk as well as 9 coastal access parking areas. If all current coastal armoring is replaced and additional structures are constructed to protect the additional 500 buildings and 35,000 feet of roadway, more than 12 miles of the Santa Cruz County coastline would need to be armored by 2060. A significant increase in the height of coastal structures would also be necessary to continue to protect properties from the risks of wave overtopping. Financial losses associated with these predicted impacts and estimated costs of rebuilding structures are reported separately (Table 7 in Section 7.1).

Santa Cruz County: 2100

By 2100, more than 1,800 residential properties within the unincorporated county are vulnerable to coastal climate change hazards. More than 170,000 feet of roadway and 210,000 feet of water pipe are at risk, and larger portions of all other land uses will be vulnerable to climate change by 2100. More than 150 acres of sand dunes (10% of dunes within the county) will be at risk by 2100; the loss of which would decrease protection of inland resources from ocean wave impacts.

City of Santa Cruz

Much of the City of Santa Cruz coastline is armored to reduce coastal erosion and wave impacts. The hazard models used for this analysis account for current protections provided by coastal armoring (2030 with armor) and have quantified the large number of properties and assets currently protected by these structures that would be vulnerable to future predicted hazards if these structures fail (2060 no armor). Appendix A Table 2b documents the combined effects of coastal climate change for The City of Santa Cruz and for each time horizon, accounting for protections currently provided by these structures and future reductions in protections as structures age.

City of Santa Cruz: 2030

Cumulative risks of Coastal Climate Change on City of Santa Cruz public and private infrastructure for 2030 is significant (*note*: the City is currently completing a focused vulnerability study and has identified some of the predicted hazards described below as being managed or protected by current storm water infrastructure). More than 250 buildings are at risk of impact (many from periodic coastal flooding) and more than 70% of those properties are private residence. Almost 15,000 linear feet of roadway will be at risk of flood and erosion damage as well as 22,000 feet of water pipe infrastructure. Ninety more buildings will be at risk by 2030 than are at risk today (2010 analysis). Residential properties within the hazard zone are predicted to almost double by 2030 compared with 2010 results. None of the City's emergency services buildings are within 2030 hazard zones.

Ninety-three acres of parks land (e.g. Natural Bridges beach and West Cliff walking paths), 60% of coastal access points and 24% of current California Coast Trail infrastructure are at risk of 2030 coastal climate change impacts. Half of Santa Cruz's coastal wetlands are at risk (most notably from saltwater flooding).

City of Santa Cruz: 2060

By 2060 we assume that coastal armoring and water control structures will no longer function as designed without upgrades or replacement. The 2060 combined hazard zone highlights the areas vulnerable to the combined effects of coastal climate change without these protective structures.

More than 260 additional buildings (a total of 547) are at risk of impact by 2060 due to continued increases in sea level and the assumed loss of current coastal protective structures. An additional 35,000 feet of roadways will become vulnerable as well as 12,000 feet of water, wastewater and storm drain pipes. Additional park lands will be at risk as well as 28 coastal access locations.

It is estimated that 50 of the vulnerable buildings could be protected if current armoring is replaced, 13 of which are private residence and 34 are commercial properties. Approximately 490 buildings would remain vulnerable to one or more of the predicted hazards. To protect these 490 structures from risks of wave overtopping and coastal flooding would likely require an increase in the height of replaced structures.

City of Santa Cruz: 2100

By 2100, more than 750 residential and 200 commercial properties within the City of Santa Cruz are at risk from coastal climate change. Almost 70,000 feet of roadway and 120,000 of water pipe are at risk, and larger portions of all other land uses (assets) studied will be vulnerable to climate change by 2100. More than 80 public buildings, two emergency service facilities (Santa Cruz Police Station and Beach Flats Health Clinic) and 90% of coastal wetlands (168 acres) will be at risk by 2100.

City of Watsonville

The City of Watsonville jurisdictional boundaries are predominantly east of Highway 1, limiting risks of city infrastructure from coastal climate change. Primary vulnerabilities identified within this study were from flooding of buildings adjacent to the Watsonville Slough which is predicted to act as a conduit for wave induced flooding to propagate inland. Appendix A Table 2c documents the combined effects of coastal climate change for the City of Watsonville for each time horizon, accounting for protections currently provided by these structures and future reductions in protections as structures age.

City of Watsonville: 2030

The cumulative risks of Coastal Climate Change on City of Watsonville public and private infrastructure for 2030 are minor. Approximately 30 industrial buildings are at risk. Almost 4,000 linear feet of roadway will be at risk of flooding (including one section of Highway 1) as well as 9,800 feet of storm drain infrastructure. Eighty-two acres of parks land and 70% of coastal wetlands within the city limits are at risk of impact from hazards of 2030 coastal climate change. The same buildings (33) will be at risk by 2030 as are at risk today (2010 and FEMA analyses).

City of Watsonville: 2060

By 2060 we assume that coastal armoring and water control structures will no longer function as designed without upgrades or replacement. The protective service of existing coastal armoring was not included in our impact analysis. Similarly, connections between the Pajaro River and the Watsonville Slough (Figure 6) were assumed for this analysis to be restricted by current structures but still connected, as was true during a January 2017 site visit. Further analysis of tide gates and water control structures along the Watsonville Slough will need to be integrated with this analysis before adaptation strategies using these structures can be well defined.

Figure 6. Tide gates at Watsonville Slough flooded during a January 2017 king tide.

More than 50 additional buildings are at risk of impact by 2060 due to continued increases in sea level. Many of these predicted impacts are a result of future flooding that current coastal structures will be unable to restrict. A significant increase in road and storm drain infrastructure is at risk and more than 50 acres of agriculture lands are vulnerable within the city (some of which has recently been transitioned to commercial use). Impacts to natural resources and costs of rebuilding structures are analyzed separately (Section 7).

City of Watsonville: 2100

By 2100, more than 140 commercial and industrial properties within the City of Watsonville are at risk from coastal climate change. Almost 13,500 feet of roadway including 400 feet of Highway 1 and 20,000 of storm drain conduit are at risk, and larger portions of parks and wetland habitat will be vulnerable to climate change by 2100.

City of Capitola

Appendix A Table 2d documents the combined effects of coastal climate change for the City of Capitola for each time horizon, accounting for protections currently provided by these structures and future reductions in protections as structures age. A more detailed analysis of future risks from individual hazards is presented within the City of Capitola Coastal Climate Change Vulnerability Report.[53]

City of Capitola: 2030

For 2030, the vulnerability analysis was completed assuming that current coastal protective structures would still be present and functioning. A total of 219 buildings are vulnerable to coastal climate impacts by 2030, only 15 more properties than currently at risk (2010 vulnerability assessment). Surprisingly, only 15 properties were found to be protected by existing coastal armoring from all predicted 2030 coastal hazards. This suggests that current coastal protection infrastructure does not provide protection from all 2030 hazards.

More than 7,000 linear feet of roadway will be vulnerable to coastal climate change (primarily flooding) by 2030 and approximately 10% of sewer and storm drain infrastructure is within the predicted hazard areas. Roads and utilities are not equally vulnerable to different coastal hazards (flooding, erosion etc.) and therefore the analysis of individual coastal hazards within the Capitola focus report[54] may be more useful to aid response planning.

City of Capitola: 2060

By 2060, 112 residential properties and 166 commercial mixed use properties will become vulnerable to the combined effects of coastal climate change. Only 86 additional buildings are predicted to be vulnerable to Coastal Climate Change by 2060 even though the 2060 vulnerability model no longer accounts for protections provided by current coastal armoring. Risks to roadways double (in linear feet) by 2060, reflecting the predicted loss of protections provided by coastal armoring for Cliff Drive.

Many properties are not currently reported as vulnerable because they reside behind aged coastal protective structures. Specifically, 36 residents, 50 commercial properties and one emergency service structure (police station) become vulnerable to erosion or flooding between 2030 and 2060 if current structures are not replaced. Estimated value of these properties is $45 million and the construction cost to replace aging coastal armoring is between $20 and $52 million.[55]

City of Capitola: 2100

By 2100 the combined models used in this analysis predict that much of the downtown area will be flooded during winter storms and high river discharges. Furthermore, most of the beach (98%) will be lost due to higher sea levels and beach erosion if back beach structures are rebuilt in their current

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[53] CCWG. 2017. City of Capitola Coastal Climate Change Hazard Vulnerability Report.

[54] Ibid.

[55] ESA-PWA. 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group.

locations. Hundreds of storm drain structures will also be compromised and may become a conduit for inland flooding if modifications are not made.

By 2100 the impacts experienced periodically during large winter storms will become more frequent and for many coastal properties, may become an annual event. Wave run-up energy will impact structures during most high tides causing flood and wave damage. River flooding is predicted to be more frequent and threats of coastal erosion will become more significant as ocean forces migrate inland and impact structures more routinely and forcefully. Maintaining and replacing coastal armoring will become more costly and difficult to engineer. By 2100, portions of Capitola may be too difficult and costly to protect from the combined hazards of Coastal Climate Change.

6. Vulnerabilities from Individual Coastal Hazards

Predictions of risks from the combined hazards of Coastal Climate Change helps delineate areas within which building guidelines may be updated and help municipalities estimate the cumulative risk to various sectors of the community. Combined hazards, however, do not provide municipal staff with the necessary information to select and prioritize adaptation responses. Therefore, to better link vulnerabilities with adaptation alternatives (Section 8.1), this project has evaluated the temporal risks of infrastructure within the unincorporated county for each time horizon and for each coastal hazard process separately.

The hazards associated with each of the modeled coastal processes (wave run-up and overtopping, coastal erosion, rising tides and fluvial flooding) threaten various types of coastal infrastructure differently. Wave and fluvial flooding can damage buildings, temporarily restrict use of public amenities, leave storm drains and tide gates ineffective and limit use of roads and walkways. Many of these impacts are temporary and repairs can be made. Cliff erosion and monthly high tide flooding, however, can lead to permanent impacts that will require extensive rebuilding, a change in property use or abandonment of the property. In Section Eight of this report we investigate possible adaptation strategies for these various hazards. Appendix A, Tables A8-A10 document the individual impacts of coastal climate change for unincorporated Santa Cruz County at each time horizon, accounting for protections currently provided by these structures and future reductions in protections as structures age. Maps for each of the sections below can be found in Appendix B.

6.1 Section 1: Santa Cruz City Limit to Año Nuevo

Rising Tides

Few impacts are predicted along this section of coast due to rising tides. By 2100 the Waddell and Scott creek marshes will flood monthly during high tides. Lombardi and Wilder beaches and creek mouth marsh plains will also be flooded by 2100. No farms, buildings, roads or rail line will be flooded by high tides. Few access points will be impacted by rising tides (see Appendix B, Map B3).

Coastal Storm Flooding and Wave Impacts

Because the County's north coast is dominated by coastal bluffs with little adjacent development, coastal storm flooding hazards threaten little other than natural wetland habitat areas within river mouth lagoons (including Waddell, Scott, Lombardi and Wilder creeks). No buildings are at risk of coastal flooding along the north coast from coastal flooding (although fluvial interactions with higher tides were not analyzed). Small sections of road and rail are vulnerable to coastal flooding by 2060 as is the Davenport Landing coastal access area (see Appendix B, Map B3).

Erosion

There currently are 2 sections of coastal armoring along Santa Cruz County north coast intended to protect the Highway 1 bridges over Scott Creek and Waddell Creek (Figure 7). By 2030, Highway 1 will again be at risk of impacts from coastal erosion (accounting for current armoring). By 2030 three sections of the highway are predicted to be vulnerable. Four sections of highway in separate locations are at risk by 2060 and 11 separate locations are within erosion hazard areas by 2100. Key infrastructure within hazard areas includes bridges over Scott and Waddell creeks (where Caltrans is currently investigating bridge replacement strategies). Almost 3.5 miles of coastal armoring will be necessary to protect the current north county highway alignment through 2100 (see Appendix B, Map B4).

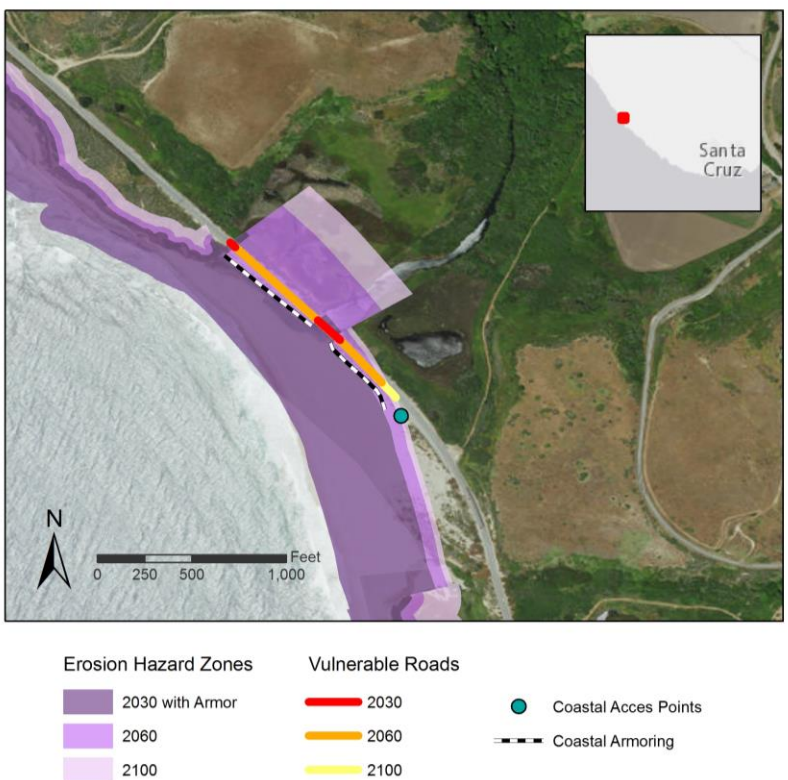

Figure 7. Highway 1 at Scott Creek vulnerable to coastal erosion.

6.2 Section 2: 7th Ave to Capitola

Rising Tides

Roads along East Cliff Drive are projected to be vulnerable to monthly tidal flooding by 2030 and Schwan, Corcoran, and Moran lakes will see greater tidal exchange, leading to a change in salinity. Few coastal access points will be impacted by rising tides but by 2060 most beach areas between Pleasure Point and Capitola will be submerged during high tides (see Appendix B, Map B6).

Coastal Storm Flooding and Wave Impacts

The East Cliff portion of the Santa Cruz County coastline is dominated by high density residential development built on coastal bluffs and along low lying coastal areas adjacent to lagoons and pocket beaches. Coastal storm flooding poses the greatest risk to infrastructure within the low-lying portions of the community (Figure 8) adjacent to the 3 “lakes” (Schwan, Corcoran, Moran). Numerous sections of road (crossing creek/lagoon mouths) are vulnerable to coastal flooding. Many coastal access points and some buildings adjacent to Moran Lake are vulnerable to coastal flooding as early as 2030. The Live Oak Library is vulnerable to coastal flooding by 2100. Coastal Storm models used for this analysis assume that areas where cliff erosion has occurred will then be susceptible to flooding. Buildings on cliffs vulnerable to 2060 and 2100 erosion are also incorrectly noted as vulnerable to flooding (see discussion

Figure 8. Resources along East Cliff vulnerable to Coastal Storm Flooding.

in Section 4.4 and Appendix B, Map B7).

Erosion

Almost all of East Cliff between Capitola and Moran Lake is armored (Figure 8). The 2.5 miles of coastal armoring along East Cliff protect 180 bluff top houses and large sections of roadway. One commercial property and 24 homes are not protected by coastal armoring and are vulnerable to projected 2030 erosion hazards. Based on the assumption that most armoring will fail before 2060, we assume that all of the existing 2.5 miles of coastal armoring will need to be replaced to protect the adjacent 180 homes. One additional mile of seawall will need to be built if the 83 additional homes located within the 2060 hazard zone are to be protected. The costs of rebuilding these seawalls are expected to be high and the feasibility of maintaining these structures as sea levels rise is uncertain. More than $130 million in seawall replacement costs will need to be spent to protect inland properties (costing approximately $650,000 per at risk property) along this section of coastline. It is uncertain if replaced structures would withstand the constant wave impacts predicted for 2100 (see Appendix B, Map B8).

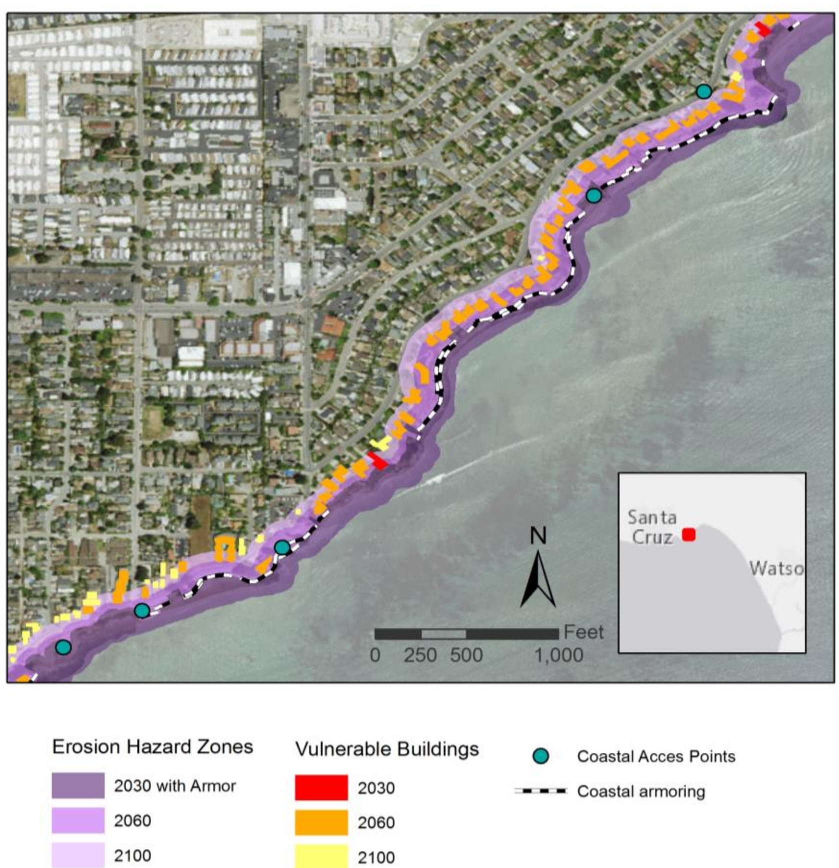

Figure 8. Resources along East Cliff vulnerable to Erosion.

6.3 Section 3: Seacliff to Manresa Beach

Rising Tides

Rising Tides do not pose significant threats to this section of coastline until the 2100 time horizon. Increases in tidal height through 2060 will affect habitat within Aptos Creek. By 2100 most of Seacliff, Aptos and Manresa beaches will be flooded during high tides if coastal bluffs are not allowed to erode inland. Only one building is at risk of flooding during high tides (see Appendix B, Map B10).

Coastal Flooding

A recent Rio Del Mar flats drainage improvement project aimed to improve drainage to this area to reduce current flooding of the flats due to storm water flooding that overwhelms the storm drain system. This action will help address recent flooding to at least 43 buildings in the flats and likely help reduce future hazards of coastal flooding caused by sea level rise by increasing the drainage capacity of local storm drains. Coastal flooding hazards for 2030 (not accounting for storm water and fluvial hazards) are predicted to impact coastal areas below an elevation of 3 meters. Portions of Rio Del Mar "village" and Rio Del Mar State Beach are within this hazard zone. Coastal flooding is predicted to propagate inland along Aptos Creek. Coastal access, parking and 80 commercial and residential buildings are vulnerable to wave damage and coastal flooding by 2030 within the low-lying sections of Rio Del Mar. By 2060 an additional 90 buildings (170 in total) are at risk along Seacliff beach and Rio Del Mar. By 2100, an additional 20 buildings (190 in total) will be periodically flooded during large winter storms.

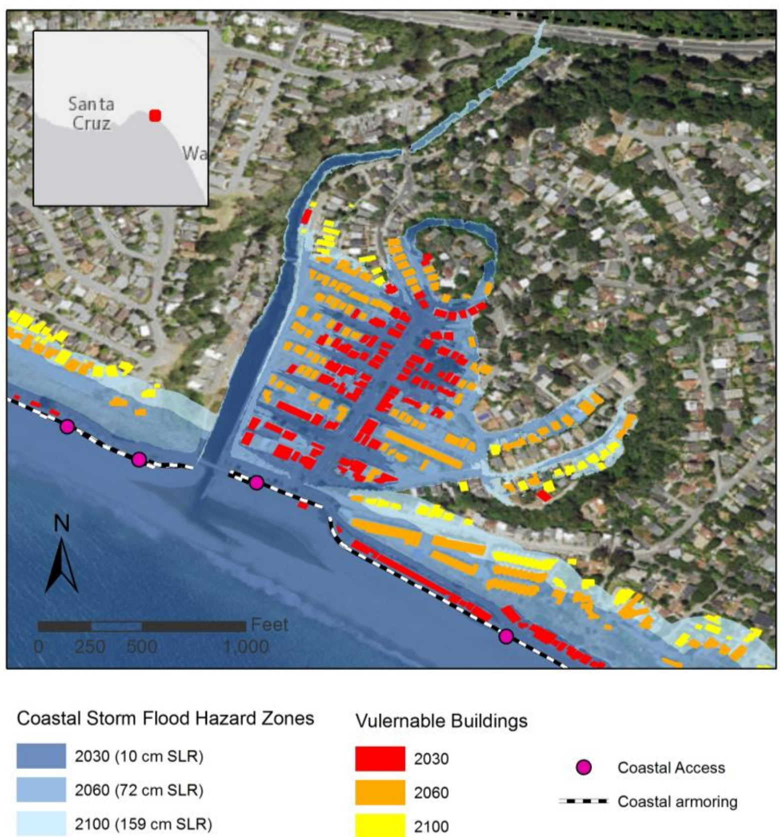

Figure 9. Resources along Rio Del Mar vulnerable to Coastal Storm Flooding.

There are 2.9 miles of sea wall between Seacliff and Manresa beaches (75% of coastline) that protect many residential and visitor serving buildings from erosion and coastal flooding. An additional 158 properties are located along the beach behind coastal protective structures (Las Olas and Beach drives) that are protected from erosion but remain vulnerable to coastal flooding (see Appendix B, Map B11).

Erosion

More than 350 residential buildings vulnerable to 2030 coastal erosion hazards are protected by the 2.9 miles of existing seawall along this section of coastline. More than 40 residential properties near Manresa Beach are not currently protected from erosion hazards. Approximately 850 feet of new seawall would be needed to protect the Trestle Beach condominiums and 1200 feet of new seawall to protect properties along Oceanview Dr. from 2030 erosion hazards. By 2060, it is assumed that most of the current sea wall and rip-rap will have failed. Without replacing this coastal armoring, 442 residential properties would be vulnerable to coastal erosion by 2060. Replaced seawalls would need to withstand coastal erosion as well as protect more than 180 properties from wave overtopping flood damage. Such structures would be expensive and challenging to design. Impacts from these structures, including restricted views and loss of beach, would most likely be significant along the approximately 3 miles of armored coastline (see Appendix B, Map B12).

The hazard projections identify bluff top development surrounding coastal canyons (inland drainage scars that continue inland further than other portions of coastal bluff) as vulnerable to erosion. A 1.4 mile section of the recently purchased county rail line within the La Selva area is within the 2100 erosion hazard zone. By 2100 erosion is predicted to progress inland to the second row of development, threatening almost 1000 residential and commercial properties including large portions of Seascape Resort.

If coastal structures are replaced and expanded to protect properties vulnerable to 2100 hazards, 5 miles of seawall must be replaced or built along this section of coastline. If new structures are constructed 3000 feet of lateral beach access will be lost during high tides and almost half of the beaches along this section of coast will be less than 20 feet wide as ocean waters meet constructed armor.

6.4 Section 4: Pajaro Valley from Sunset Beach to the County Line

Rising Tides

The low-lying areas of the Pajaro Dunes Resort (ball fields and open space) and portions of the adjacent agriculture fields are currently vulnerable to flooding during high tides when the river mouth is open (Figure 10). By 2030 tidal flooding hazards via the Pajaro River mouth and Watsonville Slough channel will increase significantly, flooding much of the open space within the development and placing additional acreage of farmland at risk of monthly flooding (see Appendix B, Map B14).

Portions of West Beach Street will be vulnerable to tidal flooding by 2060 and much of the road and parking area within the Pajaro Dunes development will be flooded monthly by 2100. By 2100 about 25 buildings within the Pajaro Dunes colony are vulnerable to rising tides near the community's entrance adjacent to Watsonville Slough.

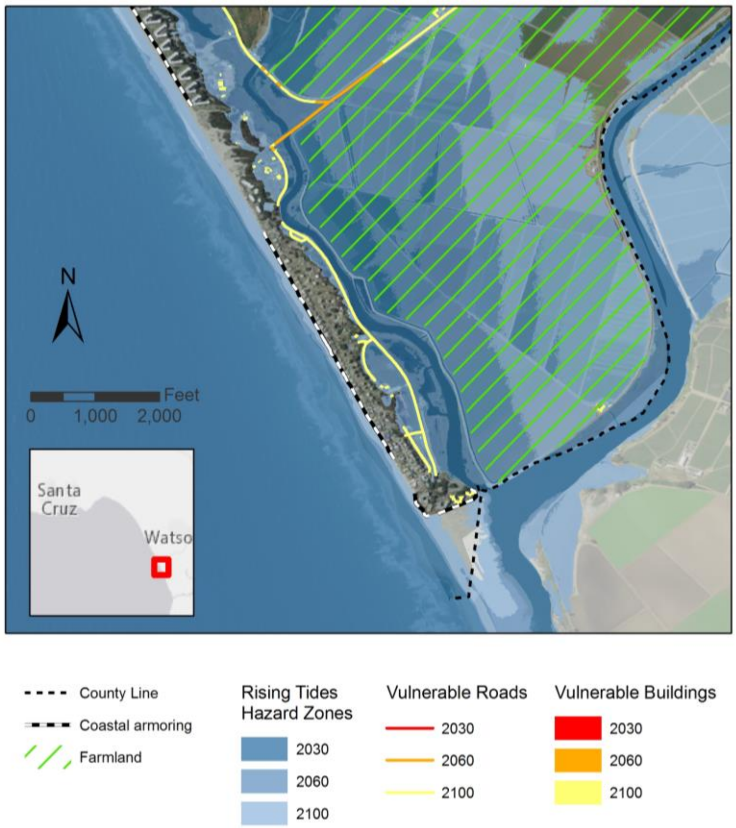

Figure 10. Tidal flooding hazard areas within the Pajaro Dunes

Coastal Flooding

Coastal flooding is predicted to be significant within the Pajaro Valley by 2030. The 2030 coastal flooding vulnerability projection assumes that coastal protective structures (including the water control structures near the end of West Beach Street) will remain functioning but will not be adequate to manage predicted storm flooding. Coastal dunes that protect inland wetland habitat, agriculture and urban development will be impacted by the increased force of wave energy, leading to the loss of dune habitat and the propagation of waves inland, risking flooding of the lower Pajaro River and Watsonville Slough drainages (see Appendix B, Map B15).

Coastal flooding hazards for 2030 are predicted to impact areas below 3 meters elevation. This hazard zone overlays with more than 130 buildings within the Pajaro Dunes Colony (many comprised of multiple residences) indicating that they are vulnerable to flooding during winter storms as early as 2030 (Figure 11). Current coastal protective infrastructure (rip-rap) is predicted to be insufficient to provide full protection from wave induced flooding. One location within the dunes is vulnerable to wave overtopping by 2030, allowing ocean waves to flow through the dunes into Watsonville Slough channel. Additional buildings within the Pajaro Dunes Colony are predicted to be flooded when ocean waves propagate inland through the Pajaro River Mouth.

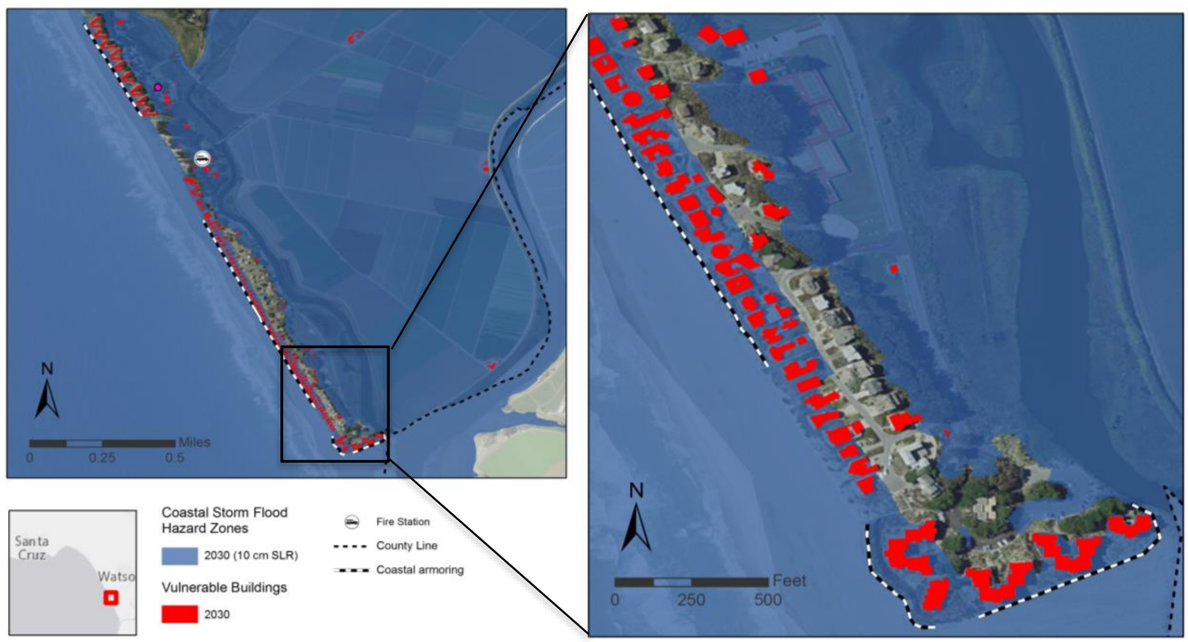

Figure 11. Low lying areas of the Pajaro Valley vulnerable to predicted 2030 storm flood hazards.

This study assumes that tide gates and levees will no longer provide flood protection from the predicted hazards of 2060 ocean derived storms. By 2060, coastal flooding is predicted to overtop the dunes near West Beach Street, circumvent or overtop inland agriculture levies and back up water at the Watsonville Slough culverts.

Wetland resources and agriculture lands further inland are vulnerable to saltwater inundation if the dunes and/or water control structures and agricultural levees fail to control connectivity between the coast and the inland valley. Within the lower Pajaro Valley, 99 agriculture and commercial buildings are vulnerable to coastal flooding west of Highway 1 if winter swells overtop or compromise current agriculture levees. More than 2500 acres of farm land are located within this hazard area. Approximately 1.8 miles of the rail line and 3.5 miles of County roads are vulnerable to coastal flooding by 2060.

Cost considerations, feasibility constraints associated with levee and tide gate upgrades and the implications on coastal resources (water quality, wetland habitat, fish migration) will likely be significant. Depending on construction and operational costs, construction feasibility and legality of replacing current infrastructure, land uses behind these structures may need to adapt to the predicted 2060 flood hazards or be lost.

Erosion

Much of the Pajaro Dunes development is protected from coastal erosion by rip-rap barriers built in front of or within the sand dune complex (Figure 12).

Assuming that current armoring will no longer protect the development by 2060, most of the Pajaro Dunes development (130 multi-family units) is vulnerable to coastal erosion. If decisions are made to protect all these properties in their current location, future structures would need to be designed to protect buildings from coastal flooding as well as erosion hazards. Achieving this level of protection within the current footprint will likely be expensive, structurally complex and will impact coastal values and natural resources significantly. By 2100, erosion is predicted to undermine most of the existing Pajaro Dunes sand spit. If the dunes are not allowed to migrate inland, the Pajaro Valley will no longer be protected by coastal dunes (see Appendix B, Map B16).

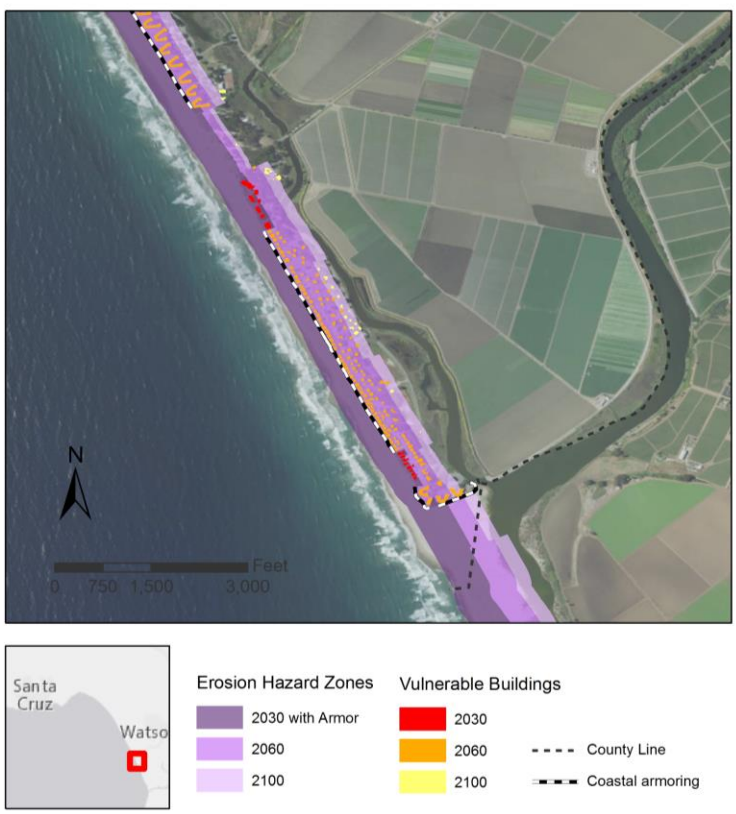

Figure 12. Erosion hazard areas within the Pajaro Dunes

6.5 Future Risks to Specific Assets

The severity of future projected hazards for Santa Cruz County buildings and infrastructure stresses the need for long-range coastal planning. It is in everyone's interest to develop policies that balance the community's concern for the protection of public and private properties with considerations regarding the resulting construction costs for these structures and the impacts to the public beach and coastline. Specific resources that are vulnerable to future coastal climate hazards (recommended within the Coastal Commission Guidance) are identified below.

Buildings

This analysis suggests that buildings within Santa Cruz County are vulnerable to different hazards at different times (Figure 13). Local hazard models predict that of the three hazards analyzed, coastal flooding will threaten the greatest number of residential buildings within Santa Cruz County through 2030. By 2060, significant numbers of these buildings are vulnerable to both coastal flooding and erosion. Between 2060 and 2100, the numbers of buildings threatened by coastal erosion increases significantly as coastal protection structures fail and wave forces continue to press inland.

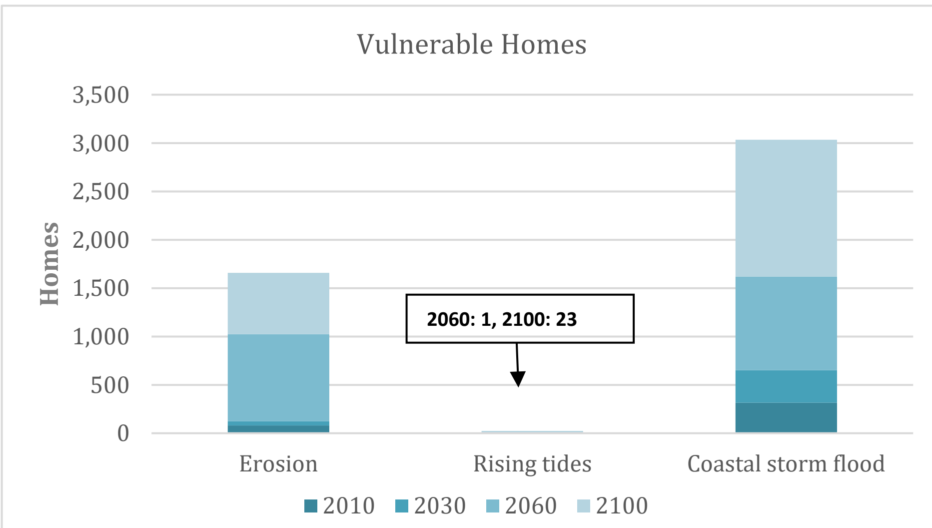

Figure 13. Numbers of residential buildings vulnerable to coastal climate change hazards during each planning horizon.

Agriculture within the lower Pajaro Valley

As many as 15,293 acres of agricultural land within the lower Pajaro Valley are less than 10ft above the current mean sea level elevation, making them extremely vulnerable to the combined hazards of sea level rise, increased fluvial discharges and coastal wave induced flooding. By 2030, 1,272 acres of agriculture are predicted to periodically flood during winter storm events. The number of acres of farmland at risk of flooding will increase to 1,852 by 2060 and to 2,565 acres by 2100 (see Figure 14). By 2030, 92 acres of these agriculture fields are projected to routinely flood as higher tides reduce discharge capacity of tide gates leading to an increase in base water elevation in these drainages. By 2060, Agricultural berms and water control structures that protect the Pajaro Valley from winter flooding are predicted to fail and dune erosion along several portions of Pajaro Dunes will lead to wave overtopping, flooding the lower Pajaro Valley. The risk to farmland from flooding is projected to increase to 1,572 acres by 2060 assuming that water control structures no longer function as intended. By 2100, much of the agricultural operations west of Highway One will be flooded during monthly high tides.

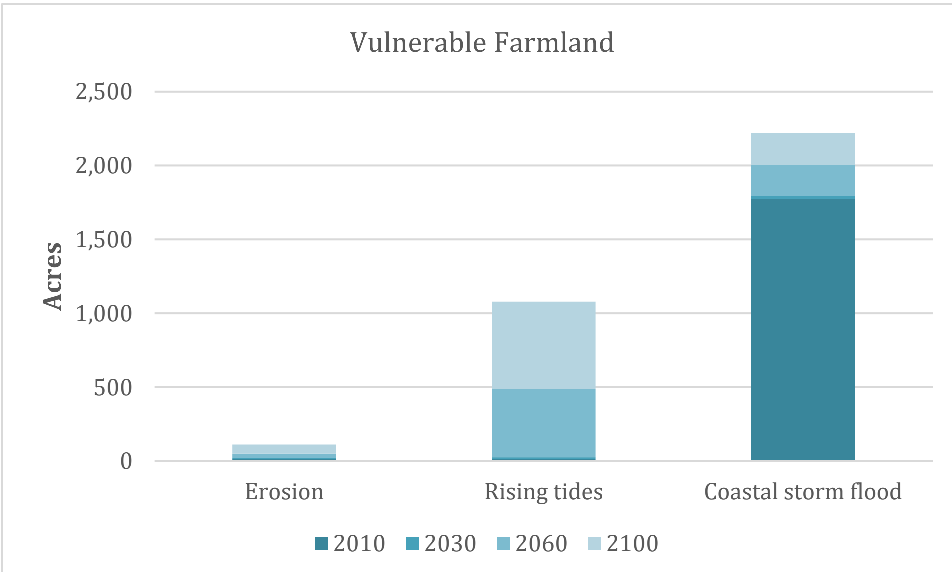

Figure 14. Acres of farmland vulnerable to coastal climate change hazards at each planning horizon.

Transportation

Roads

By 2030, approximately 40,000 feet of roads in the unincorporated Santa Cruz County are vulnerable to periodic flooding during coastal storm events (Figure 15). These include highways, access roads, and residential roads; all prone to increased coastal impacts as winter storms become more frequent and severe. By 2060 more than 40,000 feet of roadway are at risk from bluff erosion if coastal armoring is not replaced and expanded.

Rail

A portion of the Santa Cruz County rail line is already vulnerable to coastal flooding and erosion. Erosion risks will increase by 2060. The rail line becomes more vulnerable to erosion and storm flooding between 2060 and 2100 (Figure 15).

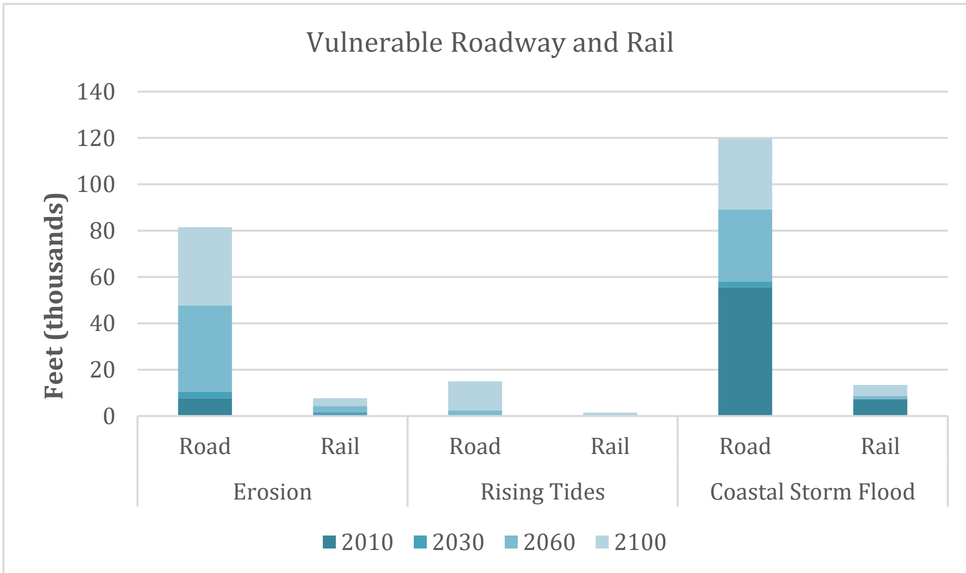

Figure 15. Feet of road and rail vulnerable to coastal climate change hazards at each planning horizon.

Recreation and Public Access

Beaches and Coastal Access

Sana Cruz County beaches are vulnerable to increased wave intensity during winter storms and the compounding effects of "coastal squeeze" as the ocean continues to migrate inland (exacerbated by climate change) towards protected backshore development (Figure 16).

Figure 16. Beaches along Santa Cruz County coast vulnerable to "Coastal Squeeze" and loss of lateral access.

There are 70 designated coastal access locations within Santa Cruz County. As many as 34 of these coastal access locations may be threatened by 2030 predicted erosion and 54 coastal access locations will be vulnerable to coastal erosion by 2100 (Figure 17).

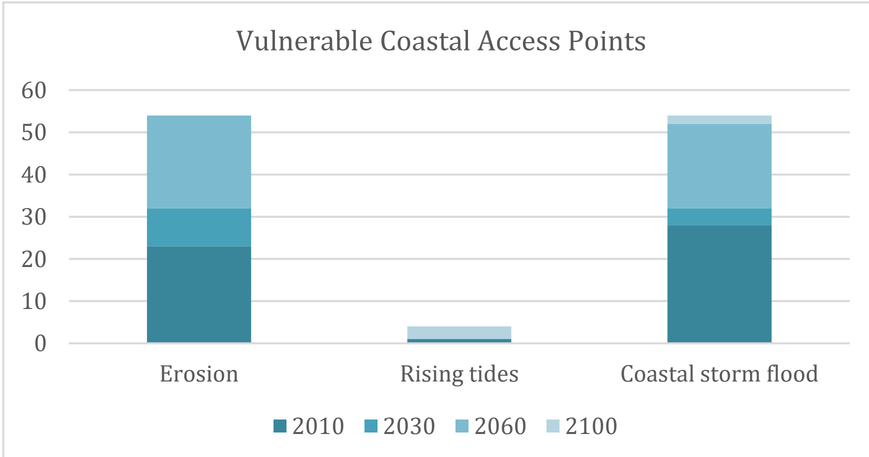

Figure 17. Number of coastal access points vulnerable to coastal climate change hazards at each planning horizon

A GIS buffering analysis found that predicted erosion will impact lateral beach access along numerous sections of Santa Cruz County during high tides (section 5.3). If coastal armoring is replaced along these sections of coastline, 0.6 miles of lateral access will be lost by 2100 (i.e. mean high water intersects with armoring). Santa Cruz County beaches of less than 20 feet in width (coastal squeeze) will increase from 3 miles in length to more than 9 miles in length if armoring is maintained within its current location. While not analyzed additional beach areas are expected to be impacted by coastal squeeze if armoring is constructed in areas currently not protected. More than five acres of coastal access parking are predicted to flood during coastal storms by 2060. Access to Santa Cruz harbor will be compromised during winter storms.

Natural Resources

Wetlands

Santa Cruz County supports high quality wetland and river mouth ecosystems within areas susceptible to the hazards of coastal climate change. These natural areas are vulnerable to an increase in the frequency and depth of flooding. Higher tides also increase salt water inundation to brackish and fresh water wetlands. The Santa Cruz County LCP identifies and maps these wetlands and creeks as Environmentally Sensitive Habitat Area (ESHA). Much of these wetland resources are vulnerable to future impacts of erosion, storm flooding and rising tides.

Nearly all of the creek and river mouth wetlands in Santa Cruz County are within the coastal storm flood zone by 2030 (700 acres of habitat) and much of this fresh and brackish water habitat will be flooded monthly by saline water by 2100 due to rising tides. Some of these wetland areas are designated critical habitat.

Sand Dunes

More than 100 acres of sand dune are currently susceptible to coastal erosion. Much of these resources are located in south Santa Cruz County between Rio Del Mar and the Pajaro River. The number of acres vulnerable to erosion doubles by 2100.

The dunes directly north of the Pajaro River mouth are narrow, and already prone to winter storm erosion and wave overtopping. Installation of rip-rap in front of the Pajaro Dunes Resort currently restricts erosion but these structures are likely insufficient to resist the wave energy and height of storms projected for 2060. By 2100, numerous breaks are predicted within the dunes complex near the Pajaro River which will leave much of the Pajaro Valley vulnerable to Coastal Flooding (Figure 18).

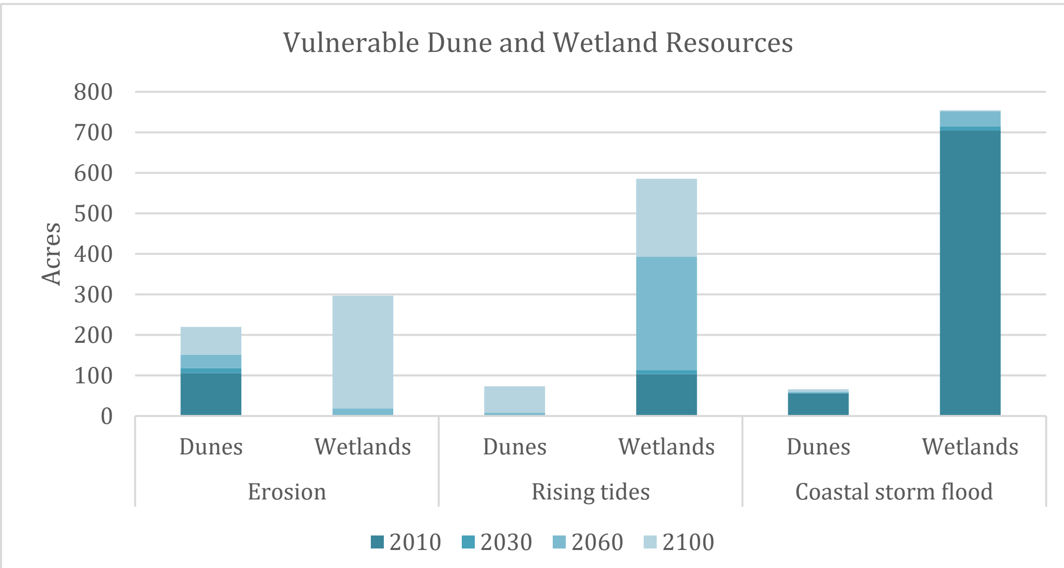

Figure 18. Acres of Dune and Wetland habitat vulnerable to coastal climate change hazards at each planning horizon.

Table 6. Specific assets vulnerable to coastal climate change hazards within the four sections of unincorporated Santa Cruz County

ASSET	COASTAL HAZARD	EARLIEST IMPACT
RESOURCES AT RISK ALONG NORTH COAST (SECTION 1)		
Highway 1	Erosion Coastal Storm Flooding	2030 2060
Coastal river mouth lagoons	Coastal Storm Flooding Rising Tides	2030 2100
RESOURCES AT RISK ALONG 7TH AVE TO CAPITOLA (SECTION 2)		
Low lying residential properties surrounding lagoons	Coastal Storm Flooding Rising Tides	2030 2060
Coastal bluff top residential	Erosion	2060
Live Oak Library	Coastal Storm Flooding	2100
Coastal access points	Coastal Storm Flooding Erosion	2030 2060
Coastal Roads	Coastal Storm Flooding Tidal Flooding Erosion	2030 2030 2060
Corcoran and Schwan lagoons	Coastal Storm Flooding Tidal Flooding Erosion	2030 2030 2060
RESOURCES AT RISK FROM SEACLIFF TO MANRESA BEACH (SECTION 3)		
Rio del Mar “village” and beach front development	Coastal Storm Flooding Erosion	2030 2060
Coastal Access and Parking	Coastal Storm Flooding Erosion	2030 2060
Development surrounding coastal canyons	Erosion	2060
Beach Resources and Lateral Access	Erosion Rising Tides	2030 2100
RESOURCES AT RISK FROM SUNSET BEACH TO THE COUNTY LINE (SECTION 4)		
Residential within Coastal Dunes	Coastal Storm Flooding Erosion Rising Tides	2030 2060 2100
Farmland	Coastal Storm Flooding Rising Tides	2030 2060
Highway 1	Coastal Storm Flooding Rising Tides	2030 2100
Wetland Resources	Coastal Storm Flooding Rising Tides Erosion	2060 2060 2100
Coastal Streets and Parking	Coastal Storm Flooding Rising Tides	2030 2100

7. Economics of Future Climate Risks

The Santa Cruz Littoral Cell study recognizes that Santa Cruz County residents "are well aware of the potential severity of coastal storm damage. Perhaps the most notorious year for coastal storm damage was 1983 when 12 large storms hit the California coastline during just the first three months of the year." It is estimated that the City of Santa Cruz spent more than $20 million dollars to recover from the 1983 storms.

The protection of the structures, properties and land uses identified within future hazard zones will likely be a high priority for local communities. Understanding the cumulative value of the properties and infrastructure that are vulnerable to predicted hazards and the costs to protect those structures may aid the prioritization of protection and adaptation strategies, and help to direct limited public and private resources towards the most effective actions. Longevity of various protection and adaptation strategies, the costs of construction and the future reliability of the constructed infrastructure should all be weighed before response strategies are selected. To aid this process, a simple valuation estimate has been completed for properties and infrastructure located within future hazard zones for the unincorporated county. This property valuation exercise and the evaluation of alternative adaptation strategies (Section 8) should be refined and improved overtime as adaptation planning evolves, and additional information is provided by local agencies, property owners and coastal engineers.

7.1 Property valuation of vulnerable properties and infrastructure

A simple cumulative valuation estimate of predicted property loss was completed to provide rough estimates of climate risks for each time horizon. The average property value for residential and commercial properties within coastal Santa Cruz County were estimated (Table 5 in Section 4.9) and used to quantify the cumulative economic impact of replacing or relocating these buildings and services. The Capitola Hazard Mitigation Plan estimated costs to replace or move critical municipal infrastructure found to be at risk of various natural hazards (not including purchase price of property to relocate). Valuations and costs within these and other local studies were used to estimate total properties values within various hazards zones.

This valuation approach attempts to estimate the scale rather than the precise costs that may be incurred for properties within various hazard zones. This analysis did not estimate the relative risk (i.e. flood damage vs. cliff failure and property loss) posed to various properties for each climate hazard, but rather assumed total loss for all hazards. This limitation in the analysis may over estimate total costs for various hazards (i.e. Risk). Limitations in property valuation methods for this analysis and limited data on construction costs for protective structures further limits the precision of this analysis.

Based on these value estimates, a table of the cumulative value of properties at risk during each time horizon was compiled (Table 7). The total value of properties at risk in 2030 was calculated assuming that all of the currently existing coastal armoring continues to protect inland structures from bluff and dune erosion. Wave overtopping risks were included in residential and commercial estimated property losses but are not included within estimate transportation losses or drinking water conduit which were assumed to resilient to those temporary impacts.

The total value of properties at risk from 2060 coastal erosion was calculated assuming that none of the existing 7.9 miles of coastal armoring (in the unincorporated portions of Santa Cruz county) is replaced (reflecting the potential costs of not replacing coastal structures). Upgraded coastal armoring is estimated to cost between $20 and $52 million per mile ($10,000 per linear foot) to construct.[56] Replacing current armoring with structures of similar size and design may not be sufficient to protect all infrastructure from damage.

Table 7. Total Value (2016 dollars) of Unincorporated Santa Cruz County Properties at Risk

ASSET	VALUE PER UNIT	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Buildings and Facilities					
Residential	$ 958,043	$452,196,530	$509,679,140	$1,187,015,892	$1,757,051,772
Commercial	$ 930,000	$78,120,000	$81,840,000	$105,090,000	$111,600,000
Public	$500,000	$10,500,000	$11,500,000	$19,500,000	$27,500,000
Emergency Services	$2,000,000	$4,000,000	$4,000,000	$4,000,000	$4,000,000
Property losses		*$544,816,530*	*$607,019,140*	*$1,315,605,892*	*$1,900,151,772*
Transportation					
Road (ft)	$ 280	$22,222,480	$24,223,920	$33,924,520	$41,928,040
Highway (ft)	$ 4,000	$75,212,000	$77,868,000	$80,872,000	$90,884,000
Rail (ft)	$ 280	$4,069,800	$4,501,000	$4,980,920	$5,294,800
Transportation losses		*$101,504,280*	*$106,592,920*	*$119,777,440*	*$138,106,840*
Water and Utility Infrastructure					
Storm Drain conduit (ft)	$ 1,080	$68,281,250	$71,361,193	$98,226,761	$118,338,693
Waste Water conduit (ft)	$ 1,080	$57,183,523	$60,245,114	$95,901,420	$118,506,023
Drinking Water conduit (ft)	$ 189	$467,614	$743,750	$1,776,705	$2,550,379
Utility Losses		*$125,932,386*	*$132,350,057*	*$195,904,886*	*$239,395,095*
Total Combine losses		**$772,253,197**	**$845,962,117**	**$1,631,288,218**	**$2,277,653,707**

[56] ESA-PWA. 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group.

By 2030, three quarters of one billion dollars in property and infrastructure are vulnerable to the combined hazards of coastal climate change within the unincorporated Santa Cruz County. Over $500 million (85%) in residential properties are at risk. Approximately 13% of property valuation at risk for 2030 is for commercial properties. Approximately $250 million in public properties, roads and utility infrastructure are within the 2030 hazard zone. 2030 property values at risk increase by only $73 million above baseline (2010), demonstrating that a significant amount of infrastructure is currently vulnerable to coastal flooding and erosion. Waste water pipes are the utility infrastructure at greatest risk of future impacts within coastal Santa Cruz County.

Private property values within the 2060 coastal climate hazard zone are estimated at almost $1.2 billion. To protect these structures from erosion, almost 8 miles of armoring will need to be upgraded or replaced before 2060 (at an estimated cost of $410 million to construct). The total value of private residential properties at risk increases to $1.76 billion by 2100.

Many of the properties identified during each time horizon are vulnerable to multiple hazards (i.e. erosion and coastal flooding). Depending on the engineering complexity and cost of replacing these coastal protection structures, and the environmental and economic impacts of their construction, protecting all of the identified properties is likely cost prohibitive.

This initial economic evaluation highlights the need for constructive discussions between county decision makers, public citizens and private property owners. These discussions can establish protection and adaptation policies for the various sections of the county coastline while fairly allocating costs of protection and adaption and weighing public and private property concerns equitably.

An expanded analysis that links the relative cost of projected impacts (property loss or relative damage) is possible using these compiled vulnerability data. A refined risk analysis would estimate the costs to construct additional protection structures and adopt alternative adaptation strategies (beach nourishment), the costs to rebuild or upgrade damaged structures and the loss to private and public entities who abandon infrastructure for which it is too difficult to adapt. An expanded analysis can help to generate temporal cost/benefit/consequence scenarios for each section of coastline and each time horizon within the Monterey Bay.

8. Adaptation Strategies Options

8.1 Adaptation Strategies by Coastal Hazard

The risks associated with each of the modeled coastal processes (wave run-up and overtopping, coastal erosion, rising tides and fluvial flooding) threaten various types of coastal infrastructure differently. Selection of adaptation options must be driven by the likely damage caused by each hazard and the frequency at which the predicted impact will reoccur.

Waves and fluvial flooding can damage buildings and temporarily restrict use of public amenities, make storm drains ineffective and limit the use of roads and walkways. Cliff erosion and tidal flooding which reoccurs during daily or monthly high tides can lead to a permanent loss of infrastructure and use of those properties. Such losses will require extensive rebuilding, a change in use of the property, or abandonment of the property entirely.

Future investments in the protection of public and private structures will need to be weighed by city staff and property owners against the property's value, construction costs of selected adaptive measures, limitations provided by regulatory agencies, and expected effectiveness and longevity of the adaptation strategy selected. Implications of adaptation options to other coastal uses and resources should also be considered, including restrictions to coastal access, loss of beach, impacts to natural resources and visual degradation of the coastline. This adaptation analysis highlights the need for long-range coastal planning in order to balance property values and adaptation measures costs with the resulting changes to public beaches and the Monterey Bay coastline.

8.2 Strategies Listed Within Existing Plans

Numerous reports have compiled lists of adaptation options and described their use for addressing different climate risks.[57] Examples of climate adaptation strategies being adopted to address local hazards are only just becoming available (see Marin Ocean Coast SLR Vulnerability Assessment[58]). Information on the costs of these strategies is limited but examples of most strategies exist and can provide a range of costs.[59] Local public works departments are best able to estimate the true costs of

[57] County of Santa Cruz Planning Department. 2013. Climate Action Strategy. 2013. Adopted by the Board of Supervisors 2/26/2013.

[58] Sea-Level Marin Adaptation Response Team and the Marin County Community Development Agency. 2015. Marin Ocean Coast Sea Level Rise Vulnerability Assessment, Draft Report. 2015.

[59] ESA-PWA. 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group.

various construction projects and municipal planners and consultants continue to evaluate the feasibility and efficacy of planning and regulatory options.

Santa Cruz County Climate Adaptation Strategy

Coastal climate change hazards cited within the County of Santa Cruz Climate Action Strategy (and integrated into the Local Hazard Mitigation Plan) as posing a risk to county infrastructure include:

- Flooding within in Santa Cruz County drainages will continue to occur.
- Low-lying areas such as Rio Del Mar Esplanade/Flats will experience more frequent flooding and inundation from sea level rise and increased wave heights.
- Rising water table beneath the Rio Del Mar Esplanade will increase as sea level continues to rise.
- Potential increase in future coastal storm frequency and/or intensity will increase cliff retreat rates as well as cause potential damage to oceanfront property or public infrastructure.
- Even though many of the areas of highest vulnerability have already been armored with riprap or seawalls, coastal cliff erosion will continue to take place.

Actions listed within the Santa Cruz County Adaptation Strategy[60] that address sea level rise and coastal flooding hazards were compared with the results of this Vulnerability Study to corroborate findings, highlight priority actions and identify additional actions needed to address newly identified vulnerabilities.

Santa Cruz Littoral Cell Study (2015)

The Santa Cruz Littoral Cell study outlines specific Sediment Management measures that could be implemented for numerous sections of the San Mateo and Santa Cruz counties coastline. Multiple recommendations regarding sediment management options were reviewed based on identified risks. Primary adaptation strategies evaluated for Santa Cruz County coastline areas include:

- Road and utility realignment
- Beach nourishment
- Groins and artificial reefs
- Managed Retreat, and
- Cliff stabilization

Information within the Santa Cruz Littoral Cell study regarding costs, engineering limitations and implications of actions were used for our analysis.

[60] County of Santa Cruz Planning Department. 2013. Climate Action Strategy. Chapter 7. Adopted by the Board of Supervisors 2/26/2013.

Table 9. Priority actions within the Santa Cruz County Climate Adaptation Strategy that address vulnerabilities reported within this report.

- Consider designing and siting all future County projects and infrastructure to account for sea level rise projections
- Develop a detailed priority list for addressing public infrastructure that has been identified as vulnerable, and consider developing retreat or retrofit plans for high priority infrastructure.
- Consider developing a plan to elevate E. Cliff Drive at Twin Lakes State Beach, Corcoran Lagoon, and Moran Lake to alleviate frequent coastal flooding and potential inundation.
- Consider relocating coastal development away from areas that will be inundated to eliminate the risk of damage and the need for coastal protection.
- Consider a program to identify those areas where managed retreat should replace engineered protection structures, based on public benefit.
- Construct a new seawall within the Rio del Mar Esplanade parking lot… divide the parking lot into two halves, with the interior side offering year-round use, and the beach side closed in the storm season only.
- Develop a forum for ongoing engagement with coastal private property owners and the California Coastal Commission to discuss frameworks for land use policies that respond to expected future losses.
- Consider evaluating unprotected developed coastal bluff areas subject to future erosion, and develop plans and timeline for either armor placement, or retreat and relocation of existing public structures and/or infrastructure.
- Consider evaluating areas that are presently armored to determine whether additional armor or managed retreat is the most practical long-term approach.
- Develop a feasible flood control alternative to reduce the potential overtopping of the Pajaro River levees within both Santa Cruz and Monterey counties, including construction of setback levees to reclaim a portion of the floodplain while increasing the flood capacity.
- Prepare a “Storm Water Facilities Master Plan” for Flood Control Districts 5 & 6, which includes portions of Live Oak, Soquel, Aptos, Seacliff and Rio Del Mar.
- Consider protecting, and/or assisting non-profit organizations to protect habitat that is essential to facilitating species adaptation to changing climate. This would include protecting potential refuge areas and large, interconnected habitat patches that achieve multiple conservation benefits.
- Consider a program to identify the key transportation infrastructure, communication infrastructure, utilities, beaches and other amenities that support tourism, agriculture and commercial activity in general, and prioritize them for protection or retrofit.
- Consider adding adaptation to climate change as a specific component of the next update of the LHMP.

8.3 Adaptation Strategy Selection

State Guidance

> *The Coastal Act allows for protection of certain existing structures. However, armoring can pose significant impacts to coastal resources. To minimize impacts, innovative, cutting-edge solutions will be needed, such as the use of living shorelines to protect existing infrastructure, restrictions on redevelopment of properties in hazardous areas, managed retreat, partnerships with land trust organizations to convert at risk areas to open space, or transfer of development rights programs. Strategies will need to be tailored to the specific needs of each community based on the resources at risk, should be evaluated for resulting impacts to coastal resources, and should be developed through a public process, in close consultation with the Coastal Commission and in line with the Coastal Act.*[61]

The risks associated with each of the modeled coastal processes (wave run-up and overtopping, coastal erosion, rising tides and river flooding) threaten various types of coastal infrastructure differently. Selection of adaptation options should be done with consideration to the value of properties at risk, the cost of repairs for damages resulting from each hazard and the anticipated frequency of reoccurring impact. This chapter is intended to encourage discussions regarding both short term risk reduction and protective strategies with mid to long-term adaptation strategy development. Adaptation measures that encourage avoidance or retreat will likely need to be adopted as policy years before they can be implemented.

Future investments in the protection of coastal structures will need to be weighed by County staff and private property owners relative to other factors including the structure's replacement costs, limitations provided by regulatory agencies, and expected longevity and effectiveness of the selected adaptation strategy. Implications of adaptation options including impedances to coastal access, loss of beach and impacts to the beauty of the coastline should also be considered.

This hazard analysis highlights the need for additional resources to develop a long-range coastal management plan that sets policies that best balance property value with construction costs of adaptation measures and the resulting changes to the public coastline and natural resources that will occur. The Central Coast Wetlands Group and the Adapt Monterey Bay technical team that aided the drafting of this document intend to seek additional state funding to complete such an analysis.

[61] California Coastal Commission Sea Level Rise Policy Guidance: Interpretative Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits. 2016. California Coastal Commission. Adopted August 12, 2015.

8.4 Potential Strategies for Climate Adaptation in Santa Cruz County by Time Horizon

2017–2030 Adaptation Options

i.) Adopt policies to limit municipal capital improvements that would be at risk [62]

Prudent adaptive management to climate change begins with adopting policies that keep new municipal infrastructure out of risk of future climate hazards. Policies that establish a review processes for proposed Capital Improvement Projects located within future hazard zones have been adopted by the City of San Francisco.[63] These guidelines help staff to review proposed municipal infrastructure projects and ensure that those projects will not become vulnerable to projected climate risks within the projects expected lifespan.

ii.) Increase short term resiliency and plan for future modifications to roads and coastal access

Increasing resiliency of coastal roads and access points through revised design, changes in infrastructure and elimination of vulnerable structures can reduce future repair costs associated with winter storms. Options to realign roads, sections of Highway 1 and relocate coastal parking outside of the 2060 coastal climate change hazard zone should be investigated and prioritized for implementation.

Table 8. Coastal infrastructure vulnerable to 2030 hazard projections.

ASSET	COASTAL HAZARD
Highway 1	Erosion
Coastal river mouth lagoons	Coastal Storm Flooding
Low lying residential properties surrounding lagoons	Coastal Storm Flooding
Coastal access points	Coastal Flooding
Coastal Roads	Coastal Flooding
	Tidal Flooding
Corcoran and Schwan lagoons	Coastal Flooding
	Tidal Flooding
Rio del Mar “village”	Coastal Storm Flooding
Coastal Access and Parking	Coastal Storm Flooding
Beach Resources and Lateral Access	Erosion
Residential within Coastal Dunes	Coastal Storm Flooding
Farmland	Coastal Storm Flooding
Highway 1	Coastal Storm Flooding
Coastal Streets and Parking	Coastal Storm Flooding

iii.) Improve resiliency to flooding within low lying areas of the Coast

This risk assessment found that flooding of residential areas adjacent to low lying pocket beaches and coastal drainages will remain a primary hazard within coastal Santa Cruz County. Continued focus on emergency response and improved building guidelines (increase free board and first floor parking) can help reduce temporary impacts of flooding. The

[62] County of Santa Cruz Planning Department. 2013. Climate Action Strategy. Adopted by the Board of Supervisors 2/26/2013.

[63] Sea Level Rise Committee of SF Adapt. 2014. Guidance for Incorporating Sea-Level Rise into Capital Planning in San Francisco: Assessing Vulnerability, Risk and Adaptation. Prepared for the San Francisco Capital Planning Committee.

construction of temporary or permanent barrier between coastal swells and adjacent development may help to reduce flooding within high risk areas (as identified within the LHMP for Rio del Mar).

iv.) Storm drain upgrades

Storm drains were found to be vulnerable to high water during winter storms within the Capitola focus study. Increases in wave induced flooding predicted in the low-lying areas may further strain the effectiveness of the storm drain system. To address this issue, the county should evaluate the need for storm drain upgrades including gates and check valves.

v.) Realign roads and utility infrastructure

Future realignment of roadways and utility infrastructure is costly but those costs can be minimized if managed adaptation and retreat policies are established decades before implementation. The County public works department as well as local utilities can integrate future adaptation strategies when making current infrastructure repair and replacement decisions and therefore minimize future costs of infrastructure loss and realignment. Highway 1 in North County will require miles of coastal armoring to maintain its current alignment. A cost estimate (based on previous reports) to realign roads and infrastructure that will be at risk is outlined above.

vi.) Investigate expanded beach nourishment in concert with construction of groins

Small to medium scale opportunistic beach nourishment has been found to be a cost effective, although temporary adaptation measure where material is available.[64] Such materials are routinely diverted from the Santa Cruz harbor down current towards Capitola (providing beach sands for the Pleasure Point area). Other sediment sources may include accumulation in local rivers (which compromises flood management) as well as sediments from dam removal and maintenance projects. Off shore sand has also been examined by the 2016 TNC report and may be cost effective but may also initiate more complex regulatory processes. Groins are likely needed to support any beach nourishment project.[65]

PREVIOUS BEACH NOURISHMENT STUDIES

A study conducted by TNC in 2016 estimated large sand placement projects to cost approximately $3,300,000 per linear km and opportunistic nourishment projects to cost approximately $400,000 per linear km, but nourishment must be repeated more frequently.[64] An example opportunistic sand placement project occurred along Del Monte Beach in Monterey where approximately 8000 cubic meters of sand was placed on the beach between 2012 and 2013. Sand helped protect inland structures but, lacking retention structures (groins) much of the sand was redistributed during 2015 winter storms. Because cliff erosion is a significant concern, the further reductions in beach width down coast of structures should be considered. The 2016 TNC study found that the combination of groin construction and beach nourishment was a cost effective medium duration adaptation measure that helped reduce the loss of public beaches and natural habitats for an estimated twenty years (periodic sand replenishment would be required).[64] The Santa Cruz Littoral Cell study also identified the construction of groins and off shore reefs in combination with expanded beach nourishment efforts as an adaptation option for portions of the Santa Cruz County coastline.

[64] Leo, et al. 2017. Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay.
[65] Ibid.

There are several groins and jetties within the Santa Cruz County portion of Monterey Bay. These structures were designed and constructed to accumulate sediment (or maintain the harbor entrance). Rebuilding or upgrading groin structures to enhance beach nourishment efforts may be a cost-effective adaptation response to mitigate short term beach loss. Long-term (2060–2100) capacity of these structures to retain beach width may be reduced as ocean elevations rise.

vii.) Prioritize coastal protection structures for upgrade and replacement

The most common policy response to cliff and bluff erosion that threatens private and public property is to construct or upgrade coastal armoring. The costs to replace or construct new sea walls however are high. Recent estimates for constructing new rip-rap or seawalls that can withstand periodic wave impacts are estimated at $20,000,000 to $52,000,000 per mile.[66]

Environmental and economic impacts that result from the construction of sea walls are significant. The 2016 TNC report found that coastal armoring was less expensive than beach nourishment and groin construction and effectively reduced municipal and private property losses. Economic and community impacts from the loss of beach area however were estimated to be significant.[67]

The future allocation of public and private funds to protect infrastructure should to be prioritized and weighed against the longevity and feasibility of the proposed protective structures. Depending on cost, construction feasibility and legality of replacing current protective structures, some sea walls may be replaced or upgraded while other structures may be removed and development behind those structures abandoned or repurposed. Both the construction costs as well as the implications of such armoring on coastal resources (access, beach width, view) will likely be significant.

Therefore, completion of a coastal bluff and beach management plan that outlines short and long-term coastal bluff management strategies will help to establish local protection and adaptation priorities, allocate costs and establish strategies to mitigate impacts. Adoption of such plans by the California Coastal Commission may help to expedite adaptation actions and reduce costs to the State and local governments.

2030–2060 Adaptation Options

Protection of all properties and infrastructure identified at risk during future time horizons is likely infeasible. Therefore, Santa Cruz County will need to establish adaptation strategies that best meet local long-term goals. Public cost considerations, longevity of adopted strategies and resultant changes to the community should be considered when setting policy.

Establishing equitable managed retreat policies early will likely best enable the long-term implementation of these policies and ensure the long-term sustainability of the community. Selecting time horizons and climate conditions for which next phase adaptation strategies are triggered will allow the community to anticipate and prepare for future actions.

[66] ESA-PWA. 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group.

[67] Ibid.

i.) Continue to employ short term protective actions in areas where future change in use is probable.

Continued focus on emergency response and improved building guidelines (increase free board and first floor parking) within areas vulnerable to coastal climate change can help reduce temporary impacts of flooding while preparing for future adaptation. A temporary or permanent barrier between coastal swells and adjacent development may help to reduce flooding within high risk areas for a period of time before more extensive protection, adaptation or retreat strategies are selected and implemented.

Special attention should be made to identify cost effective adaptation measures for properties within the Seacliff and Pajaro dunes areas that are vulnerable to multiple climate risks.

ii.) Identify priority areas for future protection accounting for costs, structural feasibility and identified environmental implications.

Coastal residential development located along the beach and dunes of South County, currently protected by coastal armoring, remain vulnerable to wave over topping and flooding. These hazards are predicted to increase by 2060. Decisions on whether to protect these structures should reference projected future hazards and costs and should be made years before implementation.

Table 9. Coastal infrastructure vulnerable to 2060 hazard projections.

ASSET	COASTAL HAZARD
Highway 1	Coastal Storm Flooding
Low lying residential properties surrounding lagoons	Rising Tides
Coastal bluff top residential	Erosion
Coastal access points	Erosion
Coastal Roads	Erosion
Corcoran and Schwan lagoons	Erosion
Rio del Mar “village”	Erosion
Coastal Access and Parking	Erosion
Development surrounding coastal canyons	Erosion
Residential within Coastal Dunes	Erosion
Farmland	Rising Tides
Wetland Resources	Coastal Storm Flooding
Wetland Resources	Rising Tides

This study assumes that almost 8 miles of coastal protection infrastructure will need to be replaced, upgraded or removed sometime after 2030. Decisions regarding which structures should be rebuild in their current location and which structures should be remove or relocate (managed retreat) will need to be made. Impacts of coastal protection include loss of public access and beach area, reduction in economic valuation of the beach and impacts to community identity.

Between 2060 and 2100, The County is at risk of losing significant portions of its public beach if all current coastal protection structures are rebuilt in their current location. Additionally, some structures (Coastal armor along Seacliff and within Pajaro Dunes) would need to be raised significantly to protect inland structures from future predicted wave impacts. The raising of these walls would likely compromise public and private valuation of the coastline significantly, making such actions undesirable and contrary to community values.

The 2016 TNC report suggests that the public benefit (recreational and ecological) of adopting alternative adaptation strategies to replacing coastal armoring (beach nourishment, groins, retreat) outweigh the public and private losses associated with managed retreat. Future funding should be sought to further investigate the cost benefit relationships of various adaptation strategies and the legal and financial strategies necessary to offset municipal and private losses with public benefits.

iii.) Identify priority areas for managed retreat to retain sufficient beach area for recreational use

The width of many Santa Cruz beaches within the Monterey Bay will be reduced (6 miles reduced below 20ft wide) if current development and coastal armoring is replaced in its current location. More than one half a mile of beach may be lost altogether during high tides by 2100 if coastal retreat is halted. Some of the development behind coastal armor may remain vulnerable to wave induced flooding, reducing or eliminating the protective benefits provided if structures are replaced after 2030. Further site-specific modeling is needed to identify which areas can be protected from the combined forces of sea level rise and increased storm intensity and the environmental and recreational implications of these actions.

Between 2060 and 2100, some properties will become too difficult or expensive to protect and therefore a change in use will be necessary. Such policy decisions should be made early enough (i.e. before 2060) for property owners to adjust to these changes. Coordination with State and federal agencies can help municipalities implement these policies and ensure that programs are established that assist private property owners for the transition from private to public use (i.e. beaches, public access and river and bluff setbacks).

2060–2100 Adaptation Options

Between 2060 and 2100, increased coastal wave damage, more frequent flooding and higher tides will threaten significant portions of beach front properties (Table 10). Protection of all properties from these risks will be costly, technically challenging and will degrade Santa Cruz County's unique character and scenic beauty. Decisions regarding what the various urban/beach front areas of the County will look like in 2100 will need to be made much earlier if adaptation is to be strategic and cost effective. A coastal bluff and beach management plan that strategically addresses future hazards should be drafted long before large scale actions to protect coastal infrastructure are completed. Adopting coastal adaptation and retreat policies once all efforts to protect existing infrastructure fails is a costly strategy.

i.) Implement managed retreat strategies

There are a number of theoretical managed retreat strategies that have been described within the literature. Examples of coastal communities adopting re-zoning, building restrictions and other land use policies to drive the removal of buildings and infrastructure from the California coast, however, are few. Collaboration with local stakeholder groups will be necessary to identify economically and legally defensible strategies to move our communities away from danger. Working with state regulatory and funding agencies to begin to implement identified strategies will be critical to success.

Table 10. Coastal infrastructure vulnerable to 2100 hazard projections.

ASSET	COASTAL HAZARD
Coastal river mouth lagoons	Rising Tides
Live Oak Library	Coastal Flooding
Beach Resources and Lateral Access	Rising Tides
Residential within Coastal Dunes	Rising Tides
Highway 1	Rising Tides
Wetland Resources	Erosion
Coastal Streets and Parking	Rising Tides

MOVING TOWARDS MANAGED RETREAT

The Coastal Commission references strategies that include “restrictions on redevelopment of properties in hazardous areas, managed retreat, partnerships with land trust organizations to convert at risk areas to open space, or transfer of development rights programs.”

Examples of successful application of this suggested policy, however, are limited. The 2014 Pacifica LCP sets policy for coastal bluff development so that: “All new development proposed on or adjacent to a coastal bluff shall require a site stability survey conducted by a licensed Certified Engineering Geologist or Geotechnical Engineer to determine the necessary setback, taking into account bluff retreat projected over the economic life of the development.” Santa Cruz County has adopted similar policies.

While many municipalities are developing a process to establish setbacks that recognize threats from Coastal Climate Change, there are no policies yet adopted that outline areas where current development will need to be modified or removed as predicted coastal hazards become a reality. The Marin Climate Adaptation effort has completed focus area analysis of coastal communities (i.e. Bolinas) similar to this Santa Cruz County report and has identified infrastructure that will need to be raised or otherwise modified to respond to tides and coastal flooding. Agriculture lands have been identified for transition to wetlands. No residential or commercial private properties, however, have been identified for removal and no procedures have yet to be identified that support municipalities efforts to “convert at risk areas to open space.”

How these retreat strategies can be adopted within fully developed communities like some parts of Santa Cruz County is unclear. Restrictions on redevelopment required within coastal development permits may lead to individual property owners implementing setbacks and building restrictions while neighbors are not required to comply. Such a case by case (or “Swiss Cheese”) approach will most likely have limited success protecting either coastal properties or coastal resources. Rather, adaptation strategies and future land use decisions (that account for the costs to private property owners and city redevelopment) should be drafted long before they become enforceable and programs to implement adopted adaptation strategies systematically along stretches of coastline (similar to Pacifica) will need support of state agencies and non-governmental organizations.

Cost sharing between private property owners and state and local agencies will need to be defined and local land trusts may play an important role in administering these programs in years to come. Adaptation strategies adopted decades before they are implemented will help property valuation, economic considerations and land use objectives accommodate these future changes.

9. Conclusion

This hazard evaluation is intended to provide a projected chronology of future hazards in order to support local adaptation planning and support informed discussions between State regulatory and funding agencies, local decision makers and the public.

This hazard assessment provides predictions of future hazards so the community can begin planning for strategic adaptation to these hazards rather than responding to future climatic events as they happen without sufficient forethought or understanding of costs and consequences. Low lying areas of Santa Cruz County are uniquely vulnerable to climate change. State funding is available to help communities adapt to future risks projected within this study. Continued progress towards defined adaptation strategies is needed for Santa Cruz to compete for limited adaptation funding.

Mechanisms to implement the identified adaptation strategies require further investigation, coordination with other municipalities within the Monterey Bay and the development of partnerships that support efficient implementation of adopted strategies. Additional strategic dialog with California Coastal Commission staff is also needed. The climate report team will work with Santa Cruz County to obtain additional funding to expand the adaptation opportunity analysis for Santa Cruz County, more fully develop the environmental and economic implication analysis and further define an adaptation implementation strategy that meets the needs of the community for integration into general plans and local coastal programs.

Possible Next Steps

Priority actions listed in the County's Local Hazard Mitigation Plan and those identified within this report that will help Santa Cruz County advance climate adaptation planning include:

- Support community outreach needed to inform stakeholders of current hazard predictions and encourage dialog needed to identify priority adaptation planning options.
- Consider relocating coastal development away from areas that will be inundated to eliminate the risk of damage and the need for coastal protection.
- Consider a program to identify those areas where managed retreat should replace engineered protection structures, based on public benefit.
- Adopt Capital Improvement Project review guidelines within sea level rise hazard areas.
- Integrate 2030 hazard maps into future Santa Cruz County Hazard Mitigation Plan updates.

- Identify and prioritize storm drain upgrades necessary to address future hazards.
- Prioritize sand nourishment and beach groin construction and estimate their cumulative costs and effectiveness.
- Use GIS model outputs to estimate the cumulative impacts and regional contexts of planning and permitting decisions, through application of different policy options (CCC guidance).
- Work with agriculture community to investigate short and long-term adaptation strategies for low lying farming operations.
- Identify mitigation alternative for unavoidable coastal resource impacts related to permitting and shoreline management decisions (CCC guidance).
- Complete a socio-economic "Risks" analysis that accounts for social equity when selecting adaptation strategies.

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Appendix A

Vulnerability Analysis Tables

Existing Hazard Zones

FEMA flood zone compared to existing (2010) coastal climate change hazard zones for the unincorporated county and local jurisdictions separately.

Table A1. Unincorporated County: Impact Analysis FEMA and Existing (2010) Vulnerability

ASSETS	UNIT	TOTAL	FEMA	2010 WITH ARMOR
Land Use and Buildings				
Total Buildings	Count	14,848	1,158	770
Residential	Count	12,468	797	472
Commercial	Count	413	122	84
Public	Count	239	32	19
Visitor Serving	Count	79	3	0
Other	Count	1,649	204	195
Schools	Count	7	0	0
Libraries	Count	4	1	1
Post Offices	Count	1	1	1
Emergency Services	Count	12	2	1
Farmland	Acres	16,627	2,184	1788
Landfills	Count	2	0	0
Cleanup Sites	Count	7	1	0
Transportation				
Roads	Feet	1,360,403	77,813	79,366
Rail	Feet	131,803	13,032	14,535
Bridges	Count	18	11	8
Highway1	Feet	148,634	4,331	18,803
Parks, Recreation, and Public Access				
Parks	Acres	29,039	1,019	1,366
Beaches	Acres	179	69	94
Coastal Access Points	Count	70	16	38
Parking Lots	Acres	23	2	6
Coastal Trail	Feet	16,214	1,133	2,334
Water and Utility Infrastructure				
Culverts and Tide Gates	Count	145	32	9
Storm Drain Structures	Count	3,296	295	264
Storm Drain Conduits	Feet	405,752	62,881	63,250
Sewer Structures	Count	2,516	201	131
Sewer Conduits	Feet	591,263	43,157	52,970
Wastewater Treatment Plants	Count	1	1	0
Natural Resources				
Dunes	Acres	1,429	54	35
National Wetlands	Acres	1,462	925	796

Table A2. City of Santa Cruz: Impact Analysis FEMA and Existing (2010) Vulnerability

ASSETS	UNIT	TOTAL	FEMA	2010 WITH ARMOR
Land Use and Buildings				
Total Buildings	Count	8,203	1,094	190
Residential	Count	7,439	828	143
Commercial	Count	358	199	33
Public	Count	79	38	2
Visitor Serving	Count	206	20	6
Other	Count	121	9	6
Schools	Count	2	0	0
Libraries	Count	1	0	0
Post Offices	Count	0	0	0
Emergency Services	Count	3	2	0
Farmland	Acres	57	2	0
Cleanup Sites	Count	3	2	0
Transportation				
Roads	Feet	304,200	53,031	10,376
Rail	Feet	10,528	6,699	1,556
Bridges	Count	8	5	6
Highway 1	Feet	2,587	2,580	0
Parks, Recreation, and Public Access				
Parks	Acres	626	127	82
Beaches	Acres	38	33	42
Coastal Access Points	Count	35	19	18
Parking Lots	Acres	38	19	5
Coastal Trail	Feet	25,170	4,997	2,857
Water and Utility Infrastructure				
Storm Drain Structures	Count	1,230	419	130
Storm Drain Conduits	Feet	109,568	46,274	21,038
Sewer Structures	Count	25	15	1
Sewer Conduits	Feet	6,047	5,978	1,583
Culverts	Count	4	3	0
Wastewater Treatment Plants	Count	1	1	0
Natural Resources				
Dunes	Acres	0	0	0
National Wetlands	Acres	186	151	140

Table A3. City of Watsonville: Impact Analysis FEMA and Existing (2010) Vulnerability

ASSETS	UNITS	TOTAL	FEMA	2010 WITH ARMOR
Land Use and Buildings				
Total Buildings	Count	170	27	33
Schools	Count	1	0	0
Libraries	Count	0	0	0
Post Offices	Count	0	0	0
Emergency Services	Count	0	0	0
Farmland	Acres	51	0	0
Cleanup Sites	Count	2	0	0
Transportation				
Roads	Feet	32,911	4,354	0
Rail	Feet	206	130	0
Bridges	Count	6	1	0
Highway 1	Feet	4,946	141	0
Parks, Recreation, and Public Access				
Parks	Acres	200	10	33
Water and Utility Infrastructure				
Storm Drain Structures	Count	103	4	0
Storm Drain Conduits	Feet	26,662	751	2,539
Culverts and Tide Gates	Count	1	0	0
Natural Resources				
National Wetlands	Acres	95	93	67

Combined Hazard Tables

Table A4. Unincorporated Santa Cruz County: Summary of assets vulnerable to future coastal hazards

ASSETS	UNIT	TOTAL	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Land Use and Buildings						
Total Buildings	Count	14,848	770	847	1,637	2,296
Residential	Count	12,468	472	532	1,239	1,834
Commercial	Count	413	84	88	113	120
Public	Count	239	19	21	34	35
Visitor Serving	Count	79	0	0	3	18
Other	Count	1,649	195	206	248	289
Schools	Count	7	0	0	0	0
Libraries	Count	4	1	1	1	1
Post Offices	Count	1	1	1	1	1
Emergency Services	Count	12	2	2	2	2
Farmland	Acres	16,627	1,788	1,798	2,013	2,135
Landfills	Count	2	0	0	0	0
Cleanup Sites	Count	7	0	0	1	2
Transportation						
Roads	Feet	1,360,403	79,366	86,514	121,159	149,743
Rail	Feet	131,803	14,535	16,075	17,789	18,910
Bridges	Count	18	8	8	8	9
Highway 1	Feet	148,634	18,803	19,467	20,218	22,721
Parks, Recreation, and Public Access						
Parks	Acres	29,039	1,366	1,377	1,493	1,590
Beaches	Acres	179	94	95	96	97
Coastal Access Points	Count	70	38	43	55	56
Parking Lots	Acres	23	6	7	9	13
Coastal Trail	Feet	16,214	2,334	2,334	2,783	2,810
Water and Utility Infrastructure						
Culverts and Tide Gates	Count	145	9	9	14	16
Storm Drain Structures	Count	3,296	264	285	487	616
Storm Drain Conduits	Feet	405,752	63,250	66,103	90,989	109,619
Sewer Structures	Count	2,516	131	150	325	427
Sewer Conduits	Feet	591,263	52,970	55,806	88,835	109,774
Water Mains	Feet	274,313	2,469	3,927	9,381	13,466
Wastewater Treatment Plants	Count	1	0	0	0	1
Natural Resources						
Dunes	Acres	1,429	35	36	102	150
National Wetlands	Acres	1,462	796	801	876	889

Table A5. City of Santa Cruz: Summary of assets vulnerable to predicted coastal hazards

ASSETS	UNITS	TOTAL	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Land Use and Buildings						
Total Buildings	Count	8,203	190	288	547	1,075
Residential	Count	7,439	143	210	372	753
Commercial	Count	358	33	62	141	228
Public	Count	79	2	2	5	34
Visitor Serving	Count	206	6	8	21	45
Other	Count	121	6	6	8	15
Schools	Count	2	0	0	0	0
Libraries	Count	1	0	0	0	0
Post Offices	Count	0	0	0	0	0
Emergency Services	Count	3	0	0	1	2
Farmland	Acres	57	0	0	0	0
Cleanup Sites	Count	3	0	0	1	1
Transportation						
Roads	Feet	304,200	10,376	14,304	43,890	68,689
Rail	Feet	10,528	1,556	1,556	5,887	5,887
Bridges	Count	8	6	6	6	7
Highway 1	Feet	2,587	0	0	0	7
Parks, Recreation, and Public Access						
Parks	Acres	626	82	93	104	136
Beaches	Acres	38	42	42	42	42
Coastal Access Points	Count	35	18	21	28	29
Parking Lots	Acres	38	5	8	22	29
Coastal Trail	Feet	25,170	2,857	6,042	15,788	17,543
Water and Utility Infrastructure						
Culverts and Tide Gates	Count	4	0	0	1	1
Storm Drain Structures	Count	1,230	130	167	322	502
Storm Drain Conduits	Feet	109,568	21,038	23,426	35,141	48,761
Sewer Structures	Count	25	1	3	7	14
Sewer Conduits	Feet	6,047	1,583	1,704	2,394	2,964
Wastewater Treatment Plants	Count	1	0	0	0	1
Natural Resources						
Dunes	Acres	0	0	0	0	0
National Wetlands	Acres	186	140	142	159	168

Table A6. City of Watsonville: Summary of assets vulnerable to predicted coastal hazards

ASSETS	UNITS	TOTAL	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Land Use and Buildings						
Total Buildings	Count	170	33	33	89	147
Schools	Count	1	0	0	0	0
Libraries	Count	0	0	0	0	0
Post Offices	Count	0	0	0	0	0
Emergency Services	Count	0	0	0	0	0
Farmland	Acres	51	0	21	48	51
Cleanup Sites	Count	2	0	0	2	2
Transportation						
Roads	Feet	32,911	0	3,994	7,118	13,001
Rail	Feet	206	0	0	147	206
Bridges	Count	6	0	4	5	6
Highway 1	Feet	4,946	0	70	350	405
Parks, Recreation, and Public Access						
Parks	Acres	200	33	82	86	87
Water & Utility Infrastructure						
Storm Drain Structures	Count	103	0	16	51	82
Storm Drain Conduits	Feet	26,662	2,539	9,803	16,172	20,541
Culverts and Tide gates	Count	1	0	1	1	1
Natural Resources						
National Wetlands	Acres	95	67	67	69	79

Table A7. City of Capitola: Summary of assets vulnerable to any of the predicted coastal hazards (including river flooding).

ASSET	UNIT	TOTAL	2030 (WITH ARMOR)	2060 (WITHOUT ARMOR)	2100 (WITHOUT ARMOR)
Land Use and Buildings					
Total Buildings	Count	3,025	219	295	370
Residential	Count	2,599	67	112	175
Commercial	Count	326	138	166	172
Public	Count	68	8	10	14
Visitor Serving	Count	15	6	7	9
Other	Count	17	0	0	0
Schools	Count	1	0	0	0
Post Offices	Count	1	0	0	1
Emergency Services	Count	2	1	2	2
Transportation					
Roads	Feet	119,994	7,012	13,316	17,138
Rail	Feet	8,503	422	2,076	3,261
Bridges	Count	4	3	3	4
Recreation and Public Access					
Beaches	Acres	5.8	6	6	6
Coastal Access Points	Count	12	11	12	12
Parking Lots	Acres	4	0.7	1.4	1.9
Coastal Trail	Feet	9,543	0	1,705	3,020
Water and Utility Infrastructure					
Storm Drain Structures	Count	667	185	239	244
Storm Drain Conduits	Feet	50,173	8,686	11,864	11,992
Sewer Structures	Count	472	56	83	102
Sewer Conduits	Feet	118,365	13,452	19,819	23,901
Natural Resources					
National Wetlands	Acres	16	16	16	16

Unincorporated Santa Cruz County Individual Coastal Hazards

Table A8. Assets vulnerable to rising tides

ASSETS	UNITS	TOTAL	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Land Use and Buildings						
Total Buildings	Count	14,848	0	0	6	92
Residential	Count	12,468	0	0	1	24
Commercial	Count	413	0	0	0	0
Public	Count	239	0	0	0	4
Visitor Serving	Count	79	0	0	0	0
Other	Count	1,649	0	0	5	64
Schools	Count	7	0	0	0	0
Libraries	Count	4	0	0	0	0
Post Offices	Count	1	0	0	0	0
Emergency Services	Count	12	0	0	0	1
Farmland	Acres	16,627	14	25	486	1,078
Cleanup Sites	Count	7	0	0	0	0
Transportation						
Roads	Feet	1,360,403	84	126	2,374	15,030
Rail	Feet	131,803	0	0	62	1,488
Bridges	Count	18	0	0	3	4
Highway 1	Feet	148,634	74	171	286	453
Parks, Recreation, and Public Access						
Parks	Acres	29,039	74	80	352	575
Beaches	Acres	179	10	12	31	117
Coastal Access Points	Count	70	1	1	1	4
Parking Lots	Acres	23	0	0	0	0
Coastal Trail	Feet	16,214	513	518	552	968
Water and Utility Infrastructure						
Culverts and Tide Gates	Count	145	1	2	3	3
Storm Drain Structures	Count	3,296	8	8	14	45
Storm Drain Conduits	Feet	405,752	1,402	1,653	3,730	13,696
Sewer Structures	Count	2,516	0	0	0	4
Sewer Conduits	Feet	591,263	107	117	163	1,889
Wastewater Treatment Plants	Count	1	0	0	0	0
Natural Resources						
Dunes	Acres	1,429	0	0	8	73
National Wetlands	Acres	1,462	103	113	393	585

Table A9. Assets vulnerable to coastal storm flooding

ASSETS	UNITS	TOTAL	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Land Use and Buildings						
Total Buildings	Count	14,848	491	514	1,211	1,708
Residential	Count	12,468	315	336	970	1,413
Commercial	Count	413	12	12	13	16
Public	Count	239	6	6	8	8
Visitor Serving	Count	79	0	0	0	15
Other	Count	1,649	158	160	220	256
Schools	Count	7	0	0	0	0
Libraries	Count	4	0	0	0	0
Post Offices	Count	1	0	0	0	0
Emergency Services	Count	12	1	1	1	1
Farmland	Acres	16,627	1,774	1,795	2,004	2,219
Cleanup Sites	Count	7	0	0	1	2
Transportation						
Roads	Feet	1,360,403	55,577	58,040	89,217	119,767
Rail	Feet	131,803	7,285	7,522	11,795	18,910
Bridges	Count	18	6	6	6	7
Highway 1	Feet	148,634	3,218	3,248	10,939	15,754
Parks, Recreation, and Public Access						
Parks	Acres	29,039	976	993	1,286	1,448
Beaches	Acres	179	91	91	95	97
Coastal Access Points	Count	70	28	32	52	54
Parking Lots	Acres	23	6	6	9	11
Coastal Trail	Feet	16,214	2,052	2,150	2,783	2,810
Water and Utility Infrastructure						
Culverts and Tide Gates	Count	145	5	5	7	9
Storm Drain Structures	Count	3,296	152	155	298	395
Storm Drain Conduits	Feet	405,752	33,805	34,302	62,403	76,692
Sewer Structures	Count	2,516	111	118	251	345
Sewer Conduits	Feet	591,263	37,621	38,720	64,542	86,317
Wastewater Treatment Plants	Count	1	0	0	0	1
Natural Resources						
Dunes	Acres	1,429	34	35	101	150
National Wetlands	Acres	1462	821	830	886	910

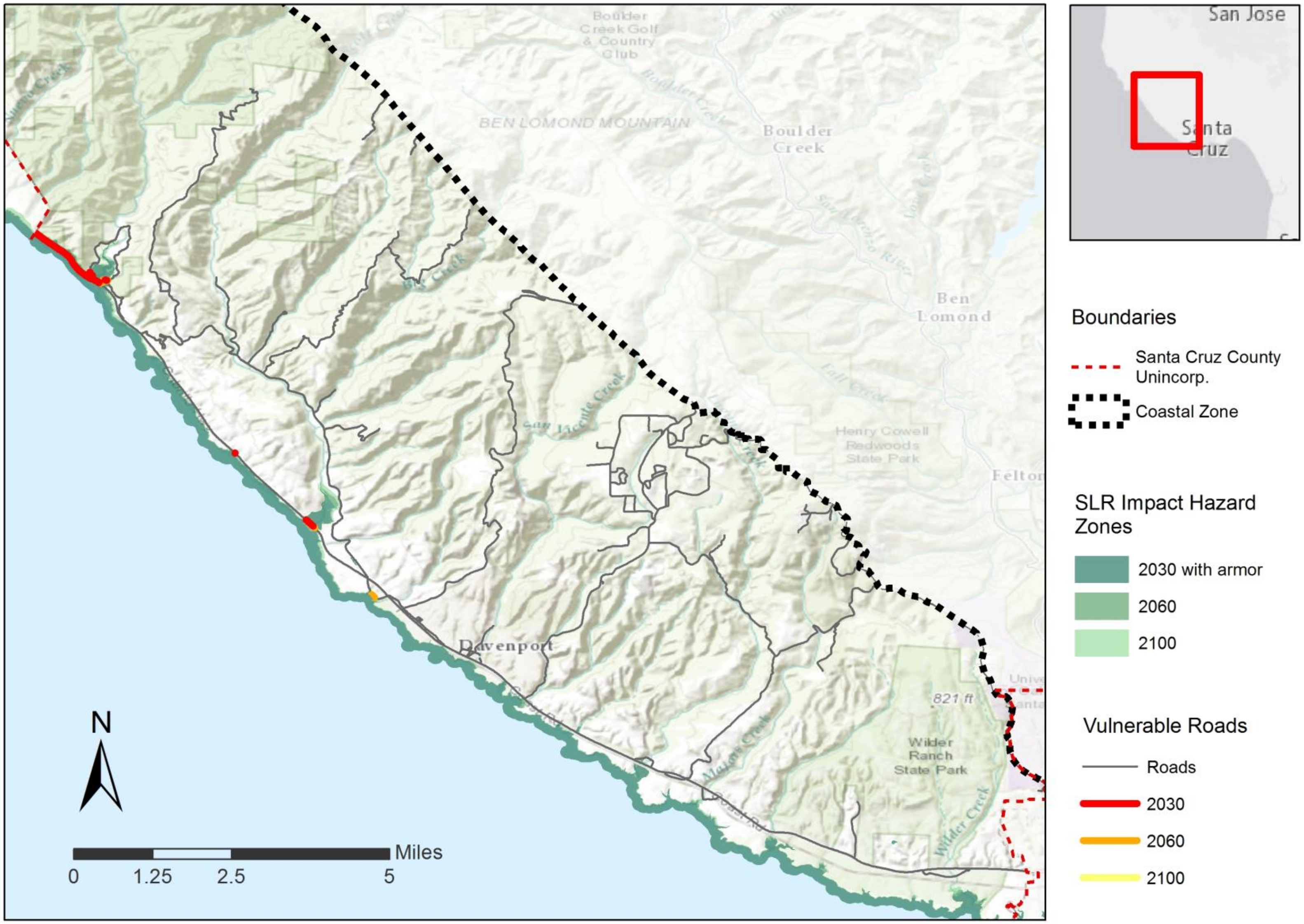
Table A10. Assets vulnerable to erosion

ASSETS	UNITS	TOTAL	2010 WITH ARMOR	2030 WITH ARMOR	2060 NO ARMOR	2100 NO ARMOR
Land Use and Buildings						
Total Buildings	Count	14,848	80	124	1,024	1,659
Residential	Count	12,468	70	106	904	1,490
Commercial	Count	413	0	0	11	16
Public	Count	239	0	0	4	9
Visitor Serving	Count	79	0	0	3	16
Other	Count	1,649	10	18	102	128
Schools	Count	7	0	0	0	0
Libraries	Count	4	0	0	0	0
Post Offices	Count	1	0	0	0	0
Emergency Services	Count	12	0	0	0	0
Farmland	Acres	16,627	13	22	50	112
Cleanup Sites	Count	7	0	0	0	0
Transportation						
Roads	Feet	1,360,403	7,663	10,419	47,830	81,478
Rail	Feet	131,803	760	1,690	4,343	7,724
Bridges	Count	18	0	1	1	2
Highway 1	Feet	148,634	5,648	6,957	9,514	14,168
Parks, Recreation, and Public Access						
Parks	Acres	29,039	442	561	692	764
Beaches	Acres	179	146	159	174	177
Coastal Access Points	Count	70	23	32	54	54
Parking Lots	Acres	23	5	5	9	11
Coastal Trail	Feet	16,214	744	1,340	2,783	2,838
Water and Utility Infrastructure						
Culverts and Tidegates	Count	145	0	2	6	6
Storm Drain Structures	Count	3,296	53	64	260	373
Storm Drain Conduits	Feet	405,752	10,283	11,583	37,420	54,505
Sewer Structures	Count	2,516	23	29	223	322
Sewer Conduits	Feet	591,263	6,098	7,451	61,605	84,598
Wastewater Treatment Plants	Count	1	0	0	0	0
Natural Resources						
Dunes	Acres	1,429	106	118	151	220
Critical Habitat	Acres	50,227	0	0	74	1,343
National Wetlands	Acres	1,462	0	0	18	297

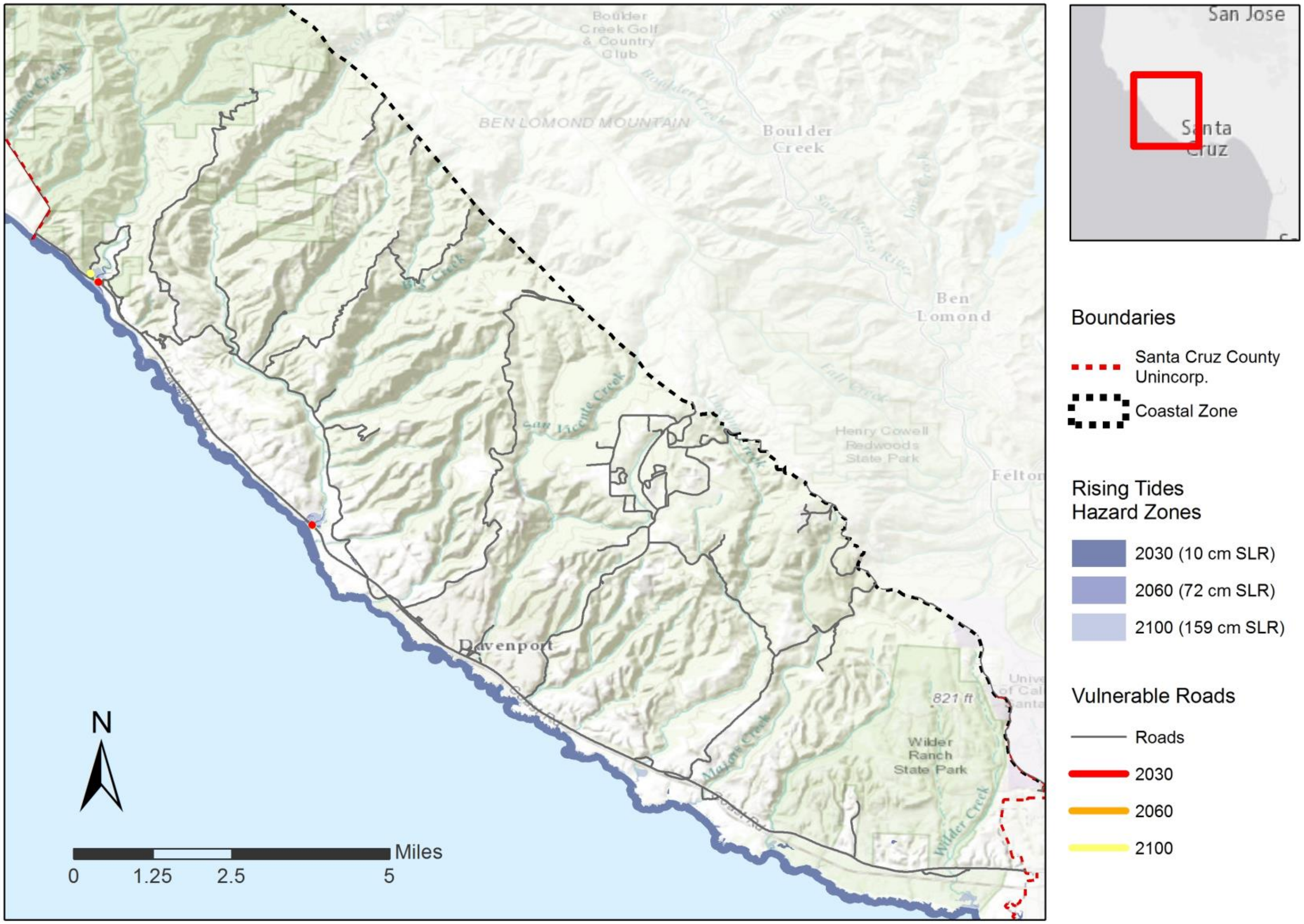
Appendix B

Coastal Hazard Maps for Santa Cruz County

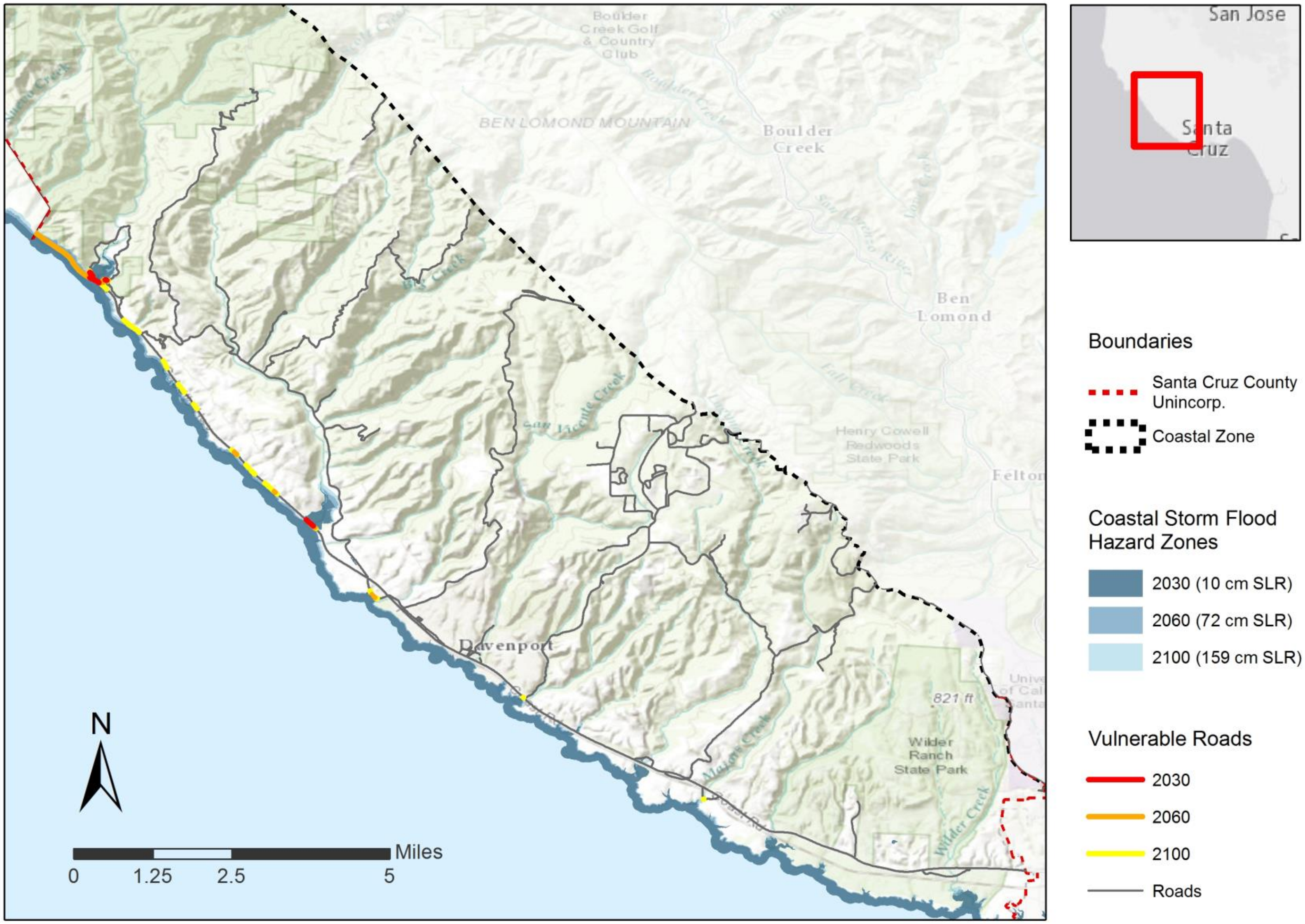
Map B1. Section 1: Combined Coastal Climate Change Hazard Zones



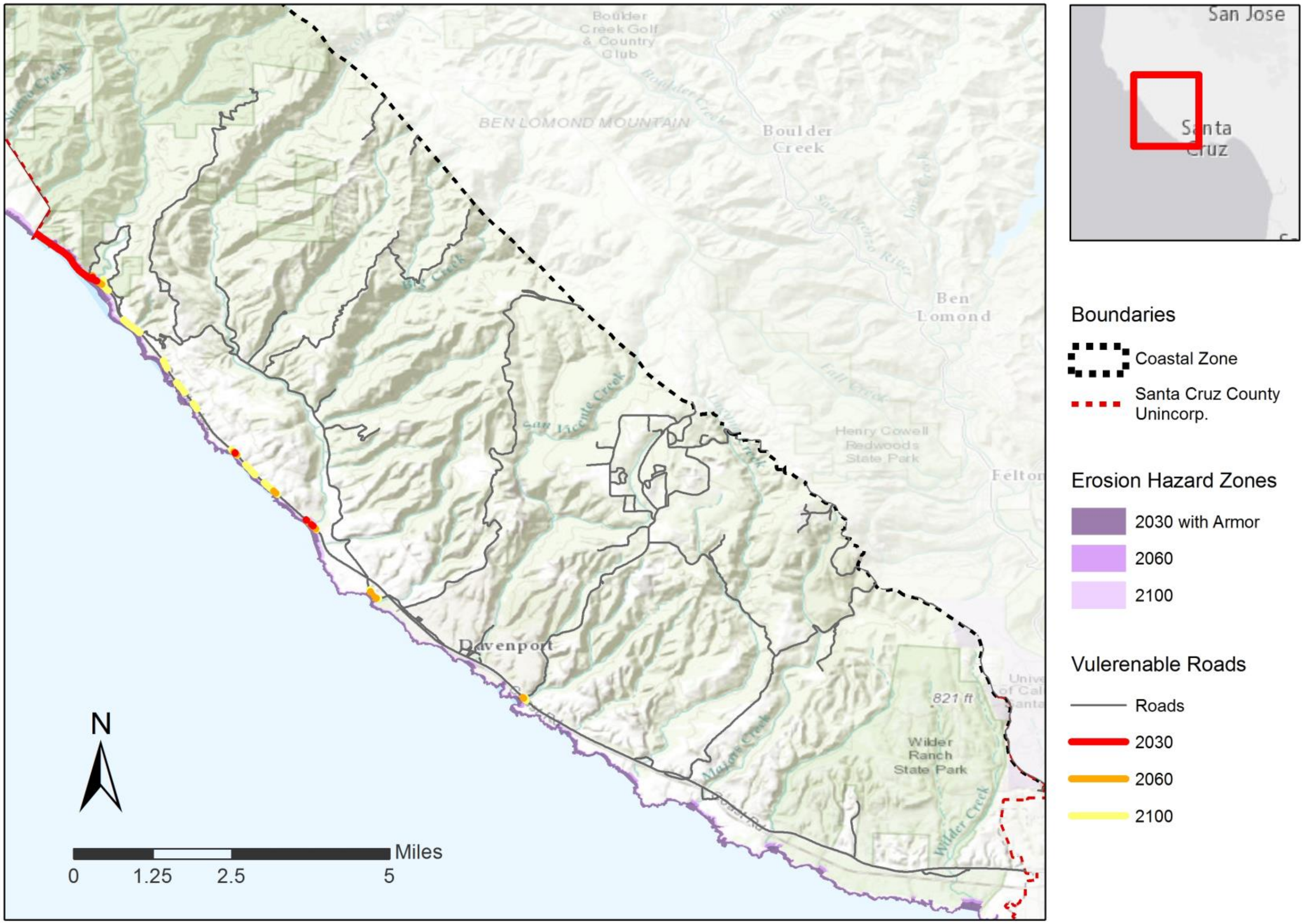
Map B2. Section 1: Rising Tides Hazard Zones



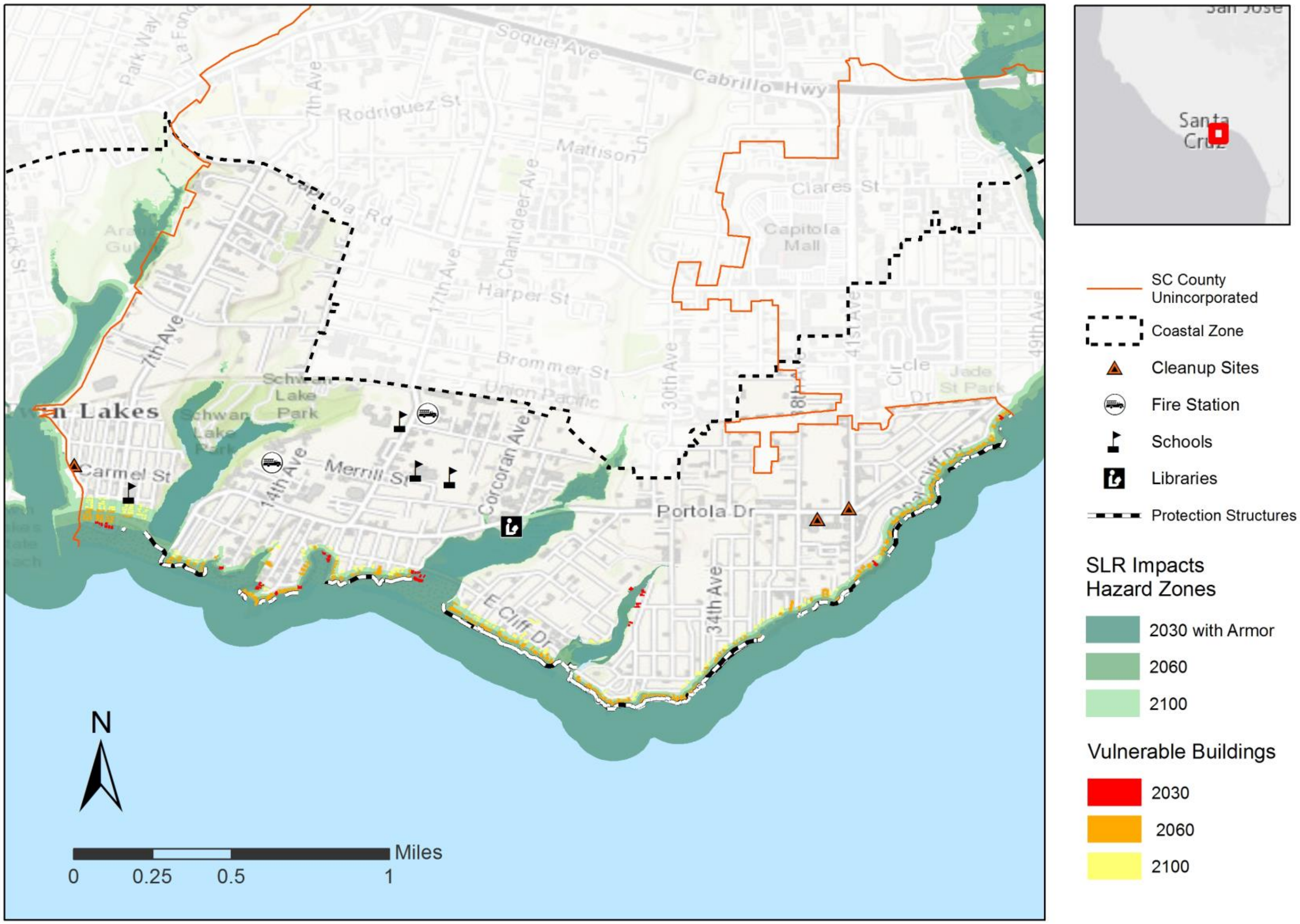
Map B3. Section 1: Coastal Storm Flood Hazard Zones



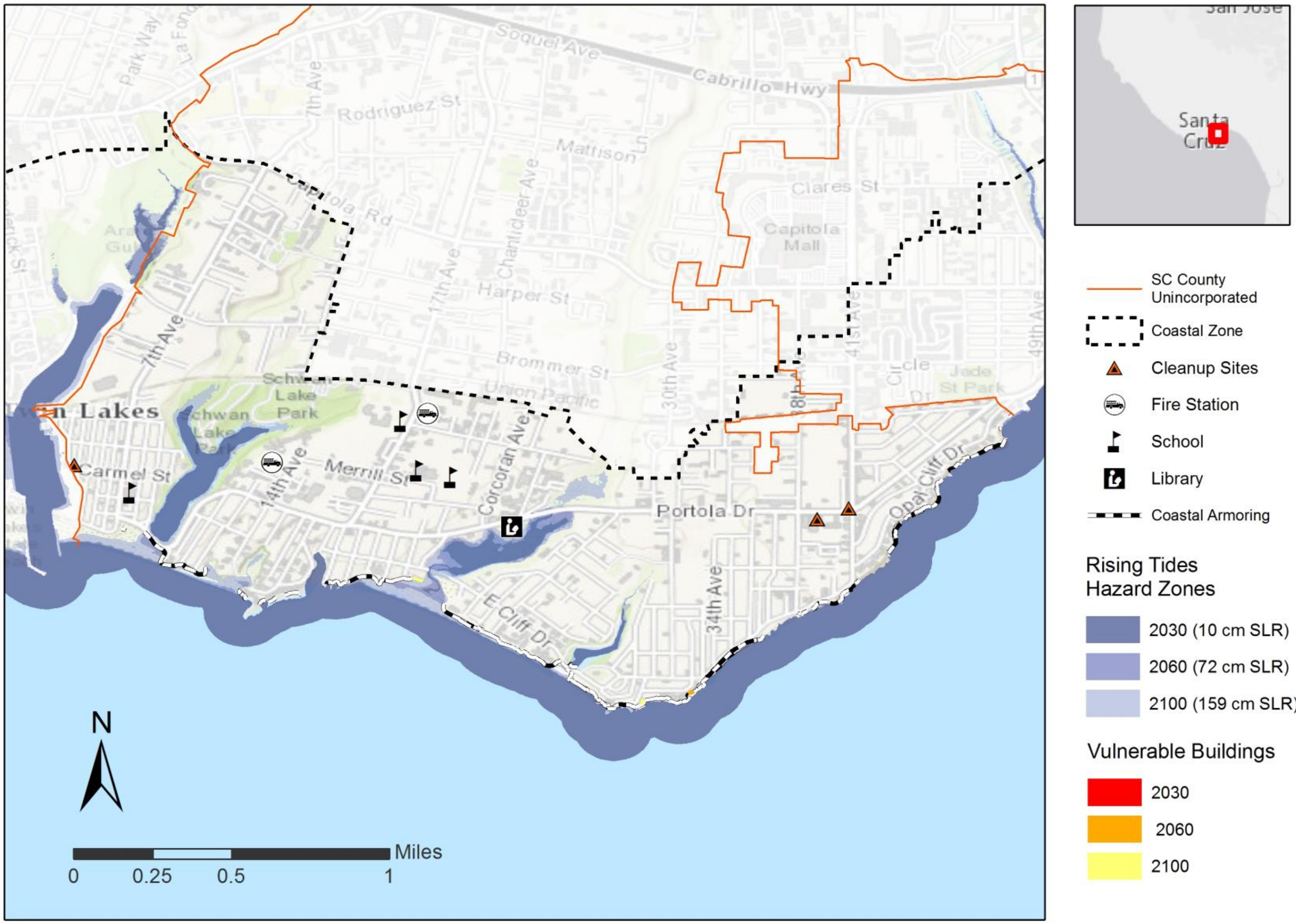
Map B4. Section 1: Erosion Hazard Zones



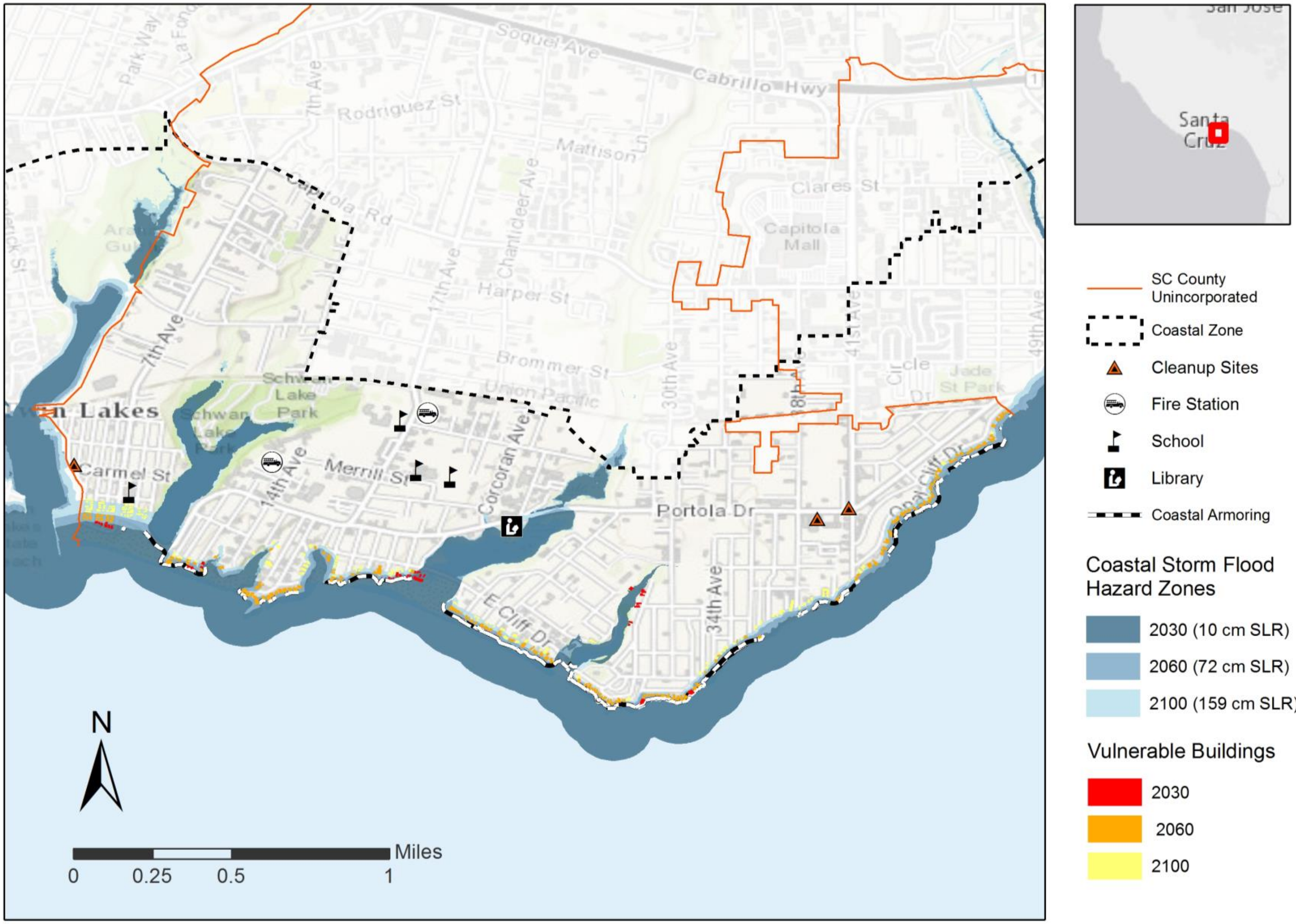
Map B5. Section 2: Combined Coastal Climate Change Hazard Zones



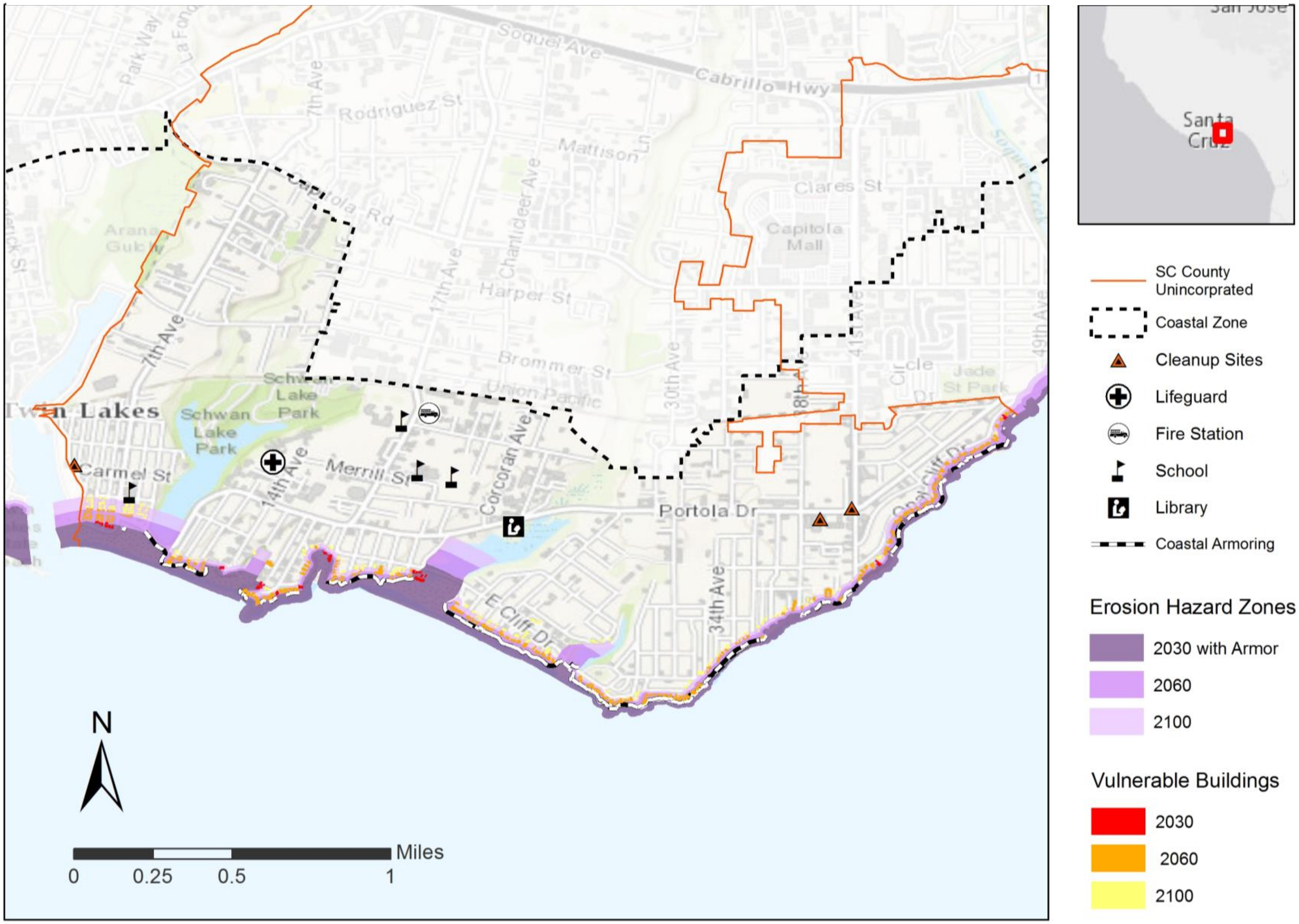
Map B6. Section 2: Rising Tides Hazard Zones



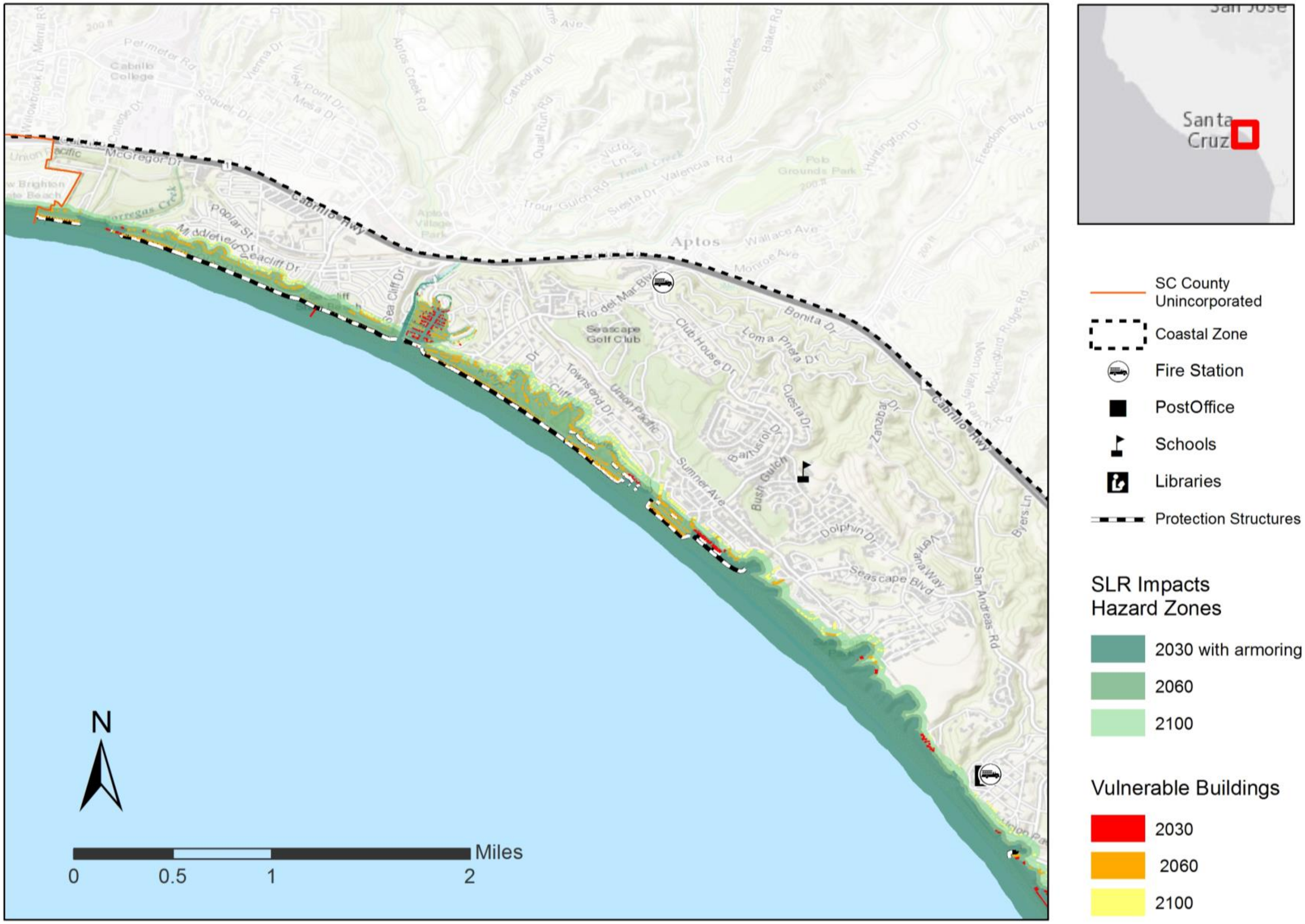
Map B7. Section 2: Coastal Storm Flood Hazard Zones



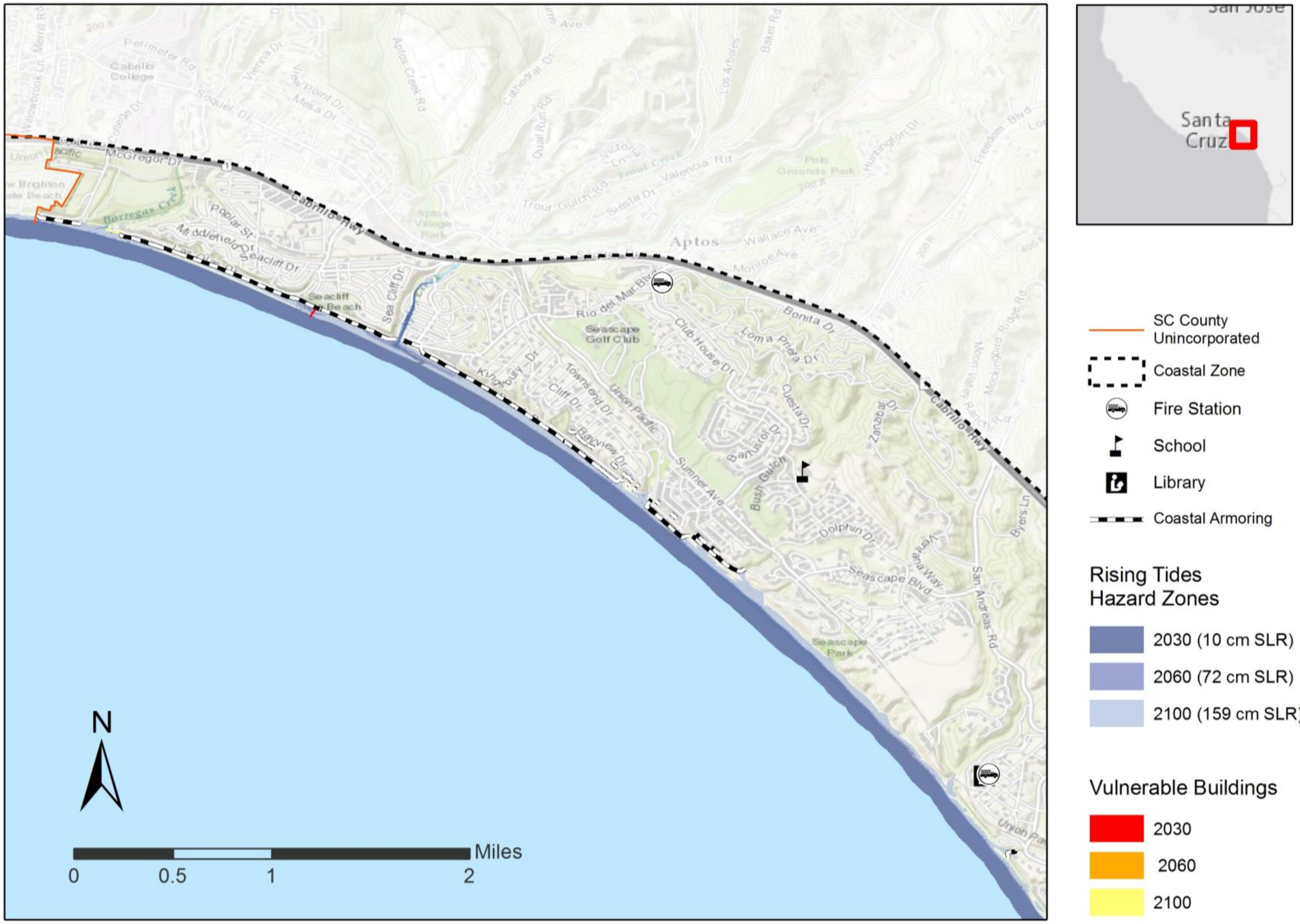
Map B8. Section 2: Erosion Hazard Zones



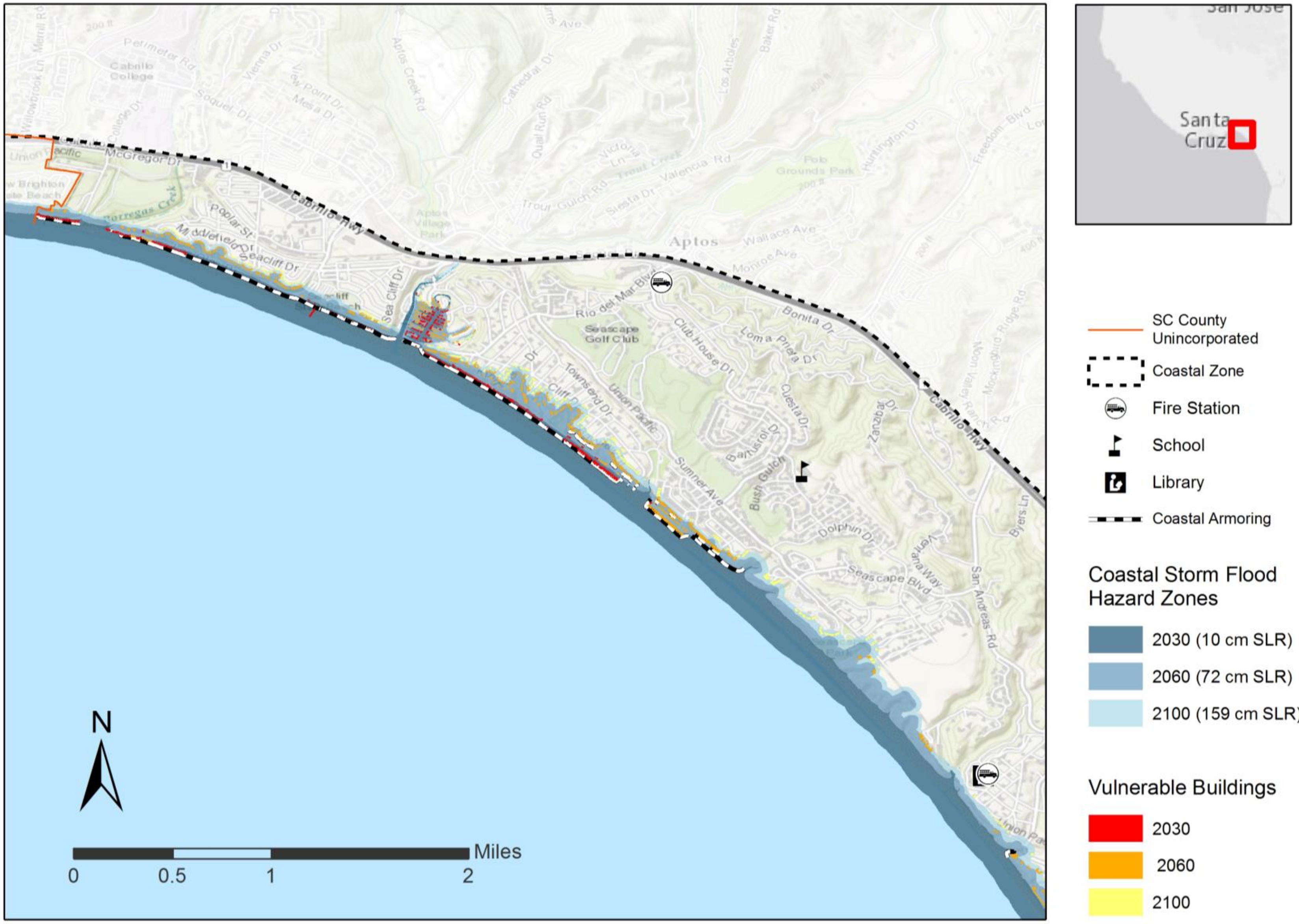
Map B9. Section 3: Combined Coastal Climate Change Hazard Zones



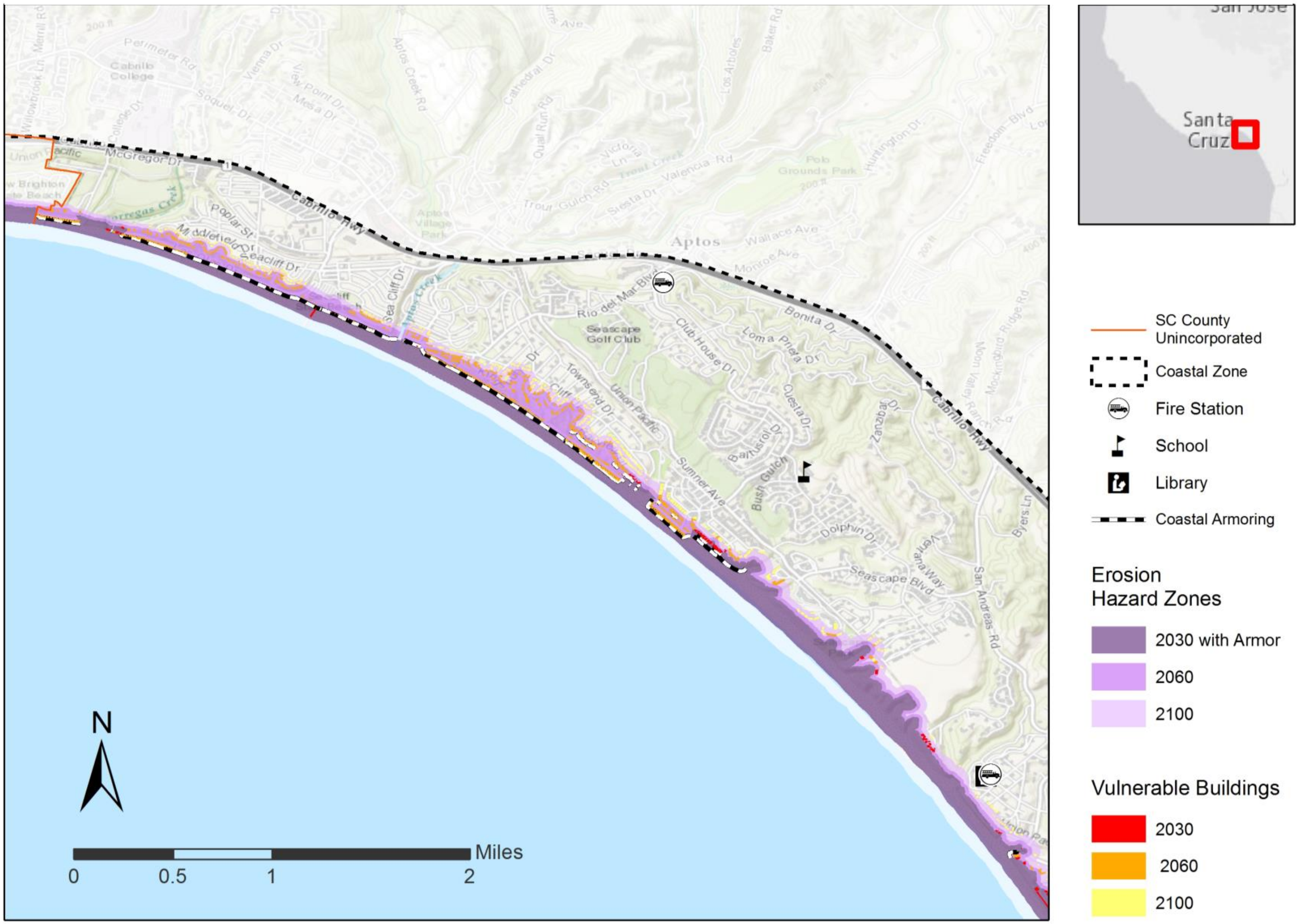
Map B10. Section 3: Rising Tides Hazard Zones



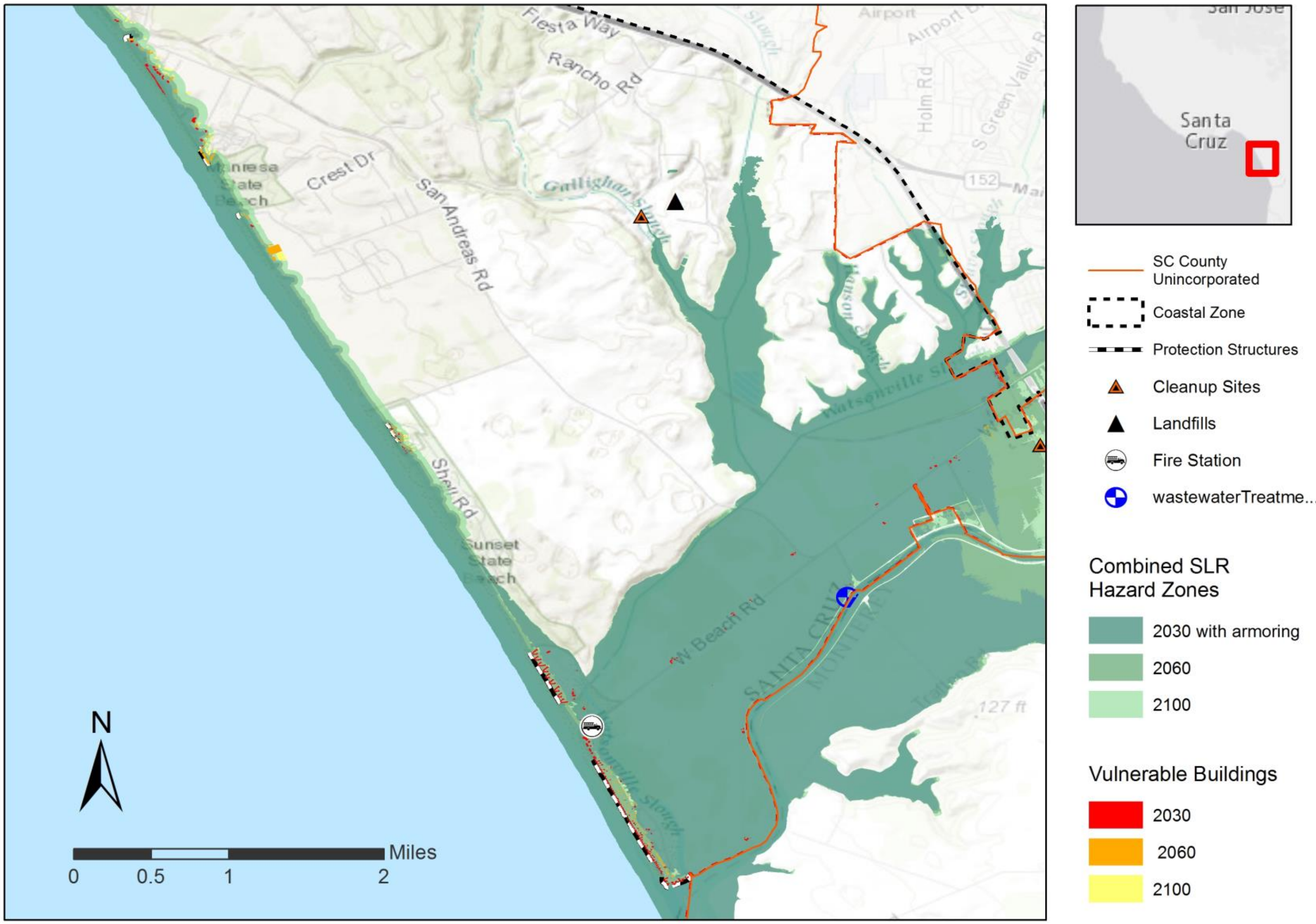
Map B11. Section 3: Coastal Storm Flood Hazard Zones



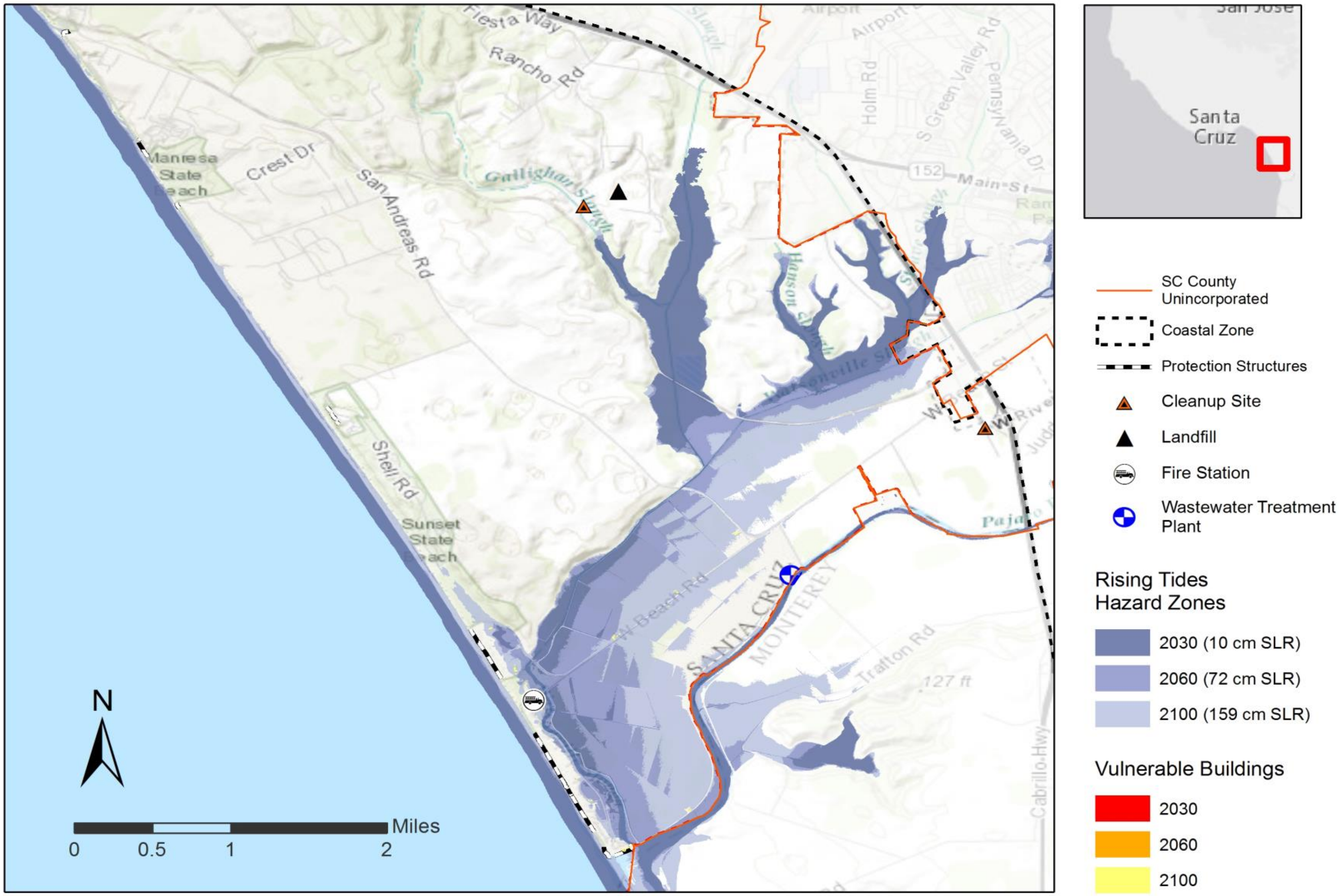
Map B12. Section 3: Erosion Hazard Zones



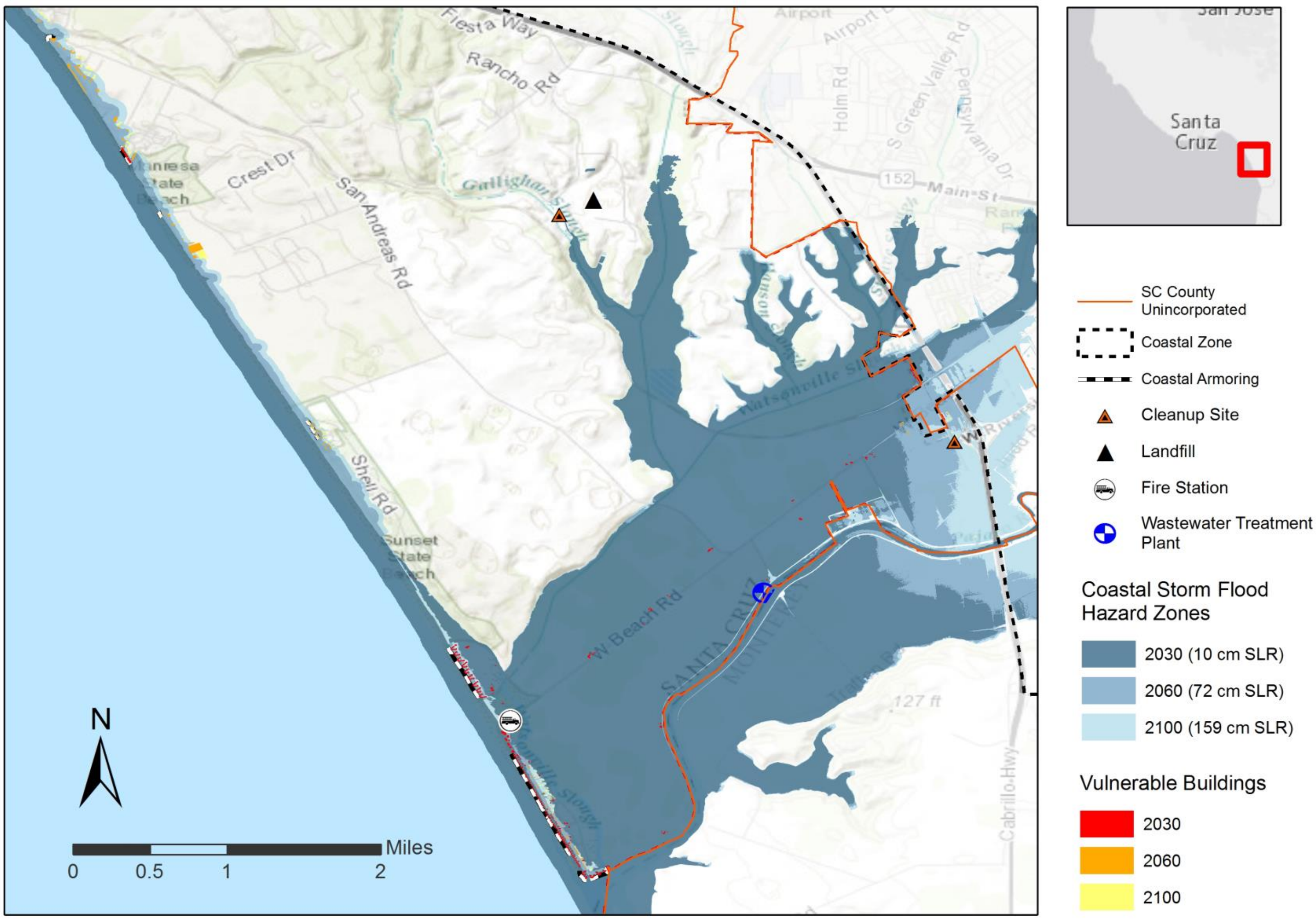
Map B13. Section 4: Combined Coastal Climate Change Hazard Zones



Map B14. Section 4: Rising Tides Hazard Zones



Map B15. Section 4: Coastal Storm Flood Hazard Zones



Map B16. Section 4: Erosion Hazard Zones